Carotenoids and Phenols of Organically and Conventionally Cultivated Potato Varieties

I. Murniece, Z. Kruma, I. Skrabule, and A. Vaivode

***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. The orange and yellow colour of the tuber flesh is due to carotenoids. The aim of this research was to determine the content of total phenolic content and carotenoids in relationship with the colour of organically and conventionally cultivated potato varieties before and after period of storage. In the research 31 potato samples of 12 potato varieties were analyzed on total carotenoid, total phenolic content and colour. Obtained results show that there was significant influence on carotenoid content between different cultivation environments (p<0.05) and between varieties (p<0.05). Total phenolic content significantly varies both per variety (p<0.001) and storage conditions (p<0.001).**

***Index Terms*—Potato variety, total phenol content, carotenoids, organic, conventional.**

I. Introduction

Potato (*Solanum tuberosum* L.) is one of the most important food crops in the world following wheat and rice to provide essential nutrients, mainly carbohydrate [1]. The research in potato chemistry has established the fact that there is a lot more in potatoes than starch. Phytochemicals content in potatoes can be enhanced by developing new varieties from available germplasm high in these compounds. Natural colourant and antioxidant present in purple- and red-flesh potatoes can be used for developing functional foods/nutraceuticals. Considering the large quantities in which potatoes are consumed throughout the world, potatoes could be a very good vehicle for addressing some health related problems [2]. Many of the compounds present in potato are important because of their beneficial effects on health, therefore, are highly desirable in the human diet [3].

Colour is an important food quality parameter. It affects consumer acceptance [4] and can even evoke emotional feelings in humans [5]. Coloured potatoes have attracted the attention of investigators as well as consumers because of their antioxidant activities, taste and appearance [6]. The antioxidant activity in coloured potatoes is associated with the presence of polyphenols anthocyanins, flavonoids, carotenoids, ascorbic acid, tocopherols, alpha-lipoic acid and selenium [7]. Therefore, coloured potatoes have the potential to be one of the richest sources of antioxidants in the human diet.

As food and life style choices have been increasingly recognised as useful approaches in prevention or delaying the onset of chronic diseases, more and more research and commercial development are focused on food phytochemicals such as polyphenolics and carotenoids [8]-[14]. In addition to supplying energy, potatoes contain a number of health promoting phytonutrients such as phenolics, flavonoids, folates, kukoamines, anthocyanins, and carotenoids [15] particularly the pigmented or coloured varieties [16]-[19].

Carotenoids are lipophilic compounds synthesized in plastids from isoprenoids [20] which are widespread in nature and have broad range of functions, especially in relation to human health and their role as biological antioxidants [20], [21]. Because of their high carotenoids content potatoes are particularly beneficial for eye health [22], [23]. Lutein, zeaxanthin, violaxanthin and neoxanthin are the major carotenoids present in potatoes and β-carotene is present in trace amounts [24].

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 μg/100 FW and 800–2000 μg 100 g^{-1} FW, respectively, in white- and yellow-fleshed potato cultivars [24].

Polyphenols comprise over 8000 identified substances, which can be divided into groups according to their chemical structure, such as phenolic acids, stilbenes, coumarins, lignins and flavonoids [15].

Phenolic compounds are considered to be health-promoting phytochemicals as they have shown in vitro antioxidant activity and have been reported to exhibit beneficial antibacterial, antiglycemic, antiviral, anticarcinogenic, anti-inflammatory and vasodilatory properties [25], [26]. Polyphenols are recognized as the most abundant antioxidants in our diet [27]. Potatoes are a good source of these compounds. Phenolic compounds represent a large group of minor chemical constituents in potatoes, which play an important role in determining their organoleptic properties. Further, phenolics have a wide-array of health providing characteristics [28], therefore, have potential for use as functional food for improving human health. The phenolic content of potatoes was reported to be high, and ranged from 530 to 1770 μg g^{-1} [29]. Potatoes were considered the third most important source of phenols after apples and oranges [30]. Talburt et al. reported presence of lignin, coumarins, anthocyanins and flavones, tannins, monohydric phenols and polyhydric phenols in potatoes [31].

