EFFECT OF STORAGE CONDITIONS ON BIOLOGICALLY ACTIVE COMPOUNDS IN PURPLE-FLESHED POTATOES

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*Potatoes (*Solanum tuberosum* L.) are an important crop. They are a source of natural phenolic compounds with high biological activity. Stress factors may decrease phenolic concentration and increase concentration of the toxin glycoalkaloid as a result of plant self-protection against stress. The aim of the current study was to evaluate the effect of storage under light on the concentration of biologically active compounds in purple-fleshed potatoes. The purple-fleshed potato variety 'Blue Congo' was harvested from test fields of the Institute of Agricultural Resources and Economics in Latvia. Storage under light was performed in a climate chamber ICH110 (Memmert GmbH + Co. KG, Germany) with constant pre-set relative air humidity 85%, temperature +22 °C, and full-spectrum light (Eecoo, 1200 W, LED) intensity of 2000 lux and total time seven days. Total phenolic concentration, antioxidant activity and total glycoalkaloid concentration was measured using spectrophotometry, and moisture was determined according to standard LVS 272:2000. Storage under artificial light of purple-fleshed variety 'Blue Congo' potatoes caused decrease of total phenolic concentration and antioxidant activity, no change in moisture level, and increase of total glycoalkaloid concentration.*

Keywords: Blue Congo potatoes, phenolic compounds, glycoalkaloids, antioxidant activity, storage under light.

INTRODUCTION

Nowadays there is a growing trend in the use of food with higher levels of natural antioxidants (Kumar *et al.*, 2015). Potato (*Solanum tuberosum* L.) production has increased tremendously in developing countries in the past two decades (Paul *et al.*, 2012). They are rich in phenolics, a biologically active compound that has proven positive influence on human wellbeing (Akyol *et al.*, 2016), and are source of phenolic compounds. They are ranked as the third consumed crop (Paul *et al.*, 2012). Phenolic compounds have antioxidant, antibacterial, anticarcinogenic, anti-inflammatory, antiglycemic, antiviral, and vasodilatory effects (Berghe, 2012; Kazeem *et al.*, 2012; Konaté *et al.*, 2012), and a positive effect on human longevity, ocular organs, mental health, and the cardiovascular system (Manach *et al.*, 2004; Scalbert *et al.*, 2005). Positive correlation between phenolic concentration and total antioxidant activity in potatoes has been found (Andre *et al.*, 2007). Phenolics

are found in the whole tuber, but the peels have highest saturation of phenolics (Lewis *et al.*, 1999; Nara *et al.*, 2006). They are present in all potato varieties, but the phenolic amount almost double in purple-fleshed (also red-fleshed) varieties compared to white-fleshed and yellow-fleshed varieties (Ezekiel *et al.*, 2013). This difference in the amount of phenolic compounds might be explained by anthocyanins, which are the main colour pigments in purple-fleshed potatoes (Im *et al.*, 2008; Al-Weshahy and Rao, 2009).

In addition to nutritional compounds, potatoes contain also glycoalkaloids, which are natural toxins. Glycoalkaloid build-up is caused by natural and human caused stress factors (Papathanasiou *et al.*, 1999). The major glycoalkaloids in potatoes are α -solanine and α -chaconine (Friedman, Levin, 2009; Omayio *et al.*, 2016). The World Health Organisation reported that the safe level of glycoalkaloids in fresh potato tubers is from 20 to 100 mg·kg⁻¹ (Evaluation of

Certain..., 1992). Other studies have shown that concentration of even up to 200 mg·kg⁻¹ glycoalkaloid in fresh potatoes is safe (Karim *et al.*, 1997; Jansky, 2010). Glycoalkaloid intoxication can lead to digestive illnesses, diarrhoea, and vomiting (Hellenas *et al.*, 1992), and higher doses might result in nerve system damage, coma and even death (Langkildea *et al.*, 2009).

Studies have shown that artificial light can accelerate development of glycoalkaloids (Dale *et al.*, 1993; Machado *et al.*, 2007) and also might increase the level of phenolic compounds and antioxidant activity (Nascimento *et al.*, 2013; Ballester and Lafuente, 2017).

