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Evaluation of selected Polish carrot cultivars for nutritive value and processing – a preliminary study

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Abstract: *Evaluation of selected Polish carrot cultivars for nutritive value and processing – a preliminary study*. In the developed world, there is now a great demand for a wide spectrum of high-quality processed vegetable products, with emphasis on freshness and convenience. Carrot is among the most important vegetables in Poland, due to its high biological value and wide range of uses in processing. The breeding of carrots in Poland is directed towards creating new cultivars, meeting the high requirements of the fresh market and processing industry. The aim of the present study was to assess the quality of Polish carrot breeding lines and cultivars and their usefulness for the production of minimally processed carrot cubes. The experiment was carried out in 2008 and 2009 at the University of Agriculture in Krakow, Poland, with selected carrot breeding lines and cultivars (‘A02’, ‘B01’, ‘Drako F_1’, ‘F03’, ‘N04’, ‘NOE 606’, ‘NOE 808’). The morphological and chemical characteristics were evaluated and processing usefulness was assessed. ‘NOE 606’ formed roots with an attractive cylindrical shape with a small core. ‘N04’ was the line with the highest biological value according to the analyzed chemical characteristics, especially with its high content of dry matter, soluble sugars, carotenoids and soluble solids, and low accumulation of nitrates. ‘NOE 808’ provided frozen cubes with the best quality, while ‘N04’, ‘A02’ and ‘NOE 606’ showed the greatest suitability for drying. Root length correlated positively with carotenoid content, but negatively with the level of nitrates. The Polish-bred carrot genotypes were characterized by high biological quality, but the differences between them were significant, enabling the identification of genotypes with the best features for particular types of use.

Key words: *Daucus carota*, carotenoids, nitrates, freezing, drying

INTRODUCTION

Vegetables are the most important nutritional products in the human diet. Among them, carrot is one of the most valuable nutritional components, in view of its high content of carotenoids, fiber, essential micronutrients and functional ingredients like phenolics, polyacetylenes, isocoumarins, terpenes and sesquiterpenes [Metzger and Barnes 2009]. Raw carrot contains on average (per 100 g FM) 12 g of dry matter, 4.7 g of total sugar, 2.8 g of total dietary fiber, 8.3 mg of β-carotene; moreover, processing (freezing, cooking, boiling, draining, without salt) only minimally affects the content of the main chemical constituents in the final product [Sharma et al. 2011][1]. The high carotene content in carrot makes it one of the richest provitamin A sources in the human diet. Carotenoids, together with polyphenols, vitamin C and other constituents, as anti-

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[1]USDA National Nutrient Database available on-line: https://www.nal.usda.gov.

oxidant compounds, play a crucial role in the prevention of diseases of civilization [Arscott and Tanumihardjo 2010]. Systematic supplementation of the human diet with carrot is facilitated by the availability of the fresh roots in convenient “cut and peeled” packages, as well as the processing of the roots to make a wide spectrum of products, including frozen, canned or dried cubes or slices, juices, concentrates, pickles, preserves, etc.

The genetic factor has the greatest impact on the nutritional quality of carrot [Hussain et al. 2008, Kim et al. 2010, Singh et al. 2012]. Flavor and industrial quality depend on the cultivar, environment, and cultivar-environment interaction [Da Silva et al. 2007]. Cultivation method seems to have only a minor influence on quality in comparison with genetic and climate-related factors [Seljasen et al. 2013]. The level of biologically active components also depends on harvest maturity and storage conditions [Gajewski et al. 2009]. Root morphological parameters may be the first determinant of biological value and processing usefulness of carrot cultivars. In the roots, carotenoids are mainly accumulated as large crystals inside chromoplasts, particularly abundant in the secondary phloem of the root, the so-called cortex, as compared with the secondary xylem or core [Kim et al. 2010, Nahimana et al. 2011]. Furthermore, Zgórska and Grudzińska [2009] determined a 10-times greater nitrate content in the core as compared with the cortex. Because of the high accumulation of carotenoids and low nitrates in the secondary phloem of the cortex, cultivars with smaller core diameter compared with the cortex are the most valuable on the fresh vegetable market and for processing usefulness.

