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Influence of cultivar and UGmax on antioxidative properties of carrot roots (*Daucus carota* L.) and their stability during freezing process

Wpływ odmiany i preparatu UGmax na właściwości antyoksydacyjne korzeni spichrzowych marchwi (*Daucus carota* L.) i ich stabilność w procesie mrożenia

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Słowa kluczowe: niepewność pomiaru, niejednorodność próbki, metoda doświadczalna, walidacja metody, dokładność metody, precyzja metody, certyfikowane materiały

Abstract

In the present experiment, the significance of cultivar (conventional and coloured) and of the application of the soil fertility enhancer UGmax on health-promoting properties of carrot roots subjected to the freezing process of carrot cubes after water blanching was investigated. The selection of cultivar turned out to be highly significant with respect to the development of health-promoting properties of carrot roots. The highest antioxidant properties were found in the purple cultivar 'Deep Purple'. Its mean antioxidant capacity accounted for 5.31 mmol $Fe^{+2} \cdot kg^{-1}$ f.m. Essential for health-promoting properties were the contents of anthocyanins (R^2=0.83), chlorogenic acid (R^2=0.81) and total polyphenolics (R^2=0.71). The application of the biological agent UGmax improved the quality of carrot significantly, increasing the content of total carotenoids and reducing the losses of ascorbic acid during processing. The freezing process negatively influenced the antioxidative properties of carrot irrespective of cultivar and applied agro-technique (use of UGmax), especially in the case of water-soluble antioxidants such as anthocyanins and ascorbic acid.

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Streszczenie

W przedstawionych badaniach zweryfikowano znaczenie odmiany (konwencjonalne i kolorowe) oraz stosowania użyźniacza glebowego UGmax na właściwości prozdrowotne korzeni spichrzowych marchwi poddanych procesowi mrożenia (kostka po uprzednim blanszowaniu wodnym). Przeprowadzone doświadczenia wykazały wysoce istotne znaczenie odmiany w kształtowaniu właściwości prozdrowotnych korzeni spichrzowych marchwi. Największymi właściwościami antyutleniającymi odznaczała się purpurowa odmiana 'Deep Purple', której pojemność antyoksydacyjna wyniosła średnio 5,31 mmol $Fe^{+2} \cdot kg^{-1}$ ś.m. Decydująca o właściwościach prozdrowotnych okazała się zawartość antocyjanów (R^2=0,83), kwasu chlorogenowego (R^2=0,81) i związków polifenolowych ogółem (R^2=0,71). Stosowanie preparatu biologicznego UGmax poprawiło jakość marchwi w istotny sposób, zwiększając zawartość karotenoidów ogółem oraz ograniczając straty kwasu askorbinowego podczas przetwarzania. Proces mrożenia negatywnie wpłynął na właściwości przeciwutleniające marchwi niezależnie od odmiany jak i stosowanej agrotechniki, w szczególności w przypadku antyutleniaczy rozpuszczalnych w wodzie takich jak antocyjany i kwas askorbinowy.

1. INTRODUCTION

Carrot is one of the most popular vegetables in Poland, which is the biggest producer of it in Europe. In Poland, 60% of yield is used for industrial purposes such as the production of juice and frozen or dried products. The most important is the production of frozen carrots [Nosecka 2008]. The popularity of carrot products is combined with its high sensory properties, high nutritional and health-promoting values, especially of the frozen products. They are rich in carotenoids, polyphenolics, minerals and sugars [Platta, Kolenda, 2008; Fik et al. 2008]. However, although the freezing process belongs to the best preservation methods, during this processing negative changes such as enzymatic browning, loss of cell sap and nutritional substances, colour and consistence changes or microbiological contamination may occur [Lavelli et al. 2006]. Freezing as such preserves the present state of quality. For the quality of the final product and the losses during the processing, the choice of raw material as well as reducing the negative physico-chemical changes is essential. One of the most important factors is the choice of an appropriate cultivar, which decides the basic properties of carrot roots such as colour intensity of root, content of biologically active or structural substances [Czapski et al. 2009; Gajewski et al. 2007; Alasalvar et al. 2005], while the corresponding agro-technique may enhance their content considerably. Besides the common treatments, the use of biological, indirect methods to improve yield quality is recommended. One of them is the application of soil fertility enhancers such as UGmax, which may increase the content of humus and improve nutrient sorption, and, hence, positive influences such as growth and development of plants [Truba et al. 2012; Wojtała-Łozowska, Parylak 2010; Sulewska et al. 2009].

As the quality and nutritional value of frozen carrot is a result of the genetic potential of the raw materials as well as of the kind of its preparation, the aim of the research was the achievement of high quality and health-promoting properties of carrot roots that are stable during processing. Furthermore, information about the changes of health properties in multi-factorial system, especially due to the application of biologically agents, is very limited.