Potato quality varies depending on the growing area, cultivar [32] and aspects of the chemical composition of main

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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 [33], [34]. Although nutrient content depends on a number of factors, the potato variety is thought to be among the most significant factors [35].

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 [36]-[38].

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%) [39]. 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 [40].

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 [41]-[42].

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

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 0.7 m and the distance between tubers 0.3 m.

Organic field. The soil type was sod podzolic (PVv), loamy sand. Organic matter content in soil was 25 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.

Conventional field. The soil type in conventional field was sod-podzolic (PVv), sandy loam. Organic matter content in soil was 27 mg kg^{-1}, pHKCl was 5.7, availability of *K* and *P* in soil was high. Fertilizer *P* – 55, *K* – 90 kg ha^{-1} was used in conventional field, two rates of N fertilizer was used *N*1 – 60 kg ha^{-1} and *N*2 – 120 kg 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.

Weather conditions. 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 ℃. 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 ℃ and at a relative air humidity of 80 ± 5%.

B. Tubers

In the experiment twelve potato (*Solanum tuberosum* L.) varieties with white, yellow and violet coloured 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 in 2011. The characterization of potato varieties is present in Table I.

C. Sample Handling

For each testing period, a total of 10 kg (around 50–60 potato tubers) of table potato tubers per variety were selected into small piles, from ten different wooden boxes (size of the box: 90 cm (l) × 50 cm (w) × 40 cm (h)). Five potatoes were selected from several location points of each box. Afterwards, the selected potato sub-piles were mixed together into one final pile and then divided into three batches. Potatoes from each batch were then mixed, homogenized and used for analyses [43]. All operations during sample preparation were performed very quickly so as to avoid deviations from the qualitatively obtained results. In the analysis on TPC, carotenoids and DM, the test and analysis was run in triplicate and averaged.

D. Dry Matter, Carotenoid and Total Phenol Content

Dry matter (DM) content of potato tubers was determined by ISO 6496:1999 [44]. Carotenoids were analyzed by spectrophotometric method (with the UV/VIS spectrophotometer Jenway 6705) at 440 nm [45].

For extraction of phenolic compounds five grams of the homogenized sample were extracted with 50 ml of ethanolwater solution (80%) in a conical flask with a magnetic stirrer (magnet 4.0 × 0.5 cm) at 700 rpm for 1 h at room temperature (20 ± 1 ℃). The potatoes extracts were then filtered via the paper with No 89.

TABLE I: DESCRIPTION OF POTATO VARIETIES

Variety	Shape of tubers	Colour of skin and flesh	Maturity	Additional information
Agrie dzeltenie	oval round	skin - russet yellow; flesh - yellow	early	bred at SPPBI*
Prelma	oval	skin - yellow; flesh - yellow	mid-early	bred at SPPBI
Imanta	long oval	Skin - yellow with pink eyes; flesh - white	mid-late	bred at SPPBI
Lenora	round oval	skin - yellow; flesh - yellow	mid-early	bred at SPPBI.
Brasla	round	skin - yellow; flesh - yellow	mid-late	bred at SPPBI
Bionica	round oval	skin - light yellow; flesh - white	mid-early	bred at C. Meyer B.V., the Nederlands
Annuscha	round oval	skin - yellow; flesh - yellow	early	bred at Europlant, Germany
Blue Congo	long oval	skin - violet; flesh - violet	mid-late	the Czech Republic Gene bank
Gundega	oval	skin - light red pink; flesh - yellow	mid-late	bred at SPPBI
S04009-37	oval	skin - violet; flesh - white	mid-late	SPPBI breeding material
S03135-10	round	skin - light pink with pink eyes; flesh - light yellow	early	SPPBI breeding material
S99108-8	round oval	skin - light yellow with pink eyes; flesh - yellow	mid-early	SPPBI breeding material