Many investigations have been carried out to determine precisely the connections between features determining carrot quality. Hussain et al. [2008] proved a high positive correlation between leaf dry weight, whole plant dry weight and leaf area and root dry weight, and a negative correlation between root-shoot ratio and root dry weight. Those authors concluded that with an increase in the proportion of assimilates partitioned to the roots, yield decreased. Sękara et al. [2012] showed that some parameters characterizing the processing usefulness of carrot can be predicted on the basis of morphological features, i.e. core diameter and root mass. Da Silva et al. [2007] found optimal correlations between root cylindrical form and minerals, and soluble and insoluble alimentary fibers, and proposed the use of these properties to differentiate carrot cultivars.

The processing industry has high requirements as regards the quality of the initial product. It is an important theoretical and practical problem to determine dependencies between morphology, chemical composition and parameters determining the processing usefulness of carrots, as a basis for the breeding and evaluation of carrot genotypes. According to Gajewski et al. [2009], carrot cultivars for processing should be characterized by high carotenoid and sugar but low nitrate content, and proper centrifugal leakage or rehydration parameters determining minimally processed product quality. One of the commonly used methods of carrot preservation is dehydration by hot drying, resulting in substantial reduction in weight and volume, thus minimizing packaging, storage and transport costs [Baysal et al. 2003]. Dehydrated slices, cubes and strips of carrot are used as ingredients in different sectors of the food industry. Loss of water and heating cause stresses in the cellular structure of the cube, leading to change in shape and decrease in dimension [Mayor and Sereno 2004]. Even though more severe heat treatment may result in a decrease in carotenoid content [Chandler and Schwartz 1988], Baysal et al. [2003] showed that mild heat treatment, for example steam blanching, protects carotenoids from degradation and isomerization. Another method of carrot preservation which avoids carotenoid damage is freezing [Kidmose et al. 2004]. Drying methods and conditions affect the quality of the product, including volume and shape changes, differently; it has been shown to be possible to use a shape factor to describe the effects of drying methods and conditions on the deformation of carrot cubes [Panyawong and Devahastin 2007]. Changes in the ratio of the surface area to the volume with water content have been found to be practically independent of drying conditions but dependent on the sample geometry [Ratti 1994]. Sękara et al. [2012] used the rehydration ratio together with poured and specific volume to describe the quality of dried carrot cubes. Poured volume characterizes the efficiency of dehydrated carrot storage and packaging, while specific volume quantifies dry product porosity and rehydrating properties. A high rehydration ratio indicates good possibilities of tissue structure reconstruction after drying. The low rehydration ratio is the main problem with dehydrated carrot products [Baysal et al. 2003].

The aim of the present investigation was to evaluate the quality of selected Polish carrot breeding lines and cultivars through the assessment of morphological and chemical features together with minimally processed carrot cube quality, evaluated by centrifugal leakage of the deep frozen product, rehydration ratio, and poured and specific volume of the dehydrated product. A determination was also made of the interaction effects between the analyzed parameters.

MATERIAL AND METHODS

Experiment design

The experiment was carried out at the Vegetable Experimental Station of the University of Agriculture in Krakow, Poland (50º04′N, 19º51′E). The soil was classified as a typical brown type, a grey brown subtype of stabilised fluvial alluvium, silt loam lying on medium-heavy soil, underlain by very fine sandy soil. The climate of the experimental station, located in southern Poland, is humid continental (Dfb) according to Köppen's classification. The object of the investigations was carrot (*Daucus carota* L.) in Polish breeding lines and cultivars: 'Draco F_1' (PlantiCo Hodowla i Nasiennictwo Ogrodnicze, Poland), 'A02', 'B01', 'F03', 'N04' (Polska Hodowla i Nasiennictwo Ogrodnicze, INWARZ-PNOS Sp. z o.o. Reguły, Poland), 'NOE 606', 'NOE 808' (Hodowla i Nasiennictwo Ogrodnicze Sp. z o.o. Spójnia, Poland). The genotypes listed were chosen for investigation on the basis of suggestions of Polish breeders.