Inappropriate storage might lead to increased toxicity (glycoalkaloids) and/or lower levels of valuable compounds (phenolics), and more study of these relationships is required. Regulated temperature and light precision can be maintained only in artificial experimental conditions that replicate specific natural conditions, which are needed to understand biochemical changes in potatoes under specific conditions.

The aim of the current study was to evaluate the effect of the storage under artificial light on levels of biologically active compounds in purple-fleshed potatoes.

MATERIALS AND METHODS

The raw material used was a harvest crop of purple-flesh potato variety 'Blue Congo', harvested from test fields of the Institute of Agricultural Resources and Economics, Latvia. Storage before treatment was with light at +4 °C temperature and 80 ± 5% relative air humidity. Treatment was storage for seven days in a climate chamber ICH110 (Mettmert GmbH + Co. KG, Germany) with constant and even pre-set relative air humidity 85%, temperature +22 °C, and full-spectrum light (Eecoo, 1200 W, LED) intensity of 2000 lux. This period was suggested in literature to represent real situations when potatoes are shortly marketed/ stored on shop shelves.

Chemical analysis. Total phenolic concentration was determined using the Folin-Ciocalteu spectrophotometric method (Singleton *et al.*, 1999) with ethanol as a solvent. Absorbance was measured at 765 nm and total phenol concentration was expressed as gallic acid equivalents per 100 g⁻¹ dry weight of plant material. Antioxidant activity was estimated on the basis of scavenging activity using the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH[•]) radical and 2,2'-azino-bis(3-ethylbenz-thiazoline-6-sulfonic) acid (ABTS^{•+}) radical cation assay. Antioxidant activity was expressed as TE · 100 g⁻¹ of plant material. Moisture content was determined according to LVS 272:2000 using an EBC 4.2. Incubator, "Mettmert, model 100-800". Total glycoalkaloid concentration was measured according to method modified by Skrabule *et al.* (2010).

Statistical analysis. Mathematical processing and interpretation of data was done in MS-Excel, SPSS 22.0 using

analysis of variance ($p < 0.05$) and correlation analysis ($p < 0.05$). Data represent means ± standard deviation ($n = 6$).

RESULTS

Total phenolics. The total phenolic concentration of the studied potato flesh ranged from 313.66 mg·100 g⁻¹ before treatment with light to 237.37 mg·100 g⁻¹ fresh weight after treatment with light on day 7 (Fig. 1). There was a rapid decrease to 241.36 mg·100 g⁻¹ after 3-day treatment and no significant differences on day 7 compared to third day. The phenolic concentration of potato peels ranged from 306.51 mg·100 g⁻¹ before treatment with light to 313.89 mg·100 g⁻¹ after treatment with light on day 7, and despite a slight decrease (287.83 mg·100 g⁻¹) of phenolic concentration on day 3, it increased and even exceeded initial total phenolic concentration on day 7.

Artificial lighting during relatively short term storage had non-significant effect on total phenolic concentration in potato peels, while the concentration in flesh showed a rapid decrease in first three days followed by stable and steady decrease during the longer period. Seven days is a considerable period that is based on real-life situations when potatoes are stored in shop shelves and are exposed to increased stress factors (high temperature/light).

DPPH scavenging activity. 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity of potato flesh ranged from 13.60 mg·100 g⁻¹ before treatment with light to 10.46 mg·100 g⁻¹ after treatment with light on day 7 (Fig. 2). There was a decrease (11.01 mg·100 g⁻¹) after 3-day treatment and no significant difference on day 7 compared to the third day. The DPPH scavenging activity of potato peels ranged from 17.96 mg·100 g⁻¹ before treatment with light to 17.82 mg·100 g⁻¹ after treatment with light on day 7. There was a slight decrease (16.14 mg·100 g⁻¹) on day 3, which then increased and on day 7 almost reached the initial DPPH scavenging activity.

While a slight decrease of DPPH scavenging activity during seven day storage under light was found for potato flesh, potato peels during same period showed stronger ability to

Fig. 1. Total phenolic concentration of potato flesh and peel. Values with different letters are significantly different ($p < 0.05$) based on the Tukey's test.

Fig. 2. DPPH scavenging activity of potato flesh and peel. Values with different letters are significantly different ($p < 0.05$) based on the Tukey's test.

