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Environmental and technological carrot safety conditions Part I. Changes in the content of nitrates determined by the environment and processing

Środowiskowe i technologiczne uwarunkowania jakości marchwi. Część I. Zmiany zawartości azotanów determinowane jakością środowiska i procesami przetwarzania

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Słowa kluczowe: środowisko, azotany, ADI, magnez, marchew, przetwórstwo, spożycie

Abstract
The aim of the research was to define changes in the content of NO3¯ determined by the environment and processing in products from five cultivars of carrot, orange in colour. Besides this, in the research, the human intake of toxic compounds found in processed foods was also assayed. All the processed foods were produced at laboratory scale compliant with the applicable guidelines and norms. The content of nitrates in processed foods depended significantly on the genetic conditions of material and on the processing method. Of all the cultivars under study, 'Karotan' was least applicable to processing since, irrespective of the processing method, the lowest decrease in nitrates was reported for that cultivar. The consumption of processed foods from the cultivars of carrot studied is not hazardous to consumer health, since the value of the ADI in adult, Acceptable Daily Intake, is not exceeded.

Streszczenie
Celem przeprowadzonych badań było określenie zmian zawartości NO3¯ determinowanych środowiskiem i procesami przetwarzania w produktach wytworzonych z marchwi pięciu pomarańczowych odmian. Ponadto określono wielkość spożycia przez człowieka związków toksycznych znajdujących się w przetworach. Wszystkie przetwory zostały wyprodukowane w skali laboratoryjnej zgodnie z zaleceniami i normami. Zawartość azotanów w przetworach zależała istotnie od uwarunkowań genetycznych surowca oraz sposobu przetworzenia. Z badanych odmian najmniej do przetwórstwa nadawała się odmiana 'Karotan', gdyż niezależnie od metody przetwarzania dla tej odmiany uzyskano najmniejszy spadek azotanów. Spożycie przetworów uzyskanych z badanych odmian marchwi nie zagraża zdrowiu konsumentów, gdyż nie zostaje przekroczona wyznaczona norma ADI czyli dziennego dopuszczalnego spożycia przez dorosłego człowieka.

1. INTRODUCTION

The occurrence of some amounts of nitrates and other harmful compounds is normal as it is a consequence of natural nitrogen cycling in nature [Niewczas et al. 2006, Malinowska et al. 2007]. Simplifications in root vegetable crops growing by eliminating some practices can enhance the environmental conditions for plant growth and development [Wszelaczyńska et al. 2014].

Nitrates accumulation in plants results from physiological process of nitrogen nutrition in plants in the form of N-NO_3, taken up by plants at definitely higher amounts than N-NH_4. With that in mind, it is important to determine the condition of natural environment pollution, especially the content of harmful compounds in plants for consumption grown in the regions exposed, today or in the future, to intensive human impact [Szwalec, Mundała 2012].

Nitrates are one of the substances most unwanted both in plant material and in its processed foods. The 70 to 90% share of nitrates in daily human rations comes from vegetables [Tamme et al. 2006, Bottex et al. 2008, Gajewska et al. 2009, Gajewski et al. 2010, Ierna 2009, Łozowicka 2009, Ciećko et al. 2010]. In the group of vegetables, carrot (Daucus carota L.) has a considerable share in human nutrition since its annual consumption is 20.0 kg per person, of which 8 kg as raw vegetable. Carrot is a plant with a high tendency to $NO3^-$ accumulation; for this reason, monitoring its content in fresh carrot and its processed foods should be a norm [Grudzińska, Zgórska 2005, Czerwińska & Zgórska 2011]. According to the norms, the content of nitrates (V) in carrot should not exceed 400 mg·kg^{-1} in fresh weight, and in the case of carrot allocated to processed foods for children below 3 years of age, only 200 $mg \cdot kg^{-1}$ in fresh weight [Gajewski et al. 2010, Grudzińska, Zgórska 2005, Murawa et al. 2008, Wrzodak, Elkner 2010]. Processed foods are the key section of food industry. Their availability on the market throughout the year facilitates satisfying high consumer needs. Processed foods, to be sold in the market, must satisfy specific quality, sensory and microbiological requirements [Pobereżny, Wszelaczyńska 2013]. About 20 % of the total carrot harvest is allocated to processing [Nawirska, Król 2004, Gębczyński 2006, Domaradzki et al. 2010]. Carrot processing mostly covers the following technologies: freezing, preserving, drying, processed foods for children and drinking juices. Also, in household conditions, carrot is exposed to processing, for example, by conserving, freezing, and so on [Jąder & Wawrzyniak 2015]. The most common method is vegetable freezing. It is considered a preservation method which is little invasive; produce differs in its content of nutrients from raw products only slightly [Zalewska - Korona et al. 2015]. To limit the content of unwanted components and prolong the processed food applicability, new solutions or improvements of the existing preservation and storage methods are explored [Kobus et al. 2014]. The quality of processed foods also depends on the adequately performed technological process [Kowalska 2006].

