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Changes of phenolic content and antiradical activity in hybrids of Nantes carrots during storage

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Carrots are one of the most consumed plant foods in the world in all seasons; they are good sources of natural antioxidants and contain many different antioxidant components. Carrots are recommended for healthy diets as recognized sources of dietary fiber and antioxidant substances, such as phenols. The current research focuses on the evaluation total phenolic and antiradical activity changes in hybrids of Nantes carrots during storage. Late-bearing variety Nantes hybrid carrots were used for experiments such as Nantes/Berlikum, Nantes/Maestro, Nantes/Forto, Nantes/Bolero and Nantes/Champion. Changes of the quality parameters were evaluated after two and four months of storage in the comparison with non-stored carrots. Standard methods were used to evaluate the quality parameters: total phenols were analysed by the Folin–Ciocalteu colorimetric method with some modifications, and the antiradical activity was measured by the DPPH radical method. The present experiments revealed significant differences ($p < 0.05$) in the content of total phenols and antiradical activity changes during carrot storage. The results of the research demonstrate that the content of total phenols decreases within four months of storage approximately 1.3 times as compared with the initial content before storage. However, changes of antiradical activity in carrots after two months of storage were not significant. The antiradical activity of carrots decreased significantly (1.8 times on average) after four months of storage.

Keywords: carrots, phenols, antiradical activity, storage

Introduction

Carrot (*Daucus carota*) is a good source of natural antioxidants, especially carotenoids and phenolic compounds [1]. Phenolic compounds account for a major portion of the antioxidant capacity in many plants. Carrots have been ranked 10th in nutritional value among 39 fruits and vegetables, and research on carrot health benefits continues [2]. The nutritional value of fruit and vegetables is often associated with their antioxidant capacities [3]. Phenolics are ubiquitous secondary metabolites in this plant. They comprise a large group of biologically active ingredients – form simple phenol molecules to polymeric structures with the molecular mass above 30000 Ds. On the basis of the number of phenol subunits, the modern classification forms two basic groups of phenolics – simple phenols and polyphenols. The group of simple phenols contains also the so-called "phenolic acids", or phenols with a carboxyl group underlying the specificity of their function. Polyphenols contain at least two phenol rings [4]. Phenolic compounds are commonly found in vegetables. In plants, these compounds have different structures, mainly esters or glycosylated forms, and may have different functional properties. As polyphenols or phenolic acids, they have powerful antioxidant proprieties, like prevention of oxidative damage caused by free radicals, as well as different health-protective action, such as antibacterial, anticarcinogenic and vasodilatory [5]. In recent years, increasing attention has been paid to plants and foods rich in natural antioxidants, particularly fruits and vegetables, which have been associated with reduced risks of a number of chronic diseases in human [6]. Phenolic antioxidants are promoters of human health through their antiradical scavenging activity by preventing chronic diseases associated with oxidative stress [7]. Polyphenols bound to the food indigestible fraction can account for a substantial part of total phenolic compounds in foods. While a minor part of dietary polyphenols can be absorbed in the small intestine, most dietary polyphenols are not bioavailable in the human upper intestine and may exert biological activity through the intestinal tract [8]. Due to the seasonal and perishable nature, raw vegetables are subjected to some form of preservation in order to make them available for later consumption [9]. Little research has systematically investigated their antioxidant content and antioxidant capacity, especially the relationship between specific antioxidants and total antioxidant capacity [2]. Active oxygen and free radical species such as superoxide and hydroxyl radicals play an essential role in the immune system. They are produced as by-products in normal metabolism. However, an excess of free radicals is believed to cause many diseases and promote aging [10]. The presence of phenolic compounds in carrots contributes to their sensory qualities such as like colour, bitterness, or aroma. Therefore, the phenolic compounds could be used as a good indicator to evaluate the vegetables' quality during processing and storage [5]. Apart from carotenoids, phenolic compounds also show antioxidative properties in vegetables. Phenolic compounds, especially flavonoids, show various types of biological activity, but

most important is the antioxidant activity [11]. Vegetables carotenoids have been receiving attention due to their health benefits, since provitamin A activity is linked with antioxidant properties. Moreover, carotenoids are responsible for the orange colour of vegetables, like carrots, and the colour intensity is considered a reliable indicator of a higher nutritive value [5]. Major phenols in carrots include chlorogenic, caffeic, and *p*-hydroxybenzoic acids along with numerous cinnamic acid derivatives. The different carrot tissues have a similar composition, but the individual phenolic content differs, and it decreases from the exterior (peel) to the interior (xylem) layers. Moreover, the reported concentration data may vary with the extraction method, the way to express the results, and other factors such as cultivars, post-harvest and processing conditions [5].

The current research focuses on the assessment in total phenolic and antiradical activity changes during storage hybrids of Nantes carrots.