* SPPBI- state priekuli plant breeding institute

TABLE II: DRY MATTER CONTENT IN TUBERS OF POTATO VARIETIES AFTER HARVESTING AND AFTER STORAGE, %

Potato variety	Before storage			After storage		
	Organic	Conventional *N*1*	Conventional *N*2**	Organic	Conventional *N*1*	Conventional *N*2**
Agrie dzeltenie	18.30±0.13	18.04±0.07	17.50±0.08	19.56±0.21	19.52±0.10	18.36±0.06
Prelma	19.10±0.09	21.56±0.09	19.50±0.07	19.84±0.07	22.37±0.22	19.33±0.16
Imanta	25.87±0.08	24.00±0.11	23.10±0.22	26.73±0.23	24.76±0.09	24.42±0.19
Lenora	22.55±0.14	23.84±0.18	22.80±0.27	23.75±0.14	25.43±0.31	24.51±0.32
Brasla	24.35±0.11	26.10±0.29	25.90±0.10	25.41±0.12	28.20±0.27	27.66±0.07
Bionica	20.80±0.21	21.05±0.13	18.80±0.20	22.18±0.11	21.87±0.06	20.56±0.05
Annuscha	18.80±0.08	19.50±0.11	19.03±0.06	19.82±0.06	20.32±0.15	19.54±0.16
Blue Congo	n.a.	20.10±0.23	18.60±0.10	n.a	20.04±0.14	20.04±0.19
Gundega	n.a.	23.10±0.17	23.10±0.20	n.a.	23.82±0.22	22.89±0.09
S04009-37	n.a.	25.60±0.21	24.10±0.09	n.a.	25.84±0.28	25.33±0.19
S03135-10	n.a.	19.80±0.14	19.20±0.19	n.a.	20.75±0.09	19.89±0.28
S99108-8	n.a.	19.55±0.06	19.28±0.13	n.a.	20.35±0.10	19.26±0.30

N fertilizer: **N*1 – 60 kg ha^{-1} and ***N*2 – 120 kg ha^{-1}

Each value is expressed as the mean ± standard deviation (*n*=9).

TABLE III: TOTAL PHENOL CONTENT IN TUBERS OF POTATO VARIETIES AFTER HARVESTING AND AFTER STORAGE, MG GAE 100 G^{-1} FW

Potato variety	Before storage			After storage		
	Organic	Conventional *N*1*	Conventional *N*2**	Organic	Conventional *N*1*	Conventional *N*2**
Agrie dzeltenie	29.906±0.162	27.925±0.066	27.104±0.379	40.561±0.179	34.560±0.098	33.494±0.169
Prelma	27.368±0.247	22.911±0.062	25.439±0.027	29.365±0.124	27.012±0.166	28.247±0.128
Imanta	21.250±0.093	16.001±0.257	16.498±0.114	17.527±0.227	21.644±0.134	19.300±0.220
Lenora	24.630±0.088	15.530±0.018	23.384±0.267	25.324±0.197	15.957±0.264	27.157±0.129
Brasla	13.393±0.009	18.305±0.192	13.937±0.092	21.516±0.134	22.648±0.231	22.062±0.195
Bionica	18.463±0.259	17.281±1.184	19.818±0.063	18.086±0.209	18.463±0.064	19.635±0.232
Annuscha	23.841±0.353	22.077±0.510	15.073±0.230	31.316±0.169	26.042±0.268	27.003±0.133
Blue Congo	n.a.	26.701±0.040	29.501±0.937	n.a	47.506±0.128	53.334±0.199
Gundega	n.a.	13.922±0.065	16.024±0.224	n.a.	16.227±0.132	21.536±0.189
S04009-37	n.a.	15.552±0.214	22.879±0.081	n.a.	19.873±0.146	18.310±0.165
S03135-10	n.a.	26.038±0.118	24.974±0.669	n.a.	24.428±0.101	28.963±0.252
S99108-8	n.a.	12.198±0.017	12.915±0.064	n.a.	12.702±0.131	17.354±0.065

The TPC of the extracts was determined according to the Folin-Ciocalteu spectrophotometric method [46] with some modifications. To 0.5 ml of extract 2.5 ml of Folin–Ciocalteu reagent (diluted 10 times with water) and, after 3 minutes 2 ml of sodium carbonate (Na_2CO_3) (75 g L^{-1}) was added. The sample was mixed. The control sample contained all the reaction reagents except the extract. After 30 minutes of incubation at room temperature, the absorbance was measured at 765 nm. Total phenols were expressed as gallic acid equivalents (GAE)/100 g fresh weight (FW) of potatoes.