Fig. 3. ABTS scavenging activity of potato flesh and peel. Values with different letters are significantly different ($p < 0.05$) based on the Tukey's test.

preserve DPPH scavenging activity. The data suggest that storage under artificial lighting generally has only a slight effect on potato DPPH scavenging activity, at least during a relatively short period of time.

ABTS scavenging activity. 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) scavenging activity of potato flesh ranged from 40.78 mg·100 g⁻¹ before treatment with light to 17.66 mg·100 g⁻¹ after treatment with light on day 7 (Fig. 3). There was a rapid decrease (30.69 mg·100 g⁻¹) after 3-day treatment and another rapid decrease on day 7. ABTS scavenging activity of potato peels ranged from 41.56 mg·100 g⁻¹ before treatment with light to 19.57 mg·100 g⁻¹ after treatment with light on day 7, and there was a quite rapid decrease (29.81 mg·100 g⁻¹) on day 3 followed by another rapid decrease on day 7.

The study showed that ABTS scavenging activity significantly decreased during storage under light in the seven-day period. The data suggests that longer storage might lead to a greater and more rapid decrease.

Total glycoalkaloid content. The total glycoalkaloid concentration of potato flesh ranged from 1.18 mg·100 g⁻¹ before treatment with light to 1.72 mg·100 g⁻¹ after treatment

Fig. 4. Total glycoalkaloid concentration of potato flesh and peel. Values with different letters are significantly different ($p < 0.05$) based on the Tukey's test.

Fig. 5. Moisture of potato flesh and peel. Values with different letters are significantly different ($p < 0.05$) based on the Tukey's test.

with light on day 7 (Fig. 4) with a rapid increase (almost double) (2.06 mg·100 g⁻¹) after 3 day treatment and no significant difference on day 7 compared to third day. The glycoalkaloid concentration of potato peels ranged from 12.09 mg·100 g⁻¹ before treatment with light to 13.81 mg·100 g⁻¹ after treatment with light on day 7, showing no significant changes during the first three days (12.04 mg·100 g⁻¹ after three-day treatment), but which was followed by rapid increase of concentration.

Moisture. Moisture of potato flesh ranged from 80.83% before treatment with light to 79.12% after treatment with light on day 7 (Fig. 5), with a slight decrease (79.23%) after 3-day treatment and another slight decrease on day 7. The moisture of potato peels ranged from 82.60% before treatment with light to 77.51% after treatment with light on day 7. Only a slight decrease (81.00%) of moisture was observed on day 3 followed by another slight decrease on day 7.

The experiment showed that purple-fleshed potato retained moisture content under artificial lighting storage conditions. Longer exposure to light and longer storage time would show further decrease of moisture, but based on the study data, the decrease could be slow and without rapid changes.

Fig. 6. Correlation between total phenolic concentration and DPPH scavenging activity of potato.

Fig. 8. Correlation between DPPH scavenging activity and ABTS scavenging activity of potato.

Fig. 7. Correlation between total phenolic concentration and ABTS scavenging activity of potato.

Fig. 9. Correlation between total phenolic concentration and total glycoalkaloid concentration of potato.

The effect of moisture content change on levels of bio-compounds was insignificant.

Correlation. Previous studies suggest that there is a strong positive correlation between phenolic concentration and antioxidant capacity (Andre *et al.*, 2007).

The current study showed strong positive correlation (coefficient: 0.84) between total phenolic concentration and DPPH scavenging activity (Fig. 6) and that a change in one of these parameter will trigger change of the other.

Correlation between ABTS scavenging activity and total phenolic concentration (Fig. 7) was moderate positive (coefficient: 0.45).

Correlation between ABTS scavenging activity and DPPH scavenging activity (Fig. 8) was weak positive (coefficient: 0.25).

Correlation between total glycoalkaloid concentration and total phenolic concentration (Fig. 9) of potato was moderate positive (coefficient: 0.57).

Correlation between total glycoalkaloid concentration and DPPH scavenging activity (Fig. 10) was strong positive (coefficient: 0.92)

There was no correlation between total glycoalkaloid concentration and ABTS scavenging activity.

Fig. 10. Correlation between DPPH scavenging activity and total glycoalkaloid concentration of potato.