Materials and methods

The research was accomplished on fresh Latvia-grown (*Daucus carota* L.) Nantes carrot hybrids Nantes/Berlikum, Nantes/Maestro, Nantes/Forto, Nantes/Bolero and Nantes/Champion harvested in the Zemgale region in the first part of October 2011. Meteorological data were obtained from the Latvian Environment, Geology and Meteorology Centre. Meteorological conditions in 2011 where characterized by relatively high temperatures; the first two months of the summer of 2011 in Latvia were unusually warm. June and July months were the second warmest – the average air temperature in June was 24.5 ºC, and the maximum was 32.3 ºC. In 2011 summer, the average rainfall was 274 mm, i. e. close to the optimal precipitation. The autumn of 2011 in Latvia was warm and relatively dry. Each autumn month was warmer and drier than normal. The autumn temperature was by 1.9 degrees above normal. The quantity of autumn precipitation was 67 % of normal.

The quality parameter changes of carrots after two and four months storage at a temperature of 8 ± 2 ºC and relative air humidity 90 ± 5 % was analyzed using standard methods.

TOTAL PHENOLIC. The total phenolic content of carrots was determined by using the Folin–Ciocalteu colorimetric method [4, 12]. The total phenolic content was expressed as gallic acid equivalents (GAE) 100 g^{-1} dry weight (DW) of a sample.

TOTAL ANTIOXIDANT CAPACITY (DPPH). The antioxidant capacity of carrots was measured by the DPPH radical method according to Faller and Fialho [13]. The antioxidant capacity was represented as the percentage of the radical scavenging capacity (RSC) remaining after each time according to the equation below:

$$\%RSC = \frac{A_0 - A_t}{A_0} \times 100,$$

where A_0 represents the absorbance of the DPPH solution alone, measured at a zero time, and A_t is the absorbance for each sample 15, 30 and 60 min after the addition of the DPPH solution. The value of A_0 is considered to be 100 % [13].

STATISTICAL ANALYSIS. Experimental results were expressed as mean ± standard deviation; for the mathematical data processing, the value of $p < 0.05$ was assumed as statistically significant. The one-way analysis of variance (ANOVA) was used to determine the significance of differences. In case of establishing statistically significant differences, homogeneous groups were determined by Tukey's multiple comparison test at the level of confidence $\alpha = 0.05$. The statistical analyses were performed using Microsoft Excel.

Results and discussion

The total phenolic compounds in carrots are a cultivar characteristic. However, it is greatly modified by the rate of N and the method of N fertilization, foliar nutrition, nitrogen form and also by the soil and climate conditions during cultivation [11]. Total phenolic compounds may depend on free flavonols increase [5]. In the present research, the results are very similar to those reported in scientific literature. The total phenolic compounds in carrots were indicated as 96.0 (GAE) 100 g^{-1} in fresh weight [4]. However, such result could be recalculated: the total phenolic compounds of carrots were ~800.0 (GAE) 100 g^{-1} and 360.56 (GAE) 100 g^{-1} in dry matter [9], what is similar to the results obtained in the present experiments (Fig. 1).

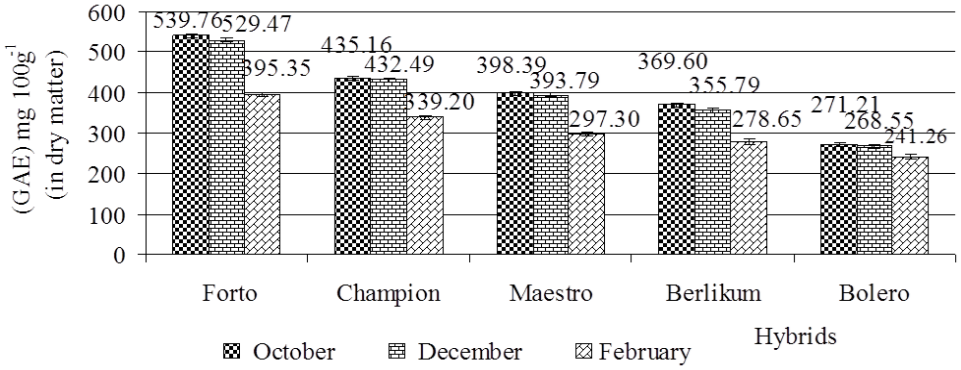

Fig. 1. Changes of total phenolic compounds in carrots during storage

There were significant differences ($p < 0.05$) in total phenolic compounds in freshly harvested carrot hybrids. However, highest total phenols content was detected in the hybrid Forto and the lowest in Bolero, what mainly could be explained by the hybrid chemical composition. Insignificant differences in total phenols content ($p > 0.05$) were found in analysed hybrids within two months storage; this is a very positive feature. Mainly, the obtained results indicated non-substantial chemical reactions running in the carrot samples. Opposite results were obtained in carrots stored for four months. The decrease of total phenols content was significant ($p < 0.05$) – 1.3 times less (Fig. 1) on average as compared with non-stored carrots' parameters. As a result, the storage time of carrots for four months could be not recommendable because non-advantageous significant changes of chemical parameters.