A. 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 µm, 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.

TABLE IV: CAROTENOID CONTENT IN TUBERS OF POTATO VARIETIES AFTER HARVESTING AND AFTER STORAGE, MG 100 G^{-1} FW

Potato variety	Before storage			After storage		
	Organic	Conventional *N*1*	Conventional *N*2**	Organic	Conventional *N*1*	Conventional *N*2**
Agrie dzeltenie	0.211±0.012	0.260±0.003	0.233±0.027	0.312±0.002	0.217±0.002	0.246±0.001
Prelma	0.147±0.001	0.136±0.017	0.104±0.008	0.121±0.003	0.148±0.001	0.148±0.001
Imanta	0.043±0.002	0.038±0.002	0.043±0.003	0.031±0.001	0.039±0.002	0.029±0.002
Lenora	0.318±0.001	0.288±0.003	0.318±0.005	0.308±0.002	0.185±0.001	0.282±0.002
Brasla	0.233±0.001	0.204±0.008	0.178±0.006	0.143±0.003	0.135±0.001	0.100±0.001
Bionica	0.227±0.003	0.039±0.003	0.073±0.007	0.036±0.002	0.039±0.002	0.024±0.001
Annuscha	0.354±0.003	0.227±0.004	0.400±0.007	0.428±0.002	0.333±0.004	0.186±0.002
Blue Congo	n.a.	0.000±0.000	0.073±0.000	n.a.	0.015±0.001	0.014±0.001
Gundega	n.a.	0.232±0.004	0.124±0.001	n.a.	0.105±0.001	0.154±0.002
S04009-37	n.a.	0.140±0.008	0.165±0.005	n.a.	0.129±0.002	0.129±0.003
S03135-10	n.a.	0.131±0.008	0.058±0.003	n.a.	0.165±0.005	0.177±0.002
S99108-8	n.a.	0.304±0.001	0.306±0.003	n.a.	0.2750.004	0.354±0.002

N fertilizer: *N1 – 60 kg ha^{-1} and **N2 – 120 kg ha^{-1}
Each value is expressed as the mean ± standard deviation (n=9).

TABLE V: CORRELATION BETWEEN COLOUR (L*A*B*), CAROTENOIDS AND TPC

Potato variety	Carotenoids			TPC		
	Organic	Conventional *N*1*	Conventional *N*2**	Organic	Conventional *N*1*	Conventional *N*2**
L*	-0.58	n.c.	n.c.	n.c.	-0.62	n.c.
a*	n.c.	-0.53	n.c.	n.c.	0.51	n.c.
b*	0.74	0.75	0.53	0.57	n.c.	n.c.

N fertilizer: *N1 – 60 kg ha^{-1} and **N2 – 120 kg ha^{-1}
Each value is expressed as the mean ± standard deviation (n=9).
n.c. – no correlation was found.

A. 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 carotenoid, total phenolic content and dry matter were made by Principal Component Analysis (PCA).

III. RESULTS AND DISCUSSION

Dry matter (DM) content after a period of storage has increased in organically; conventionally (*N*1) and conventionally (*N*2) cultivated potatoes per 5.1%, 5.4% and 5.2%, respectively. The highest loss in water content after a period of storage was found in the Bionica variety when cultivated conventionally (*N*2). In the very few potato tubers of the Prelma, Blue Congo, Gundega and S99108-8 varieties cultivated conventionally has been determined very small decrease in DM content after a period of storage (Table II).

The highest DM content before storage was found in the Brasla variety when cultivated conventionally (*N*1) (i.e. 26.10±0.29 g 100 g^{-1}) while the lowest – was for the Agrie dzeltenie variety when cultivated conventionally (*N*2) (i.e. 17.50±0.08 g 100 g^{-1}). After a period of storage the highest DM content was also found in the Brasla variety in the same growing conditions – conventionally (*N*1) (i.e. 28.20±0.20 g100 g^{-1}) and the lowest, like in the case of the Brasla variety, it was in the Agrie dzeltenie variety cultivated conventionally (*N*2) (i.e. 18.36±0.06 g 100 g^{-1}).