Sowing took place on 21 April 2008 and 18 April 2009. Seeds were treated with Thiuram (Organica-Azot, Jaworzno, Poland). Plants were cultivated on standard ridges in two rows at a spacing of 8 × 4 cm. The distance between the centers of ridges was 67.5 cm, and the height of a ridge was 30 cm. The experimental plot was a section of a 3-m--long ridge, which included 150 plants. The experiment was established in three replications. Fertilizers were applied to maintain the content of available nutrient forms at the level recommended for the carrot, calculated based on a soil analysis, which showed: pH [H_2O] 6.2; organic carbon content 2%; and nutrient content ($mg \cdot dm^{-3}$; in 2008 and 2009, respectively): N-NH_4 35.0 and 23.2; N-NO_3 38.5 and 21.0; P 59.0 and 47.5; K 147 and 191; Mg 113 and 84; Ca 1287 and 778.

Data concerning the mean monthly temperature and total rainfall during the vegetation seasons of 2008 and 2009 are presented in Table 1. April, July, August, and September 2008 were slightly colder, and May and June warmer, compared with 2009. In 2008 the highest total rainfall was recorded in July, and in 2009 in June. Manual harvesting was performed on 2 October 2008 and 28 September 2009. Directly after harvesting the root length, the diameter of 1 cm below the top and 1 cm above the base, and the diameter of the core on a cross-section made at one half of the root length, were measured on 20 roots in three replications. On the basis of the root measurements, two shape indices were calculated to describe precisely the shape of the roots: (i) the slenderness index, defined as the ratio between the root length and the root top diameter; (ii) the taper index, being the ratio of the root top diameter to the base diameter.

Chemical analysis

Directly after harvesting randomly selected roots were subjected to analysis. All laboratory analyses were made in three repetitions. The roots were washed under running tap water, drained, manually peeled (1 mm), topped and tailed (1.0 to 1.5 cm) and homogenized. The dry matter content was determined by drying at 105°C until constant weight was attained. Total soluble sugars were determined by the anthrone method [Yemm and Willis 1954]. The total carotenoid content was determined by the modified Lichtenthaler and Wellburn method [1983] after ethanol extraction,

TABLE 1. Monthly mean temperature and total rainfall in the experimental years

Month	2008		2009	
	Temperature (°C)	Sum of rainfall (mm)	Temperature (°C)	Sum of rainfall (mm)
April	9.8	15	11.9	1
May	14.5	76	13.3	91
June	18.7	23	15.5	128
July	18.9	134	19.5	83
August	18.6	47	18.9	53
September	12.8	65	15.1	35

at 470 nm, with a Helios Beta spectrophotometer (Thermo Fisher Scientific Inc., USA). Nitrate ion content in the plant material was determined using an Orion® 920A ion-selective pH-meter (Thermo Electron Corp., USA) after extraction in 0.02 M $Al_2(SO_4)_3$ $18H_2O$. The content of soluble solids in the juice was determined with a digital refractometer and expressed in °Bx.

Processing usefulness assessment

The washed and peeled roots were cut into cubes (10 × 10 × 10 mm). The cubes were carefully mixed, blanched (95°C for 4 min), cooled to 20°C, drained, and then subjected to freezing and drying. Three 400 g samples from each genotype were stored in polyethylene bags (–20°C for 4 weeks) in a 2 MXP300 laboratory deep freezer [Danfoss, Denmark]. Centrifugal leakage was assessed as the percentage decrease in defrosted material mass after centrifuging of samples (2000 g for 10 min in 20°C) with an MPW-351 centrifuge (MPW Med, Poland).