The aim of the present research was to determine changes in the content of NO3¯ determined by the environment and processing in the products of five carrot cultivars, orange in colour, as well as the human intake of toxic compounds found in processed foods.

2. MATERIAL AND RESEARCH METHODS

The research material was derived from 3-year field experiments carried out at Mochełek (the kujawsko – pomorskie province). The research involved five cultivars of orange carrot (‘Berjo’, ‘Flacoro’, ‘Karotan’, ‘Koral’ and ‘Perfekcja’) grown compliant with the requirements of agrotechnical practises, with a constant fertilisation rate of nitrogen - 70 kg $N \cdot ha^{-1}$, phosphorus - 80 kg $P_2O_5 \cdot ha^{-1}$ and potassium 100 kg $K_2O \cdot ha^{-1}$. An experiment factor was made up by biofortification with magnesium at the rate of 0, 45 and 90 kg $MgO \cdot ha^{-1}$ in the form of magnesium sulphate (16%). Magnesium was applied as a foliar fertiliser in the form of 3% solution of magnesium sulphate over the period of an intensive plant growth.

In material and once it has been preserved, in processed foods, the content of nitrates (V) was assayed with the ionoselective method with multifunctional computer device CX-721 provided by Elmetron [Baker & Thompson 1992]. Carrot allocated to preserved and frozen foods was cut into cubes $1 \times 1 \times 1 \cdot 10^{-2}$ m, while carrot for drying was sliced into $4 \cdot 10^{-3}$ m pieces. The cut carrot was blanched at a temperature of 95ºC for 3 minutes and cooled under running cold water. Freezing was performed in a box freezer (Whirlpool, CO405W, Electronic Control System) at the temperature from –22 to –24°C. Drying was done at 60ºC in the laboratory drier (SUP – 100) with forced air circulation. The preserved carrot was prepared compliant with the norm (PN–A-77807:1997/Az1:2004).

The paper has been an attempt at model-determination of daily intake of nitrates (V) assuming the consumption of 55 g of processed carrot per person. The data was compared with the norms (JECFA 2002) considering the Acceptable Daily Intake (ADI).

The results of the 3-year research were exposed to statistical calculations with the analysis of variance for two-factor experiments, with the Tukey test to verify the significance of differences.

3. RESULTS AND DISCUSSION

The content of nitrates (V) in frozen foods, preserved carrot and dried materials from the five cultivars are provided in (Tables 1, 2 and 3). The research has shown differences in the content of nitrates (V) between frozen foods, preserved foods and dried materials produced at laboratory scale from various cultivars. The lowest content of nitrates (V) was contained in frozen foods from ‘Perfekcja’ and ‘Karotan’ and preserved foods and dried materials from ‘Perfekcja’ and ‘Koral’. The highest content of nitrates (V) was shown for all the processed foods from ‘Flacoro’ and ‘Berjo’. Wojciechowska [2005], Bender et al. [2009] and Wrzodak & Elkner [2010] have proven that the accumulation of nitrates (V) in vegetables is not only plant specific – but also plant cultivar specific.

In the present research, irrespective of the cultivar, the content of nitrates (V) in processed foods from carrot as a result of magnesium application was lower than in processed foods from carrot without magnesium (Table 1, 2, 3). The lowest content of nitrates (V) was reported for processed foods from carrot after applying magnesium at the rate of 90 kg. Only for preserved carrot, a significant decrease in the content of nitrates (V) was recorded following Mg application at each rate: 45 kg and 90 kg. The applicable literature shows that plant biofortification with magnesium enhances the plant health status by limiting the development of pathogenic bacteria, which, as a consequence, decreases the contents of nitrates (V) in material. Apart from this, applying magnesium in a sulphate form increases the soil reaction and helps decreasing the accumulation of nitrates (V) in plants. Additionally, magnesium increases its concentration in plants and intensifies photosynthesis, which can also decrease the content of nitrates (V) [Smoleń & Sady 2007].

