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CHARACTERISTICS OF THE BLACK CARROT (*DAUCUS CAROTA* SSP. *SATIVUS* VAR. ATRORUBENS ALEF)

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K e y w o r d s: purple carrot, black carrot, chemical compounds, anthocyanins.

A b s t r a c t

The aim of this study was to characterize chemical composition of the black carrot and to assess the effects of processing methods and storage conditions of the carrot root on anthocyanin stability.The black carrot is characterized by a large content of phenolic compounds, including acylated anthocyanins, which ensure colour stability. The process of carrot freezing reduces anthocyanin stability. The degree of fragmentation, as well as the pH value determine the intensity of changes in the content of anthocyanins present in the black carrot.

CHARAKTERYSTYKA MARCHWI CZARNEJ (*DAUCUS CAROTA* SSP. *SATIVUS* VAR. ATRORUBENS ALEF)

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S ł o w a k l u c z o w e: czarna marchew, skład chemiczny, antocyjany.

A b s t r a k t

Celem badań była charakterystyka składu chemicznego korzeni czarnej marchwi oraz oszacowanie strat antocyjanów powstałych podczas stosowania różnych metod przechowywania i przetwarzania. Ustalono, że czarna marchew charakteryzuje się dużą zawartością związków fenolowych, w tym antocyjanów acylowanych. Na podstawie otrzymanych wyników wykazano, że proces zamrażania zmniejsza stabilność antocyjanów, a stopień degradacji zależy od pH środowiska oraz obróbki korzeni marchwi.

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Introduction

An increasing number of diseases which are often caused by inappropriate dietary patterns has led to growing interest in food whose composition stands out against basic food products. Currently, there are about 600 natural dyes and 200 synthetic dyes, while about 50 of them can be absorbed and metabolized in the human body (GRAJEK 2007). Colour is a physical property of the product, which definitely affects its positive or negative reception by consumers. It can provide information on the chemical composition of the product, therefore its suitability for processing, storing or transporting (ZAPOTOCZNY, ZIELIŃSKA 2005). Therefore, attempts have been undertaken to find new sources of natural dyes with both attractive colours and durability. The colour of products containing anthocyanin depends mainly on the structure and the content of individual dyes, environmental pH and the occurrence of substances accelerating processes of their degradation (oxygen, metal ions) (SIKORSKI 2002).

The garden carrot *Daucus carota* L., var. *sativus* Hoffm. can be divided into two cultivars: east-Asian and western. Roots of the western cultivar (*Daucus carota* ssp. *sativus* var. *Dativus* Alef.) are orange, yellow, red or white. The eastern cultivar (*Daucus carota* ssp. *sativus* var. Atrorubens Alef.) is characterized by red-purple or yellow colour of the root (DIETMAR et al. 2005).

The orange carrot is a popular, widely-consumed vegetable. The roots of the purple carrots have been cultivated and consumed for millennia in Asia, but in Poland this raw material is little known. The black carrot is an interesting agricultural product due to its colour and high content of anthocyanin dyes, which show very high stability while preserving its red colour in a wide pH range (CZAPSKI et al. 2009). This results from the fact that acylated peonidin and pelargonidin glycosides present in the black carrot ensure stability of the extract obtained from this raw material. This can be explained by an effect of intramolecular co-pigmentation of acylated anthocyanins, which prevents nucleophilic activity of water and the creation of chalcones through hydrolytic disintegration of the aromatic chain, leading to colour loss (KAMMERER et al 2004).

The aim of this study was to characterize chemical composition of the black carrot and to assess the effects of processing methods and storage conditions of the carrot root on anthocyanin stability.

Material and Methods

The subject of the research were roots of the black carrot. The carrot was cultivated on a plot near Olsztyn, and the seeds were brought from Holland, from Bejo Zaden b.v.. Fresh carrot was cleaned and divided into two parts. One part of the carrot was frozen in the form of 1 × 1 cm cubes, while the other part was ground in colloid mill, and afterwards further divided into two parts – one of which was frozen and the other was acidified before freezing to pH 2 with hydrochloric acid.

Determination of the chemical composition of fresh carrot included an analysis of the dry matter content (*Przetwory owocowe*... PN-90/A-75101/03), total acidity (*Przetwory owocoew*... PN-90/A-75101/04), sugar content (*Przetwory owocowe*... PN-90/A-75101/07), vitamin C content (*Przetwory owocowe*... PN-90/A-75101/011), and total carotenoids (*Przetwory owocowe*... PN-90/A-75101/12). Pectins were determined with the modified Carre-Heynes method (PIJANOWSKI et al. 1973). Total content of phenolic compounds was spectrophotometrically assessed, applying the method with the Folin-Ciocalteau reagent, using D-catechine to draw a calibration curve (AOAC 1974). Total anthocyanins were analysed using the Ronald E. Wrolstad method (AOAC 1974).