2. MATERIALS AND METHODS

The present study comprised a 2-year field experiment conducted at the Experimental Station of UTP in Mochełek as a three-factorial split-plot design with three repetitions. The considered experimental factors comprised: carrot cultivars with different colours of the root: purple – 'Deep Purple', yellow – 'Mello Yello' and orange – 'Flacoro' and 'Karotan', as well as the application of UGmax (total amount of 1.2 l ha^{-1}). Carrots were cultivated under constant mineral nutrition of: N – 70 kg N•ha^{-1}, P – 80 kg•ha^{-1} as P_2O_5 and K – 100 kg•ha^{-1} as K_2O. Half of the produced carrot roots were cut into cubes (1×1×1 cm) and subjected to blanching (95°C for 3 minutes), then to freezing at temperatures of 22°C to 24°C. Evaluations of health-promoting properties of carrot roots were performed colorimetrically on raw as well as on processed material and comprised the determination of the contents of total carotenoids [PN-90/-75101/12], total polyphenolics [Keutgen, Pawelzik 2007], anthocyanins [Keutgen, Pawelzik 2007], total antioxidant capacity FRAP [Keutgen, Pawelzik 2007] and chlorogenic acid [Griffiths et al. 1992]. Ascorbic acid was determined titrimertrically after the method of Pijanowski. The efficacy of the applied agricultural methods for quality improvement and the suitability of different cultivars (traditional and colourful) for the freezing process as well as the increase of their stability were evaluated by the statistical program Statistica 10 for Windows. Results were evaluated statistically by the application of one-way and multiple ANOVA, where homogeneous groups were built after Tukey test at $p \leq 0.05$.

3. RESULTS AND DISCUSSION

The conducted research confirmed a significantly lower content of total carotenoids in carrot roots of the yellow cv. 'Mello Yello' compared with the other cvs, irrespective of the used agro-techniques and processing (Table 1). Similar results were obtained by Platta and Kolenda [2008], Gajewski et al. [2007] and Alasalvar et al. [2005], who determined higher carotenoids content in orange and purple carrot roots than in yellow ones. Cultivar determined also the content of polyphenolics (Table 1). The highest content was detected in cv. 'Deep Purple' with a mean value of 4.16 g•kg^{-1} f.m, and the lowest in cv. 'Mello Yello' (0.4 g•kg^{-1} f.m.). Similar results were published by Grassman et al. [2007], Gajewski et al. [2007] and Alasalvar et al. [2005]. The mean polyphenol content in carrot roots, mainly as chlorogenic acid, was highest in cv. 'Deep Purple' (2.12 g•kg^{-1} f.m.). The other cvs did not differ in their content and their mean value was 0.51 g•kg^{-1} f.m. (Table 1). Sun et al. [2009] reported a polyphenol content of purple cvs of 7.7–18.7 g•kg^{-1} f.m., of yellow cvs of 0.3 g•kg^{-1} f.m. and of orange ones of 0.63–1.15 g•kg^{-1} f.m. In addition, in cv. 'Deep Purple' the amount of anthocyanins was 76.3 mg•kg^{-1} f.m (Table 1) comparable with those reported by Sun et al. [2009], Alasalvar et al. [2005] and Kidoń et al. [2008]. Cultivars differed also in their ascorbic acid contents (Table 1), which was highest in cv. 'Mello Yello' (74.1 mg•kg^{-1} f.m) and lowest in the orange cv. 'Flacoro' (67.9 mg•kg^{-1} f.m). These results are opposite to those of Alasalvar et al. [2005]. The results of single antioxidants were also reflected in the total antioxidant capacity FRAP of carrot roots (Table 1), where the cv. 'Deep Purple' reached a 5.7 times higher content compared with other cvs (5.31 mmol Fe^{+2}•kg^{-1} f.m.). The results are in line with those of Sun et al. [2009], Gajewski et al. [2007] and Alasalvara et al. [2005].

The application of the soil fertility enhancer UGmax significantly increased the content of total carotenoids in all investigated cvs (Table 1), especially in cvs 'Deep Purple' (31.9%) and 'Karotan' (33.5%). This increase was probably caused by higher availability of minerals, reduction of losses in soil leaching processes, and in consequences with their higher accumulation, and plant quality [Frąckowiak-Pawlak 2009]. No statistical influence of UGmax on the contents of polyphenolics, chlorogenic acid and FRAP value was found (Table 1). In the case of anthocyanins, UGmax significant reduced their concentration by 25.5%. This influence was also found after freezing (drop of 31.5%). Observed changes were a result of higher availability of minerals and better growing conditions of carrot roots and lower incidence of suboptimal cultivation conditions, which favoured the synthesis of antioxidants. In fresh carrots of cv. 'Mello Yello', the application of UGmax significantly improved root quality by increasing ascorbic acid content by about 7.5% (Table 1).