Three 400 g samples from each genotype were convection-dried (50°C for 12 h) in a drying oven (Binder, Germany). The dried samples were stored in polyethylene bags (20°C for 4 weeks) until rehydration. Twenty randomly chosen pieces of the dried samples were weighed (M1) and placed in a glass with 100 ml of distilled water at 20°C and allowed to rehydrate for 24 h, the surplus water was removed with absorbent paper, and then the samples were weighed (M2). The rehydration ratio (R) was determined as the water absorbed (g) by 1 g of dried material, calculated using the equation R = (M2 – M1) / M1.

The poured volume (Vp) and specific volume (Vs) were determined as the volume taken up by 1 kg of dry solids with and without air pores respectively. A known mass of sample (M) was poured into a glass measuring cylinder and the total volume was evaluated by reading the scale of the cylinder (V1). The poured volume was calculated using the equation Vp = V1 / M. A known mass of sample (M) was immersed in a known volume of distilled water (Vc) in a measuring cylinder, and the dry solids volume (V2) was read off the scale of the cylinder. The specific volume (Vs) was calculated using the equation Vs = (V2 – Vc) / M. The data were expressed as the volume of the sample (dm^3) per 1 kg.

All of the data obtained were subjected to one-way ANOVA, and the difference of the means was compared by the HSD Tukey test at P = 0.05. Simple correlation coefficients were calculated between the investigated quality parameters. Equations for predicting the processing indices as functions of independent morphological and chemical variables were obtained with the use of a multiple regression method.

RESULTS AND DISCUSSION

Minimally processed carrot cube is a raw material used in many branches of the food industry to supply the market with high-quality convenience products, popular mainly in developed countries. Quality management in the processing industry specifies requirements for the production sector concerning the morphological, physical and chemical characteristics of carrot root. Genotypes with long, uniform roots of cylindrical shape are the most valuable in terms of reduction of waste. The cortex should make up most of the root weight, because of the higher content of carotenoids and sugars and lower content of nitrates in the cortex as compared with the core [Zgórska and Grudzińska 2009, Kim et al. 2010]. In the present study we used two indices to precisely describe the shape of carrot roots. 'Drako F_1' and 'F03' formed the longest roots, with a cone-cylinder shape, returning the lowest slenderness indices and highest taper indices (Table 2). 'NOE 808' had roots with a similar cone-cylinder shape, but the roots were significantly shorter than those of 'Drako F_1'. The highest slenderness indices and lowest taper indices were found for cylinder-shaped roots such as 'A02' and 'NOE 606'. The correlation matrix showed that positive correlation existed between the root length and carotenoid content for all investigated cultivars, although Kidmose et al. [2004] did not find a significant effect of root size on the content of α- and β-carotene, even though the content seemed to decrease with increasing root size. A positive correlation between root length and carotenoid content, and a negative correlation with nitrate content, were also reported by Sękara et al. [2012]. Rodriguez-Concepcion and Stange [2013] showed that at later stages of carrot development, secondary root growth resulted in a dramatic enlargement and boosted production of carotenoids in the chromoplasts of the secondary phloem, which is an explanation for the observed correlation between root size and carotenoid content. Nahimana et al. [2011] investigated drying and radial shrinkage characteristics and changes in the color and shape of the carrot cortex as compared with the core, during air drying. Better color, higher chroma and lower whitening index were determined for the cortex tissue. In the present study, all genotypes with the exception of 'F03' had roots with a higher percentage of cortex tissues. We also showed a negative correlation between slenderness index and core diameter, and a positive one between taper index and core diameter; hence roots with cylindrical shape were characterized by a small core. Da Silva et al. [2007] compared

TABLE 2. Root morphological indices (means for 2008–2009)

Cultivar	Root length (cm)	Core share (% of root diameter)	Root shape indices	
			slenderness	taper
A02	17.91 a	40.7 ab	6.11 d	1.27 a
B01	18.14 a	44.8 bc	5.51 cd	1.44 ab
Drako F_1	22.32 b	42.3 ab	5.29 abc	1.69 bc
F03	20.64 ab	56.8 d	4.80 ab	1.83 c
N04	18.26 a	39.7 ab	5.32 bc	1.36 a
NOE 606	20.57 ab	36.8 a	5.94 cd	1.25 a
NOE 808	18.99 a	42.3 ab	4.64 a	1.91 c
Mean	19.54	44.34	5.63	1.54

*Values in columns marked with the same letter do not differ significantly at P = 0.05.

carrot cultivars with cylindrical roots, but they did not find a significant correlation between root length and its physical, sensory and chemical properties.