Chromatographic analysis of anthocyanins was carried out with the use of a Hewlett Packard 1050 high-performance liquid chromatography unit, with a UV-Vis detector provided by the same manufacturer using the method described by GOIFFON et al. (1999). A mobile phase was a mixture of acetonitrile, water and formic acid. Separation of the examined compounds was performed on a LiChrospher C_{18} column (250 × 4.6 mm). Peak detection was carried out at the wavelength of 520 nm. The volume of the sample collected for injection was 10 μl.

Identification of peaks was carried out on the basis of a comparison of spectra and retention times determined for patterns.

Results and Discussion

The suitability of vegetal raw materials for obtaining natural dyes depends not only on the amount, but also on its durability and the presence of accompanying substances, which can limit dye availability.

On the basis of the research conducted, it was established that the content of chemical compounds in red-orange and black carrots occurs on the same or a similar level (Table 1).

Sugar content in the raw material from which dyes are obtained is important due to the viscosity of extracts. According to various authors, sugar concentration in the roots of the black carrot amounts to 5.9–52% in dry matter (KAMMERER et al. 2004, KIRCA A. et al. 2007). The black carrot root under analysis was particularly rich in sugars – the total content averaged

Table 1

Characteristics of chemical composition of the black carrot

Discriminant		Mean content in fresh carrot	Mean content in dry matter
Reducing sugars [g in 100 g]		4.89 ± 0.06	43.08 ± 0.56
Total sugars [g in 100 g]		7.95 ± 0.04	70.04 ± 0.37
Vitamin C [mg in 100 g]		1.68 ± 0.04	14.80 ± 0.31
Total acidity [g in 100 g]		0.19 ± 0.01	1.67 ± 0.12
Total carotenoids [mg in 100 g]		1.93 ± 0.10	17.00 ± 0.93
Pectin [g in 100 g]	acc. to Morison	0.57 ± 0.03	5.02 ± 0.25
	acc. to Carre-Haynes	1.03 ± 0.06	9.08 ± 0.50
Total phenolic compounds [mg in 100 g]		248.07 ± 4.21	2185.72 ± 37.13
Anthocyanins [mg in 100 g]		44.25 ± 3.90	389.91 ± 34.38
Dry matter [g in 100 g]		11.35 ± 0.03	–

70.04% in dry matter. These differences can be caused by cultivar, climate and soil condition features. Anthocyanin content in the carrot under examination was, on average, 44.25 mg in 100 g, which converted into dry matter corresponds to 389.91 mg. Similar values were obtained by KAMMERER et al. (2004). Considering the aim of this study, the dye content was most important in the carrot under analysis. It was established that fresh black carrot was characterized by a high content of phenolic compounds (2185.72 mg in 100 g d.m.), 17.84% of which were anthocyanins. Anthocyanins identified as a result of quality analyses include: 1 – cya 3-xylglcgal, 2 – cya 3-xylgcgal acylated with caffeic acid, 3 – cya 3-xylgal, 4 – cya 3-xylglcgal acylated with sinapic acid, 5 – cya 3-xylglcgal acylated with ferulic acid, 6- cya 3-xylglcgal acylated with p-cumar acid (Figure 1). Four out of six determined anthocyanins occurred in their acylated forms.

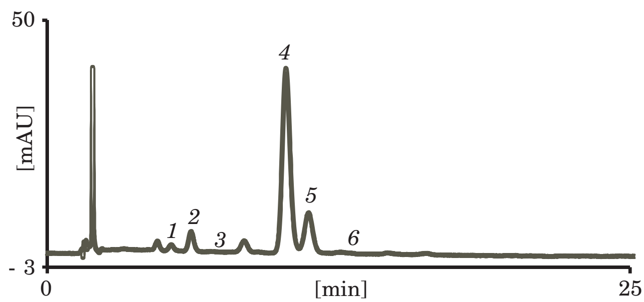

Fig. 1. Characteristics of anthocyanins – fresh root: *1* – cya 3-xylglcgal, *2* – cya 3-xylgcgal acylated with caffeic acid, *3* – cya 3-xylgal, *4* – cya 3-xylglcgal acylated with sinapic acid, *5* – cya 3-xylglcgal acylated with ferulic acid, *6* – cya 3-xylglcgal acylated with p-cumar acid