Comparing results of the same potato tubers of Brasla, Imanta and Lenora varieties with the previous research results when potatoes were cultivated conventionally (*N*1) and analysed on DM [43], DM content in the tubers of Imanta variety are closely the same while in the tubers of the Lenora and Brasla varieties, DM content in this study year is much higher [43]. Tajner-Czopek et al from Poland has reported that DM content of the potato tubers of Blue Congo variety was 21.45±0.20 g 100 g^{-1} when potatoes were cultivated in year 2009 and 2010 [47] and comparing to the results obtained in this research is a little bit higher.

Significant differences in DM content were found between varieties (p<0.001), storage (p<0.001) and cultivation type (p<0.001). In regard to the cultivation type, significant differences in DM content were noticed between conventionally (*N*1) and conventionally (*N*2) cultivated potatoes and no significant differences (p>0.05) were found in both (*N*1 and *N*2) conventionally cultivated potatoes comparing to potatoes cultivated organically.

Changes in DM content determined for potatoes 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 [48], [49]. 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 [48]-[51]. Transpiration causes water loss, and as a consequence increases the content of all the components of the dry matter.

Potatoes (*Solanum tuberosum* L.) is considered a good source of antioxidants such us ascorbic acid, α-tocopherol and polyphenolic compounds. In the research total phenolic content (TPC) in potatoes stored for the period of six months was higher than in potatoes just after harvesting and in average it has increased in organically cultivated potatoes per 16.9%, conventionally (*N*1) – 18.3% and (*N*2) – 29.2% respectively.

In the analyzed potatoes before storage, the highest TPC was determined for the tubers of the Agrie dzeltenie variety when cultivated organically (i.e. 29.906±0.162 mg GAE 100 g^{-1} FW) and after a period of storage – of the Blue Congo variety when cultivated conventionally (*N*2) (i.e. 53.334±0.199 mg GAE 100 g^{-1} FW) Table III. Before a period of storage, in the yellow flesh potato tubers were higher amount of TPC comparing to tubers with violet flesh while vs. was after a period of storage.

Since in the research early, mid-early, mid-late and late varieties were used, potato maturity can be found to be different and during the post-harvesting stage some of the varieties can reach the maturity stage. It has been found that maturity stage can be one of the factors influencing TPC. Reyes et al. has observed that TPC in tubers decreased with tubers growth and maturity [52]. The TPC may be affected during the development of the flesh colour (purple, violet, yellow) of potato tubers [53], due to the environmental conditions, such as longer days and cooler temperatures or fertilization [52], [54], [55]. The effect of the cultivar and the differences between yellow and purple-fleshed cultivars in TPC has been found significant. The purple-fleshed cultivars contained on average58.1% more total phenolics compared to the yellow-fleshed cultivars. In regard to the agronomic practise, it was suggested that application of synthetic fertilizers make the nitrogen available, which is utilized for growth but not allocated for the production of secondary metabolites such us phenols. Where as organic agriculture leads to an enhancement of natural defence substances such as phenolic compounds (Winter and Davis, 2006). In the current research, TPC has been found to be predominantly higher in organically cultivated potato tubers comparing to conventionally cultivated potato tubers while focusing on the amount of nitrogen used in each of conventionally cultivation practise (*N*1 – 60 kg ha^{-1} and *N*2 – 120 kg ha^{-1}), TPC was predominantly higher in potato tubers cultivated conventionally with doubled dose of *N* - 120 kg ha^{-1} (*N*2), but it varied per variety.

Like it was reported by Faller and Failho (2009), also in this particular research, significant differences were noticed in TPC when evaluating it within the varieties ($p<0.001$) used in the research and within non-stored and stored potato tubers ($p<0.001$) while no significant differences were noticed within the agricultural practise used ($p>0.05$). In some studies have been found that storage generally increases TPC abut little changes or a decrease have also been reported [57]-[59].