The dry matter content was the highest in the roots of ‘N04’ and ‘B01’, with the mean value for all analyzed genotypes equal to 12.47% (Table 3). Similar values were obtained by Fikselová et al. [2010] for four carrot cultivars grown in three regions of Slovakia, and by Sękara et al. [2012] for 10 Polish carrot cultivars. In the present investigation the significant dry matter was positively correlated with soluble sugars and solid content. This is in accordance with the results of Pokluda [2008], who confirmed a significant positive correlation between dry matter and sugar content in carrot. Da Silva et al. [2007] described a correlation between soluble solids and dry matter content on the basis of an evaluation of four carrot cultivars grown in Brazil.

‘B01’ and ‘N04’ had the highest levels of soluble sugars and soluble solids (Table 3). There were slight differences in carotenoid content between the investigated genotypes; only ‘N04’, ‘B01’ and ‘NOE 606’ had a higher carotenoid content than ‘A02’. The mean levels of the aforementioned parameters were slightly higher than those published by the USDA National Nutrient Database from 2013 (on-line access: https://www.nal.usda.gov). Trajer and Swiderski [2009] suggested that the high content of carotenoids and low content of undesirable compounds, especially nitrates are major indicators of the high nutritional value of carrot roots. The permissible level of nitrates in vegetables for the Polish market is defined only for lettuce and spinach (2000–4000 mg $NO_3 \cdot kg^{-1}$ FM) and food for children (200 mg $NO_3 \cdot kg^{-1}$ FM) [Dziennik Ustaw 136, 2010]. We determined 201.3–521.4 mg $NO_3 \cdot kg^{-1}$ FM in the roots of the investigated carrot genotypes, the lowest content being found in ‘F03’ and ‘N04’.

Carrot cube is a valuable component of frozen and canned vegetable products. Its quality is determined by a low value of cell sap leakage during defrosting resulting from slight tissue destruction during frosting. To describe this parameter we use the centrifugal leakage measurement, because free leakage of cell sap was not observed for all investigated genotypes

TABLE 3. Root biochemical indices (means for 2008–2009)

Cultivar	Dry matter (%)	Soluble sugars ($mg \cdot 100\ g^{-1}$ FM)	Carotenoids ($mg \cdot 100\ g^{-1}$ FM)	Nitrates ($mg\ NO_3^- \cdot kg^{-1}$ FM)	Soluble solids (°Brix)
A02	11.81 ab	5.38 a	12.74 a	413.6 ab	8.83 a
B01	13.40 c	6.86 c	15.75 b	403.7 ab	10.77 c
Drako F_1	12.24 b	5.88 c	14.79 ab	366.9 ab	8.37 a
F03	11.20 a	5.80 c	14.20 ab	201.3 a	9.67 b
N04	14.10 c	7.97 c	16.41 b	269.1 a	11.60 d
NOE 606	12.46 b	5.53 b	15.30 b	311.8 ab	9.02 ab
NOE 808	12.07 b	5.72 b	14.72 ab	521.4 b	9.00 ab
Mean	12.47	6.16	14.84	355.4	9.61

For explanation see Table 2.

during cube defrosting. Cubes of 'NOE 808' had the lowest values of this parameter, and can be regarded as the best material for frosting on the basis of this parameter, while 'A02' and 'Drako F_1' had significantly the highest values (Table 4). Centrifugal leakage was negatively correlated with root length, soluble solids and carotenoid content, and positively – with nitrate content (Table 5). Similar observations were made by Sękara et al. [2012] for 10 Polish carrot genotypes, where centrifugal leakage values were negatively correlated with features indicating the high biological value of roots.