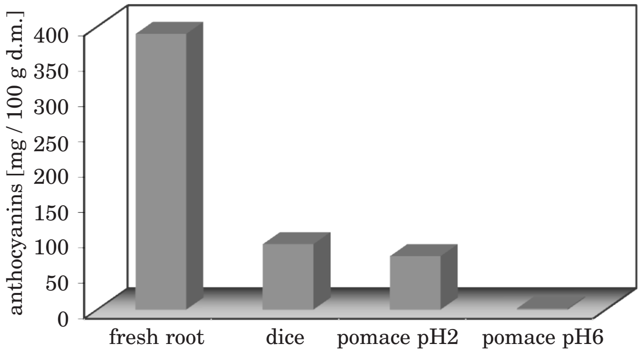

Fig. 2. Total content of anthocyanins during freezer storage

Technological processing of the carrot root and its storage in the frozen state (Figure 2) affected the anthocyanin dyes to a various extant. All samples of frozen carrot revealed a lower content of anthocyanins in comparison to the fresh root. The degree of root fragmenting had a significant effect on changes in anthocyanin content. Better values were obtained for diced carrot as compared to the pomace. Anthocyanins in a non-acidified pomace underwent complete degradation. The effect of acidification of the pomace to pH = 2 on anthocyanin durability proved to be minimal. Anthocyanins present in black carrot stored in the form of non-acidified pomace were completely degraded, while at pH 2 they revealed a slightly higher stability. KIDOŃ and CZAPSKI (2009) analysed the content of anthocyanin dyes in juices during their storage. For juices stored at 4°C for 107 days, they did not notice any visible loses of anthocyanin dyes in comparison to their initial value. Nevertheless, at 35°C the decrease was significant, reaching 45–54%, depending on the cultivar. KIRCA et al. (2007) claim that a significant decrease in anthocyanin stability occurs at a pH value of about 5. Stability of the black carrot under conditions of lowered pH results from acylation of anthocyanins with hydroxycinnamic and hydroxybenzoic acids (KAMMERER et al. 2004).

The most convenient form of storage proved to be freezing carrot in dices in the natural environment. Among the determined anthocyanins, cya 3xylglcgal acylated with ferulic acid, proved most stable in frozen carrot dices.

Conclusions

1. The black carrot is characterized by a large content of phenolic compounds, including acylated anthocyanins, which ensure colour stability.
2. The process of carrot freezing reduces anthocyanin stability.

3. The degree of fragmentation, as well as the pH value determine the intensity of changes in the content of anthocyanins present in the black carrot.

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References

AOAC (Association of the Official Analytical Chemists). 1974. *Official Methods of Analysis*. Washington DC, 9. 110.

Chemia Żywności. 2004. Ed. Z.E. SIKORSKI. Wyd. IV. WNT, Warszawa.

CZAPSKI J., KIDOŃ M., OLEJNIK A., WITROWA-REJCHERT D. *Marchew purpurowa jako surowiec do przetwórstwa owocowo-warzywnego*. Przemysł Fermentacyjny i Owocowo-Warzywny, 1: 31–33.

DIETMAR R., KAMMERER D. 2005. *Black carrots – history, recent findings and perspectives*. Fruit Processing, 10: 302–308.

GOIFFON J.P., MOULY P.P., GAYDOLU E.M. 1999. *Anthocyanic pigment determination in the red fruit juices, concentrated juices and syrups using liquid chromatography*. Analitica Chemica Acta, 382: 39–50.

KAMMERER D., CARLE R., SCHEIBER A. 2004. *Quantification of anthocyanins in black carrot extracts (Daucus carota ssp. Sativus var. atrorubens Alef.) and evaluation of color properties*. Eur Food Res Technol., 219: 479–284.

KIDOŃ M., CZAPSKI J. 2009. *Ocena zmian zawartości składników bioaktywnych oraz zdolności antyoksydacyjnej soków z marchwi purpurowej podczas przechowywania (Assessment of the changes in the bioactive components and anti-oxidizing properties of black carrot juice during storage)*, Bromat. Chem. Toksykol., 3: 848–853.

KIRCA A., ÖZKAN M., CEMEROĞLU B. 2007. *Effects of temperature, solid content and pH on the stability of black carrot anthocyanins*. Food Chemistry, 101: 212–218.

PIJANOWSKI E. 1973, *Technologia produktów owocowych i warzywnych*. PWRiL, Warszawa.

Przeciwutleniacze w żywności. 2007. Ed. GRAJEK, Wyd. I. WNT, Warszawa 2007, 171–174.

Przetwory owocowe i warzywne. Oznaczanie zawartości cukrów. PN-90/A-75101/07.

Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizykochemicznych. Oznaczanie zawartości suchej masy metodą wagową. PN-90/A-75101/03.

Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizykochemicznych. Oznaczanie zawartości witaminy C. PN-90/A-75101/011.

Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizykochemicznych. Oznaczanie kwasowości ogólnej. PN-90/A-75101/04.

Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizykochemicznych. Oznaczanie zawartości sumy karotenoidów i β-kartotenu. PN-90/A-75101/12.

ZAPOTOCZNY P., ZIELIŃSKA M. 2005. *Rozważania nad metodyką instrumentalnego pomiaru barwy marchwi*. Żywność. Nauka. Technologia. Jakość, 1(42): 121–132.