# CAROTENOIDS AND TOTAL PHENOLIC CONTENT IN POTATOES WITH DIFFERENT FLESH COLOUR

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**Abstract**

Polyphenols are recognized as the most abundant antioxidants in our diet. 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. The aim of this research was to determine the content of total phenolic and carotenoid (TPC) content in relationship with the colour of organically and conventionally cultivated potato varieties (*Solanum tuberosum* L.) with different flesh colour. In cooperation with the State Priekuli Plant Breeding Institute (Latvia), sixteen potato genotypes were studied. The highest TPC and carotenoid content was determined in potatoes of Purple Peru variety when conventionally cultivated. Correlation was found between TPC and colour L* (r=-0.813). The changes in carotenoid content and TPC of potatoes vary significantly according to the type of cultivation practise, depending on variety. There are common tendencies in the changes of TPC and carotenoid content – the variety was the most significant factor ($p<0.001$).

***Keywords***: potato, colour, TPC, carotenoids, organic and conventional.

## Introduction

The research in potato chemistry has established the fact that there is a lot more in potatoes than starch. Natural colorant and antioxidant present in yellow-, purple- and red-flesh potatoes can be used for developing functional foods. 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 (Ezekiel et al., 2013). Many of the compounds present in potatoes are important because of their beneficial effects on health, therefore, they are highly desirable in the human diet (Katan, De Roos, 2004).

Colour is an important food quality parameter. It affects consumer acceptance and can even evoke emotional feelings in humans (Crisosto et al., 2003; Ou et al., 2004). Coloured potatoes have attracted the attention of investigators as well as consumers because of their antioxidant activities, taste and appearance (Jansen, Flamme, 2006). The antioxidant activity in coloured potatoes is associated with the presence of polyphenols anthocyanins, flavonoids, carotenoids, ascorbic acid, tocopherols, alpha-lipoic acid and selenium (Lachman et al., 2005a). 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 (Maiani et al., 2009; Spencer, 2008; Minich, Bland, 2008; Hunter et al., 2008; Stevenson, Hurst, 2007).

Carotenoids are lipophilic compounds synthesized in plastids from isoprenoids which are widespread in nature and have broad range of functions, especially in relation to human health and their role as biological antioxidants (Dellapenna, Pogson, 2006; Fraser, Bramley, 2004). Because of their high carotenoids content potatoes are particularly beneficial for eye health (Tan et al., 2008).

Potato cultivars with white flesh contain less carotenoids as compared to cultivars with yellow or orange flesh. Total carotenoids content was reported in the range of 50–350 μg 100 $g^{-1}$ FW and 800–2000 μg 100 $g^{-1}$ FW, respectively, in white- and yellow-fleshed potato cultivars (Brown, 2008).

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 (Ross, Kasum, 2002).

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 (Duthie et al., 2000; Mattila, Hellstrom, 2006). Potatoes are a good source of phenolic 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 (Bravo, 1998), 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 $g^{-1}$ (Al-Saikhan et al., 1995). Potatoes were considered the third most important source of phenols after apples and oranges (Chun, 2005).

Potato quality varies depending on the growing area, cultivar 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 (Dangour et al., 2009; Moschella et al., 2005). Although nutrient content depends on a number of factors, the potato variety is thought to be among the most significant factors (Toledo, Burlingame, 2006).

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 (Carillo et al., 2012). 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 (Bourn, Prescott, 2002).

The aim of this research was to determine the content of total phenolic and carotenoid content in relationship with the colour of organically and conventionally cultivated potato varieties (*Solanum tuberosum* L.) with different flesh colour.

## Materials and Methods

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 $kg^{-1}$, $pH_{KCl}$ was 5.7, availability of K and P in soil was high. Fertilizer P – 55, K – 90 kg $ha^{-1}$ and N – 60 kg $ha^{-1}$ was used in conventional field. 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 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±1 °C and at a relative air humidity of 80±5%.

*Plant material*. In the experiment 16 potato (*Solanum tuberosum* L.) varieties with white, yellow and purple coloured flesh were evaluated, whose seed was obtained in the State Priekuli Plant Breeding Institute (SPPBI) (Latvia). Potatoes were grown in organic and conventional field and controlled by SPPBI. The characterization of potato varieties and the type of cultivation practise used per each potato variety is presented in Table 1.