DISCUSSION

In the current study, full-spectrum light was used as an artificial light source. Such light imitates sunlight (negative factor during potato harvest) and covers the light spectrum existing on shop shelves and in storage facilities (usually uses fluorescent light bulbs, which is a negative factor during potato short-term and long-term storage). The temperature and light intensity level that was used in the study was based on mean temperature and light measured in thirty shops in Latvia.

Antioxidant activity (scavenging activity of an extract) is the ability of redox molecules in potatoes to suppress free

radicals (Puchau *et al.*, 2010) such as DPPH and ABTS, and that ability is closely linked to total phenolic concentration (Leo *et al.*, 2008). Studies have shown that light has negative influence on the anti-oxidative profile of potato (Chellaram *et al.*, 2014). The current study confirms these studies, as storage under light caused decreased total phenolic concentration and DPPH scavenging activity in potato flesh. In peels, both of these parameters decreased after the third day and returned to the initial level on the seventh day. There was a drastic drop in ABTS scavenging activity during the seven-day storage period in both flesh and peels. This shows that, compared to DPPH scavenging activity, ABTS scavenging activity (antioxidant activity) suffers (decreases) the most from storage artificial light. The present study thus showed that bright light and high temperature as stress factors negatively affected antioxidant activity. Phenolics as bio-active compounds are directly linked to antioxidant activity (ABTS and DPPH scavenging activity) of potatoes. When phenolic concentration decreases, antioxidant (scavenging) activity also decreases. It cannot be excluded that there are also other compounds that are directly or indirectly linked to antioxidant (scavenging) activity in potatoes. This study was focused on the most widely known compounds: phenolics and toxic glycoalkaloids with antioxidant (scavenging) activity.

Previous studies have shown that artificial light might promote glycoalkaloid development (Dale *et al.*, 1993; Machado *et al.*, 2007). The present study also found that total glycoalkaloid concentration in potatoes flesh increased, almost doubling, during the first three days of storage under light, but there were no significant differences on seventh day compared to the third day. In potato peels there was no significant change in total glycoalkaloid concentration during the first three days, but in the period from day three to seven there was a rapid increase.

In the storage experiment, purple-fleshed potato had the ability to retain moisture to a large extent in artificial lighting storage conditions. However, longer exposure to light and storage might result in decrease of moisture, based on current study data, the decrease could be slow and without rapid changes.

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UZGLABĀŠANAS APSTĀKĻU IETEKME UZ BIOAKTĪVAJĀM VIELĀM KARTUPEĻOS AR VIOLETU MĪKSTUMU

Kartupeļi (*Solanum tuberosum* L.) ir nozīmīgs dārzeņis, kas dabiskā veidā satur augstas bioloģiskās aktivitātes fenolu savienojumus. Stresa faktori var radīt auga aizsargreakciju, kuras rezultātā var samazināties fenolu savienojumu koncentrācija un vienlaicīgi palielināties glikoalkaloīdu (dabisko auga toksīnu) koncentrācija. Šī pētījuma mērķis bija izvērtēt uzglabāšanas mākslīga apgaismojuma apstākļos ietekmi uz bioaktīvajām vielām kartupeļos ar violetu mīkstumu 'Blue Congo'. Eksperimentā tika izmantota šīs šķirnes bumbuļi, kas ievākti eksperimenta laikā Agroresursu un ekonomikas institūtā. Uzglabāšana septiņas dienas tika veikta mikroklimata uzturēšanas kamerā ICH110 (*Memmert GmbH + Co. KG*, Vācija) ar iestatītu un nemainīgu gaisa relatīvo mitrumu 85%, temperatūru +22 °C, pilna spektra 2000 luksu apgaismojumā (*Eecoo*, 1200 vati, LED). Kopējā fenolu koncentrācija, antioksidatīvā aktivitāte un kopējā glikoalkaloīdu koncentrācija tika noteikta ar spektrofotometrisku metodi, savukārt mitrums tika noteikts atbilstoši standartam LVS 272:2000. Šis pētījums pierādīja, ka violetās šķirnes 'Blue Congo' kartupeļu uzglabāšana mākslīgā apgaismojuma apstākļos samazina kartupeļos kopējo fenolu koncentrāciju un antioksidatīvo aktivitāti, mitruma līmenis nemainās, savukārt kopējā glikoalkaloīdu koncentrācija pieaug.