The results of changes in the content of nitrates (V) due to processing are given in Table 1, 2 and 3. The highest loss of nitrates (V) was caused by preserving; mean for cultivars 58% and the lowest - freezing 27%. Drying decreased the content of nitrates (V), mean for cultivars, by 40%. A decrease in the content of nitrates (V) in processed foods from carrot storage roots due to thermal treatment was noted by Grudzińska & Zgórska [2005]. The authors in their research with varied carrot cultivars throughout processing recorded a decrease in the content of nitrates (V) on an average, for all the cultivars from 11 to 30%. The authors also note that material peeling increases the content of nitrates (V) by 3% and claim that it must have been due to the highest amounts of nitrates (V) in carrot being found in inner spine and by peeling the total root weight decreases, thus increasing its ratio to the weight.

Table 1. Changes in the content of nitrates (V) in carrot exposed to freezing.

Cultivar [I]	Content of nitrates (V) ($mg \cdot kg^{-1}$ fresh weight)		Change in content (%)
	Fresh carrot	Frozen carrot	
Berjo	229.3	163.3	-29
Flacoro	277.2	186.3	-33
Karotan	236.0	182.4	-23
Koral	245.4	187.2	-24
Perfekcja	223.9	163.0	-27
Magnesium application* [II]	**Fresh carrot**	**Frozen carrot**	**Change in content (%)**
0	235.8	166.5	-29
45	242.9	173.4	-29
90	249.1	186.3	-25

* Magnesium rate [kg $MgO \cdot ha^{-1}$]
LSD at α = 0.05
I – 11.0 II/I – n.s.
II – 8.2 I/II – n.s.

Table 2. Changes in the content of nitrates (V) in carrot preserved in jars.

Cultivar [I]	Content of nitrates(V) ($mg \cdot kg^{-1}$ fresh weight)		Change in content (%)
	Fresh carrot	Carrot preserved in jars	
Berjo	229.3	96.8	-58
Flacoro	277.2	112.0	-60
Karotan	236.0	107.1	-55
Koral	245.4	99.6	-59
Perfekcja	223.9	87.8	-61
Magnesium application* [II]	**Fresh carrot**	**Carrot preserved in jars**	**Change in content (%)**
0	235.8	100.2	-58
45	242.9	97.4	-60
90	249.1	103.9	-58

* Magnesium rate [kg $MgO \cdot ha^{-1}$]
LSD at α = 0.05
I – 16.7 II/I – n.s.
II – 6.6 I/II – n.s.

In the present research, the highest loss of nitrates (V) was reported for frozen foods from ‘Flacoro’ and ‘Berjo’ (mean of 60%), for preserved carrot from ‘Perfekcja’ and ‘Flacoro’ (mean of 31%) and for dried materials from ‘Berjo’ and ‘Perfekcja’ (mean of 60%). All the preserved foods, on the other hand, from ‘Karotan’ showed the lowest loss of nitrates (V); 23% for frozen carrot, 55% for preserved carrot and 24% for dried material, respectively. As seen from Tables 1, 2 and 3, the material that was not biofortified with magnesium received the highest losses of nitrates (V) in the process of carrot preserving and drying. The use of different environmental conditions (with and without the use of magnesium) significantly affected the nitrates content in the tested products processed from carrots. Applying magnesium showed unfavourable as it limited the losses of nitrates (V) in dried and preserved carrot, as compared with losses in products from non-biofortified materials.