Table 1

**Description of potato varieties**

| Name and acronym* of potato variety | Flesh colour | Origin of variety | Cultivation practice applied** |
|---|---|---|---|
| Agrie Dzeltenie (Adz) | yellow | Latvia | O/C |
| Prelma (P) | yellow | Latvia | O/C |
| Imanta (I) | white | Latvia | O/C |
| Lenora (L) | yellow | Latvia | O/C |
| Brasla (Br) | yellow | Latvia | O/C |
| Bionica (Bi) | white | Netherlands | O/C |
| Anuschka (An) | yellow | Germany | O/C |
| Gundega (G) | yellow | Latvia | O/C |
| S04009-37 (S37) | yellow | Latvia | C |
| S03135-10 (S10) | white | Latvia | C |
| S99108-8 (S8) | light yellow | Latvia | C |
| Fenton (F) | purple | US | C |
| Purple Fiesta (PF) | purple | US | C |
| British Columbia Blue (BCB) | purple | US/Canada | C |
| Purple Peru (PP) | purple | Peru | C |
| Blue Congo (BC) | purple | Czech Republic | C |

* Acronyms of potato varieties used throughout the paper presented in brackets

** Cultivation practice: O/C – cultivated organically and conventionally, C – cultivated conventionally

*Sampling*. For testing, 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. Five potatoes were selected from several location points of each box (Murniece et al., 2011). All operations during sample preparation were performed very quickly so as to avoid deviations from the qualitatively obtained results. Potato tubers were peeled and analysed without a skin. In the analysis on total phenolic content (TPC) and carotenoids, the test and analysis were run in triplicate and averaged.

*Carotenoids* were analyzed by spectrophotometric method (with the UV/VIS spectrophotometer Jenway 6705) at 440 nm (Ермаков, 1987) and is expressed on mg 100 $g^{-1}$ fresh weight (FW) of potatoes.

*Total Phenolic Content (TPC)*. For extraction of phenolic compounds five grams of the homogenized sample were extracted with 50 mL of ethanol water 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 °C). The potatoes extracts were then filtered via the paper with No 89.

The TPC of the extracts was determined according to the Folin-Ciocalteu spectrophotometric method

(Singleton et al., 1999) 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. After 30 minutes of incubation at room temperature, the absorbance was measured at 765 nm. Total phenols were expressed as gallic acid equivalents (GAE) mg 100 $g^{-1}$ FW of potatoes.

*Colour analysis.* The colour of potato samples was measured by "Colour Tec-PCM" device. For evaluation of the colour of potato samples, potato slices were cut shortly before measurement in order to avoid formation of melanin pigments during 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 equipment 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 processing, "ColorSof QCW" software was used.

*Statistical Analysis*. For statistical analysis, the data were processed using the S-PLUS 6.1 Professional Edition software and XLSTAT 2014 program. Data are presented as a mean ± standard deviation (SD). The differences between independent groups were specified by one way and 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 colour were made by Principal Component Analysis (PCA).

**Results and Discussion**

Carotenoid content in potatoes cultivated organically varied from 0.089 to 0.385 mg 100 $g^{-1}$ FW while in conventionally cultivated potatoes – from 0.068 to 0.371 mg 100 $g^{-1}$ FW (Fig. 1). Bonierbale et al. (2009) has found that carotenoid content might vary in potatoes from 0.103 to 2.135 mg 100 $g^{-1}$ FW). The results of current research make the range much wider. Differences in this case might be influenced by several factors, for example variety and maturity stage of tubers (Murniece et al., 2011). It has been found that total carotenoid content is higher in immature tubers and it decreased with tuber maturity (Kotikova et al., 2007; Morris et al., 2004).

Comparing coarotenoid content between potato tuber varieties with white and yellow flesh, content was found to be the highest in Lenora variety when cultivated organically and Anuschka variety when cultivated conventionally.

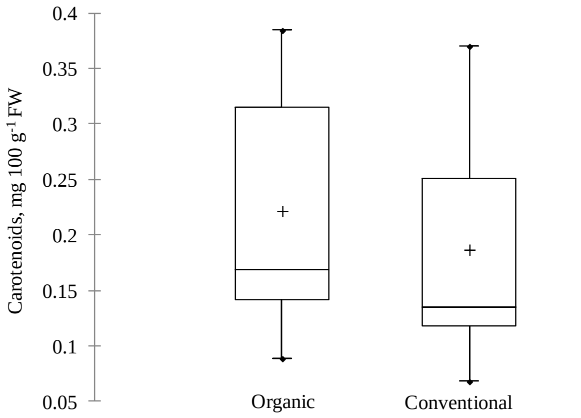


**Figure 1. Carotenoid content in potato tubers with white and yellow flesh**

In potato tubers with purple flesh carotenoid content was 78% lower than in potato tubers with white and yellow flesh and it varied from 0.012 to 0.084 mg 100 $g^{-1}$ FW (Table 2).