The freezing process belongs to the best preservation methods of food, where frozen products remain their nutritional, sensory and health-promoting values to higher extents [Fik et al. 2008]. In the present research, the freezing process did not significantly influence carotenoids content in carrot roots. This indicates their stability during processing combined with a low suceptibility to leaching, whereas UGmax did not stabilize root quality significantly. These findings are inconsistent with the results of Koca and Karadeniz [2008], Kozłowska-Wojciechowska [2007] and Gębczyński [2006], who deteced considerable losses of about 20–40% of carotenoids during freezing. Furthermore, no significant losses of total polyphenolics as by Koca & Karadeniz [2008] and Gębczyński [2008] were found. In contrast to these studies, no significant influence of processing on total antioxidant capacity FRAP was detected; however, cv. 'Deep Purple' showed higher amounts compared with other cvs. The situation was different in the case of anthocyanins and vitamin C. Here, considerable losses as a result of the blanching process were found. Observed losses accounted for 52.8% and 6.1%, respectively. These changes were combined with material grinding, oxygen availability and leaching of substances by water blanching, because these substances are easily soluble in water, especially as glycosidic bonds. High ascorbic acid losses of 40–50%, even up to 100% as a result of freezing, were also noted by Wronowska and Zadernowski [2012] and Fik et al. [2008]. The highest losses during freezing were determined in cv. 'Mello Yello' (7.4%) and 'Karotan' (6.1%), and lowest in cv. 'Deep Purple' and 'Flacoro' (on average 4.7%). Application of UGmax reduced the losses by about the half (49.3%).

A higher FRAP value was positively associated in the investigated carrot roots with higher content of water-soluble antioxidants such as anthocyanins ($R^2 = 0.83$**), chlorogenic acid ($R^2 = 0.81$***) and total polyphenolics ($R^2 = 0.71$***). A correlation between the FRAP value and total carotenoids was not observed. which can be partially explained by the characteristic of antioxidant capacity measurement.

4. CONCLUSIONS

The conducted research determined the largest influence of cultivar on health-promoting properties in carrot roots. The highest antioxidative quality was found in the cv. 'Deep Purple'. The application of UGmax played a minor role; however, it caused the

Table 1. Health-promoting properties of carrot roots of different cultivars depending on application of UGmax and processing

Processing		**Raw**				**frozen**			
Combinations	**UGmax**	**'Mello 'Yello'**	**'Deep Purple'**	**'Flacoro'**	**'Karotan'**	**Mello 'Yello'**	**'Deep Purple'**	**'Flacoro'**	**'Karotan'**
Total carotenoids [mg•kg^{-1} f.m.]	Without	48.1±3.95g	106.8±3.17de	133.9±3.26bc	106.2±4.52e	38.1±2.78h	99.2±3.35ef	92.0±0.44f	100.7±2.00ef
	With	54.1±2.03g	143.7±1.34a	138.2±4.19ab	139.5±4.34ab	45.7±3.86gh	128.3±1.14c	115.3±1.40d	136.5±2.12abc
Total polyphenolics [g•kg^{-1} f.m.]	Without	0.48±0.009ef	4.43±0.859a	2.36±0.330c	1.57±0.317cd	0.34±0.022f	3.97±0.066ab	2.34±0.224c	1.30±0.045de
	With	0.68±0.133ef	4.77±0.226a	3.39±0.207b	2.24±0.147c	0.38±0.025f	3.46±0.360b	1.69±0.106cd	0.96±0.054def
Chlorogenic acid [mg•kg^{-1} f.m.]	Without	0.61±0.048bc	2.76±0.590a	0.55±0.017bc	0.52±0.021bc	0.51±0.053bc	2.47±0.556a	0.40±0.133c	0.32±0.023c
	With	0.65±0.043bc	2.15±0.149a	0.57±0.094bc	0.62±0.015bc	0.56±0.007bc	1.12±0.148b	0.47±0.114bc	0.38±0.143c
Ascorbic acid [mg•kg^{-1} f.m.]	Without	75.0±4.27b	75.1±4.00b	70.7±0.75bcde	73.9±0.83bc	69.6±1.10cde	68.0±0.82def	64.2±0.47f	66.9±0.55ef
	With	80.6±0.76a	72.5±1.15bcd	69.6±0.93cde	72.5±1.30bcd	71.1±0.65bcde	69.8±0.60cde	67.1±1.07ef	67.2±0.56ef
Anthocyanins [mg•kg^{-1} f.m.]	Without	-	87.45±2.72a	-	-	-	43.02±2.10c	-	-
	With	-	65.13±8.34b	-	-	-	29.45±2.56d	-	-
Antioxidative capacity [mmol Fe^{2+}kg^{-1} f.m.]	Without	0.67±0.093c	5.87±0.037ab	0.92±0.078c	0.94±0.056c	0.54±0.024c	5.09±1.562ab	0.80±0.031c	0.75±0.036c
	With	0.72±0.111c	6.27±0.062a	1.38±0.034c	1.45±0.269c	0.74±0.042c	4.00±2.334b	1.35±0.392c	0.88±0.036c

f.m. – fresh matter, different letters within one parameter (two rows) means differences between the group after Tukey test at $p \le 0.05$.

increase in carotenoids content, reduction of ascorbic acid losses during processing and the decrease of anthocyanins. Generally, the negative effects of processing were found only in the case of instable ascorbic acid and water-soluble anthocyanins, which indicates an appropriate freezing process. In summary, it is recommended to apply the biological UGmax for the improvement of antioxidant properties of carrots roots and their stability during processing. For a high health-promoting value of the raw and processed product, the cv. 'Deep Purple' should be cultivated.

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