A few studies on the antioxidant properties of vegetables have suggested that vegetables are excellent dietary sources of natural antioxidants. Vegetables, including broccoli, carrot, potato, and tomato are rich in phenolic compounds, and all of their 50 % MeOH extracts suppressed lipid oxidation in lower density lipoproteins [14]. One of the important characteristics of polyphenolic compounds is their antioxidant capacity. A higher DPPH (24.28 %) was detected in Forto carrots, however, the DPPH of non-stored carrots was similar ($p > 0.05$) (Fig. 2).

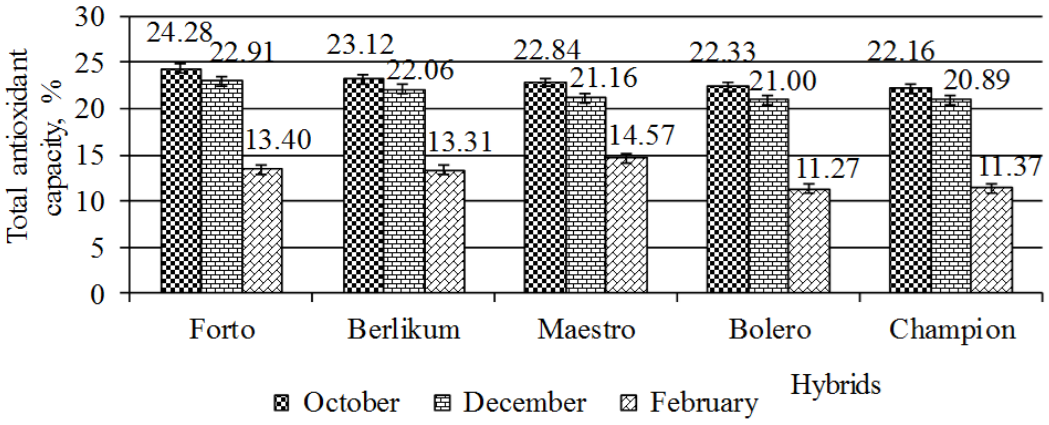

Fig. 2. Changes of DPPH scavenging by carrots during storage

After two months of storage, changes of DPPH scavenging were not significant ($p > 0.05$); DPPH scavenging decreased only 1.05 times on average as compared with the DPPH of non-stored carrots. After four months of storage, a relevant DPPH decrease ($p < 0.05$) in carrot hybrids was established; the amount of this parameter decreased 1.8 times on average as compared with non-stored carrots. The obtained results, as well as the content of total phenolic compounds mainly indicate negative changes in chemical composition. Therefore, the storage of carrots for four months could not be recommended, mainly because of the decrease of the nutritive value of carrots.

Conclusions

Relevant differences were found in total phenolic compounds and DPPH in non-stored carrot hybrids: highest in Forto and lowest in Bolero. Not relevant differences in the content of total phenols and DPPH were found in the hybrids after two months of storage. After four months of storage, a relevant decrease of the content of total phenols (1.3 times less on average) and DPPH (1.8 times less on average) were found in carrot hybrids as compared with non-stored carrot parameters.

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FENOLIŲ KIEKIO IR ANTIRADIKALINIO AKTYVUMO POKYČIAI „NANTE“ MORKŲ HIBRIDUOSE JAS SAUGANT

S a n t r a u k a

Morkos vartojamos visais metų laikais ir yra geras natūralių antioksidantų šaltinis. Jos rekomenduojamos sveikai mitybai palaikyti, nes yra dietinių maistinių skaidulų ir antioksidantinių medžiagų – fenolių – šaltinis. Atliktuose tyrimuose analizuoti fenolių ir antiradikalinio aktyvumo veiklos pokyčiai morkų „Nante“ hibriduose jas saugant. Atliekant tyrimus, naudoti vėlyvųjų morkų „Nante“ hibridai: „Nante/Berlikum“, „Nante/Maestro“, „Nante/Forto“, „Nante/Bolero“ ir „Nante/Champion“. Kokybės parametrų pokyčiai vertinti po dviejų ir keturių saugojimo mėnesių. Taikyti standartiniai vertinimo metodai: fenoliai analizuoti *Folin-Ciocalteu* kolorimetriniu metodu, antiradikalinis aktyvumas matuotas DPPH metodu. Eksperimentuose nustatyta, kad saugant morkas vyksta reikšmingi fenolių kiekio ($p < 0,05$) ir antiradikalinio aktyvumo pokyčiai. Gauti tyrimų rezultatai rodo, kad fenolių kiekis morkose, palyginti su pradiniu ir po keturių mėnesių saugojimo kiekiu, vidutiniškai sumažėja 1,3 karto. Po keturių mėnesių saugojimo antiradikalinis aktyvumas vidutiniškai sumažėja 1,8 karto.