In the evaluation of carotenoid content within the factor of variety and factor of cultivation practise, statistical results showed that significance was noticed between varieties ($p=0.019$) while no significant difference was noticed when potato tubers were cultivated organically or conventionally ($p=0.316$). The most significant difference in carotenoid content was determined between Imanta and Anuschka varieties.

Kotikova et al. (2007) have obtained the same result that the application of fertilizers did not bring any significant changes in carotenoids of potatoes.

The TPC might be affected during the development of the flesh colour (purple, violet, yellow) of potato tubers (Lachman et al., 2005b), due to the environmental conditions, such as longer days and cooler temperatures or fertilization (Kumar et al., 2004; Reyes et al., 2004).

TPC in potato tubers cultivated organically varied from 34.475 to 64.230 mg GAE 100 $g^{-1}$ FW, in 25% of analysed potato tubers TPC was no higher than 36.937 mg GAE 100 $g^{-1}$ FW while in 75% of analysed potato tubers TPC reached to 49.436 mg GAE 100 $g^{-1}$ FW. In the case when potato tubers were cultivated conventionally TPC was in lower amount and it varied from 26.854 to 52.172 mg GAE 100 $g^{-1}$ FW. In 25% of analysed potato tubers TPC was no more than 31.410 mg GAE 100 $g^{-1}$ FW of while in 75% – 49.040 mg 100 $g^{-1}$ FW (Fig. 2).

Comparing the obtained results with Faller and Failho (2009), also in this particular research, TPC significantly differed between varieties ($p=0.015$) while cultivation practise did not present significance ($p=0.164$). The most significant difference in TPC was determined for Anushcka variety when compared with Brasla, Imanta and Lenora varieties.

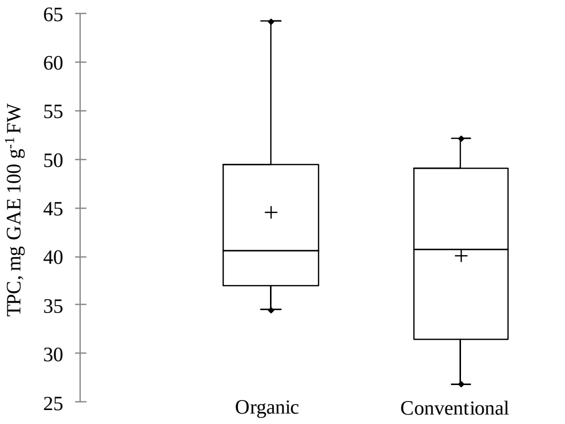


**Figure 2. Total phenolic content in potato tubers with white and yellow flesh**

Comparing TPC of potatoes with white and yellow flesh with purple fleshed it was 81% higher in potato tubers with purple flesh. The highest TPC between purple fleshed varieties was determined for Purple Peru variety while the lowest – in Purple Fiesta variety (Table 2).

Table 2

**Total phenolic and carotenoid content in potato tubers with purple flesh**

| Name of potato variety | Carotenoids | TPC |
|---|---|---|
| | mg 100 g$^{-1}$ FW | mg GAE 100 g$^{-1}$ FW |
| Fenton | 0.012±0.002 | 75.92±0.14 |
| Purple Fiesta | 0.070±0.002 | 69.54±0.56 |
| British Colombia Blue | 0.084±0.005 | 73.02±0.38 |
| Purple Peru | 0.029±0.002 | 86.72±0.25 |
| Blue Congo | 0.030±0.001 | 77.07±0.23 |

Results present means of triplicate determinations with ± standard deviation

To better understand the relationship between TPC and carotenoid content with colour of organically and conventionally cultivated potato varieties, PCA was applied. In Figure 3 the first and second principal components accounted for 73.47% of total variance (PC1 – 51.22% and PC2 – 22.25%). Projection of the samples in the space formed by PC1 and PC2 shows that colour intensity (L*) is low of potato tuber flesh of Imanta variety and for the same (i.e. Imanta variety) the difference in flesh colour was noticed when potatoes were cultivated organically and conventionally (Fig. 3). In addition, the projection of PCA presents the opposite side of potato varieties with yellowish flesh (b*) and with higher carotenoid content (carotenoids) of potato varieties projected in the same area. Potato varieties projected in the positive area of F1 and F2 are higher in TPC and colour flesh is much lighter than in the varieties projected in the positive area of F1 and negative of F2 i.e. of b* and carotenoids.