The highest carotenoid content for non-stored potatoes was determined for the tubers of the Annuscha variety (i.e. 0.400±0.007 mg 100 g^{-1} FW) when potatoes were conventionally cultivated (*N*2) with the rate of *N* fertilizer 120 kg ha^{-1}. The second highest carotenoid content was found in the same Annuscha variety when organically cultivated (i.e. 0.354±0.003 mg 100 g^{-1} FW). Detailed information is shown in Table IV. Bonierbale et al has found that carotenoid content might vary in potatoes from 0.103 to 2.135 mg 100 g^{-1} FW) [60].

Carotenoid content per 100 g of tubers after a period of storage for some of the varieties was increased but for some it was decreased, but it does not show significant differences between non-stored and stored potatoes ($p>0.05$) while between varieties differences were found to be significant ($p<0.001$).

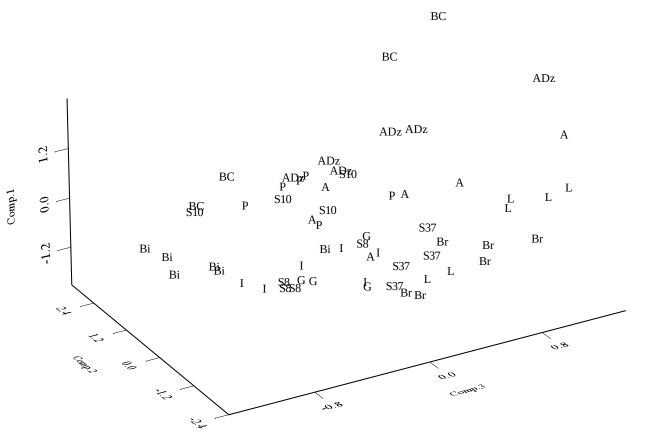

Fig. 1. Principle component analysis. Projection of the analyzed potato samples showing the influence of storage and cultivation type on carotenoids, TPC and DM in the space formed by the comp.1, comp.2 and comp.3. Abbreviations used in the figure: ADZ-Agrie dzeltenie, P-Prelma, I-Imanta, L-Lenora, Br-Brasla, Bi-Bionica, A-Annuscha, BC-Blue Congo, G-Gundega, S37-S04009-37, S10-S03135-10, S8-S99108-8

These differences might be influenced by several factors, for example variety and maturity stage of tubers [43]. It has been found that total carotenoid content is higher in immature tubers and it decreased with tuber maturity [61], [62]. In addition, Katikova et al. have found that the application of fertilizers does not bring any significant changes in carotenoids of potatoes while particular research show significant changes in the content of carotenoids between organically and conventionally (*N*1) grown potatoes ($p<0.05$).

Dissimilarities between varieties, especially in case of wide ranges within one and the same variety, explain the importance of factors was taken into account (cultivation type and storage) and their affect on TPC, carotenoids and DM content.

In the research colour was analysed on potato tubers with white, yellow and violet flesh and relationship between colour and carotenoid and TPC was found (Table V).

In the analysis of the tubers' flesh colour, it has been found that there is a tendency having darker potato flesh with higher carotenoid content. The orange and yellow colour of the tuber flesh is due to zeaxanthin and lutein, respectively [24].

IV. Conclusion

The changes in carotenoid content, total phenolic content (TPC) and dry matter (DM) content of potatoes vary significantly according to the type of cultivation practise, depending on the potato variety and the type of season (before or after storage). There are common tendencies in the changes of separate indices: in the case of cultivation practise (organically, conventionally (two different amounts of *N* fertilizer were used: *N*1 – 60 kg/ha and *N*2 – 120 kg/ha)), significant differences were noticed in DM ($p<0.001$) and carotenoid content ($p<0.05$); between non-stored and stored potatoes – on DM ($p<0.001$) and TPC ($p<0.001$) while the variety was most significant factor in all cases – on DM, TPC and carotenoid content ($p<0.001$).

Correlation between colour (b^*) and carotenoid content was found from 0.53 to 0.74 in organically and conventionally (*N*1 and N2) cultivated potatoes; on colour a^* was found the correlation in conventionally (*N*1) cultivated potatoes both on carotenoids and TPC while on L^* - on carotenoid content in organically cultivated potatoes and on TPC in conventionally (*N*1) cultivated potatoes.

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