Opposite results were recorded for frozen carrot. Applying magnesium, irrespective of the amount, increased the losses of nitrates (V) in frozen foods, as compared to frozen foods from carrot without biofortification. After freezing, a decrease in the content of nitrates (V) was noted for biofortified carrot with 45 kg of magnesium by 1% and with the rate of 90 kg MgO – by 4%. According to various sources, vegetable consumption should be about 500 g in 4-5 meals a day, including 55 g of carrot. An attempt was made at a model-determination of the daily intake of nitrates (V) in processed foods from the cultivars under study (Table 4). The highest nitrates (V) intake is noted for consuming 55 g of frozen carrot and preserved carrot from ‘Flacoro’; it is 10.2 mg for frozen carrot and 6.2 mg for preserved carrot. For the other cultivars, the intake is lower and it is, on an average, 9.6 mg for frozen and 5.4 mg for preserved carrot. Considering the Acceptable Daily Intake (ADI) by an adult, which equals 222mg of nitrates (V), the consumption of frozen carrot and preserved carrot from the cultivars studied does not exceed the norm. Much higher amounts of nitrates (V) are introduced with the consumption of dried material from those cultivars and most nitrates (V) are introduced to the body with dried material from ‘Karotan’. As for ‘Karotan’ dried material, we introduce 75.8 mg

Table 3. Changes in the content of nitrates (V) in carrot exposed to drying.

Cultivar [I]	Content of nitrates (V) (mg·kg^{-1} fresh weight)		Change in content (%)
	Fresh carrot	Dried carrot	
Berjo	229.3	920	-48
Flacoro	277.2	1219	-43
Karotan	236.0	1379	-24
Koral	245.4	1194	-37
Perfekcja	223.9	922	-47
Magnesium application* [II]	**Fresh carrot**	**Dried carrot**	**Change in content (%)**
0	235.8	1055	-42
45	242.9	1105	-41
90	249.1	1203	-37

* Magnesium rate [kg MgO·ha^{-1}]
LSD at α = 0.05
I – 88.3 II/I – n.s.
II – 48.6 I/II – n.s.

Table 4. Daily intake of nitrates (V) while consuming 55 g of carrot* (mg·day^{-1}).

Cultivar	Fresh carrot (Right after harvest)	Frozen carrot	Carrot preserved in jars	Dried carrot
Berjo	12.6	9.0	5.3	50.6
Flacoro	15.2	10.2	6.2	67.0
Karotan	13.0	10.0	5.9	75.8
Koral	13.5	10.3	5.5	65.7
Perfekcja	12.3	9.0	4.8	50.7
Magnesium application**				
0	13.0	9.2	5.5	58.0
45	13.4	9.5	5.4	60.8
90	13.7	10.2	5.7	66.1
MEAN	**13.3**	**9.6**	**5.5**	**61.7**

ADI – Acceptable Daily Intake*** for nitrates(V) is 222 mg·day^{-1} for adult's weight of - 60 kg.
* - mean consumption of fresh and processed carrot (without juice) is 20 kg·year^{-1} per person in Poland.
** - Magnesium rate [kg MgO·ha^{-1}]
*** - The Joint FAO/WHO Expert Committee [JECFA 2002] for foodstuffs has determined the (ADI) daily intake of nitrates (V) by adult amounting to 0 – 3.7 mg per kg of body weight [Burt et al. 1993]

per day to the body, which accounts for about 34% of ADI and as for the other cultivars – an average of 58.5 mg, which accounts for 26.4% of the ADI. Tamme et al. [2006], monitoring the Estonian market, defined the daily intake of nitrates (V) introduced into the body with vegetables for adults as 58 mg day^{-1}, for children at 4 to 6 years of age – 30 mg and for new-born children – 7.8 mg. Similarly, as in the present research, they did not exceed the ADI norm.

4. CONCLUSIONS

Changes due to the use of modern cultivation technology (biofortification plants of magnesium with standard plant protection products) enhanced the environmental conditions for carrot growing in the vegetation period, which decreased the content of nitrates (V), especially in frozen carrot. In that respect the application of magnesium at the amount of 90 kg MgO was most beneficial. The content of nitrates (V) in processed foods depended significantly on genetic conditions of material and on the processing method. The processing technology and genetic conditions significantly affected the safety of the processed foods, and thus, the safety of consumers.

Of all the cultivars, 'Karotan' was least applicable to processing since, irrespective of the processing method, the lowest decrease in nitrates (V) was noted in 'Karotan'. The calculated mean daily intake of carrot in a processed form does not exceed the ADI norm. Due to the toxic effect of nitrate compounds, regular monitoring of content and the occurrence of those compounds, not only in material but also in processed foods, allowed in the market is necessary.

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