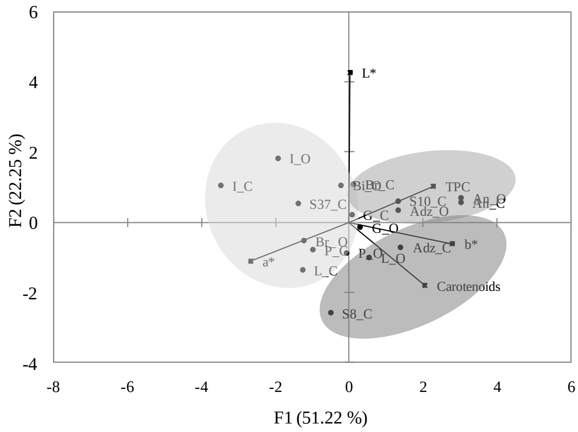


**Figure 3. Principal component analysis, projection of potato varieties with white and yellow flesh cultivated organically and conventionally**

The first letter indicates variety and the second – cultivation practice. An example: I_O – Imanta variety cultivated organically while I_C – Imanta variety cultivated conventionally. Acronyms are summarized in the Table 1.

When potatoes of purple flesh were analysed by applying PCA, the projection of factors was different from potatoes with white and yellow flesh. In the Figure 4 first and second principal components accounted 86.58% of total variance (PC1 – 55.51% and PC2 – 31.07%). Potato varieties which are projected in the negative area of F1 are higher in TPC and colour flesh is much darker (purplish to bluish) whereas in the positive area of F2 with the predominant factor L* Blue Congo variety cultivated conventionally comparing to other potatoes tubers with purple flesh was with lighter colour (Fig. 4).

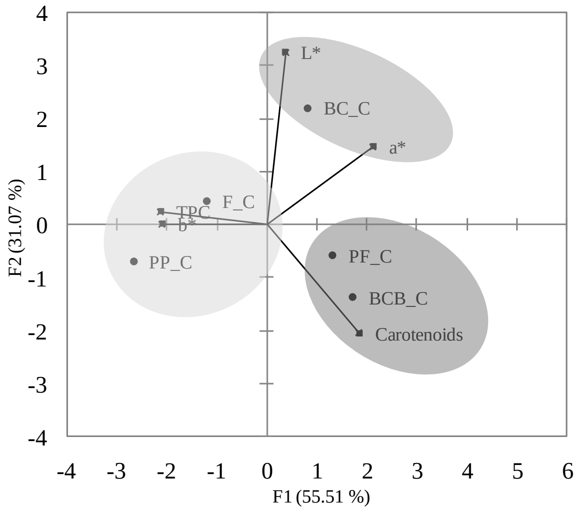


**Figure 4. Principal component analysis, projection of potato varieties with purple flesh cultivated conventionally**

First letter indicates variety and second – cultivation practise. An example: BC_C – Blue Congo variety cultivated conventionally. Acronyms are summarized in the Table 1.

In the correlation analysis (Fig. 5) of potato tubers with white and yellow flesh obtained results represented negative correlation between TPC with the colour of redness value a* (r=0.594), positive correlation was found between TPC and carotenoid content with the colour of yellowness value b* (r=0.490) and (r=0.591) respectively.

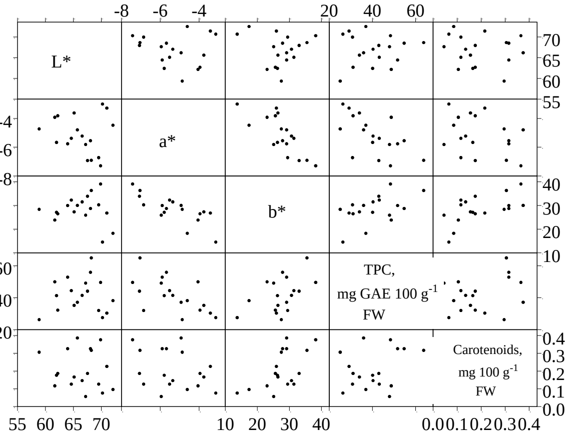


**Figure 5. Relationship of total phenolic and carotenoid content with colour L* a* b***

When correlation analysis was applied to all potato varieties used in the research, between TPC and L* correlation was found (r=0.813).

In the colour analysis the obtained results showed that colour intensity within potato tuber varieties with white and yellow flesh significantly differed between Imanta and Prelma varieties ($p<0.05$). Significant difference was noticed on yellowness value b* ($p\leq0.001$) while factor a* which represents redness did not show significance on colour flesh between all potato varieties with white and yellow flesh ($p>0.05$). In the case of statistical analysis of potato tubers with purple flesh there were no significant affect on any of parameters determined in research ($p>0.05$).

## Conclusions

From the nutritional point of view, apart from the macronutrient content, potatoes contain traces of nutrients which are proved to be beneficial for human health. From the results of this particular research it might be concluded that the colour of potato flesh could be one of the factors taken into account for modelling and predicting health promoting substances like carotenoid, anthocyanin content and also TPC. In future, much deeper investigation is required in this particular field of interest.

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