Carrot cube is also used for the production of drying material, a valuable semi-finished product in many sectors of the processing industry. The course of the moistening of dry material, crucial for the final quality of the dehydrated product, is dependent on tissue structure regeneration after drying. To precisely describe dry carrot cube quality we used three indices: the rehydration ratio; the poured volume, indicating the efficiency of dried product packaging and storage; and the specific volume, which quantifies dry product porosity and rehydrating properties. The greatest capacity for drying, based on the highest values of the rehydration ratio, was found for 'N04', 'NOE 606', 'A02' and 'F03'. The same genotypes, together with 'B01' and 'Drako F_1', exhibited the lowest poured volume, indicating the greatest usefulness for packaging and storage. Dried cubes of 'N04' and 'F03' had the highest poured volumes among all investigated cultivars. 'F03' had a higher specific volume than 'A02'. Baysal et al. [2003] found that the color of dried carrot most resembled the fresh product after hot air drying, whereas its rehydration capacity was then the lowest: infrared dehydrated carrot had the best rehydration capacity. The present investigation did not confirm the correlation between carotenoid content and the rehydration ratio of the dried product. Another important consequence of shrinkage is the decrease in the rehydration capability of the dried product [Mayor and Sereno 2004]. Analysis of the correlation matrix from the present experiment did not show any connection between the rehydration ratio and the poured and specific volume of frozen and dried carrot cube.

TABLE 4. Processing indices of deep frozen and dried carrot cube (means for 2008–2009)

Cultivar	Centrifugal leakage (%)	Rehydration ratio (g $H_2O \cdot g^{-1}$)	Poured volume ($dm^3 \cdot kg^{-1}$ DM)	Specific volume ($dm^3 \cdot kg^{-1}$ DM)
A02	19.53 b	5.81 ab	2.23 a	0.57 a
B01	15.00 ab	4.60 a	2.13 a	0.66 ab
Drako F_1	19.17 b	4.63 a	2.26 a	0.62 ab
F03	16.09 ab	5.52 ab	2.79 b	0.77 b
N04	15.79 ab	6.37 b	2.71 b	0.68 ab
NOE 606	14.58 ab	5.82 ab	2.28 a	0.60 ab
NOE 808	12.07 a	4.48 a	2.26 a	0.75 ab
Mean	16.03	5.32	2.38	0.66

For explanation see Table 2.

TABLE 5. Coefficients of correlation (r) between morphological, biochemical and processing parameters of carrot quality, N = 48

×	RL	CD	SI	TI	DM	SSu	C	N	SSo	CL	RR	PV	SV
RL	1.00												
CD	0.06	1.00											
SI	0.01	–0.39*	1.00										
TI	0.49***	0.31*	–0.44**	1.00									
DM	–0.22	–0.35*	0.14	–0.33*	1.00								
SSu	0.01	–0.04	–0.19	–0.09	0.72***	1.00							
C	0.31*	–0.14	–0.13	0.23	0.23	0.19	1.00						
N	–0.48***	–0.13	0.16	–0.22	0.17	–0.18	–0.71***	1.00					
SSo	–0.15	0.03	–0.03	–0.09	0.61***	0.60***	0.54***	–0.35*	1.00				
CL	–0.27	0.07	0.30	–0.34*	0.01	–0.17	–0.68***	0.64***	–0.35*	1.00			
RR	0.02	–0.16	0.32*	–0.09	–0.10	–0.17	0.21	–0.20	0.11	0.16	1.00		
PV	0.20	0.24	–0.10	0.23	–0.20	0.02	0.34*	–0.41**	0.29*	–0.02	0.72***	1.00	
SV	–0.32*	0.31*	–0.14	–0.01	–0.01	0.01	–0.61***	0.67***	–0.16	0.58***	–0.06	0.01	1.00

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

RL – root length, CD – core diameter, SI – slenderness index, TI – taper index, DM – dry matter, SSu – soluble sugars, C – carotenoids, N – nitrates, SSo – soluble solids, CL – centrifugal leakage, RR – rehydration ratio, PV – poured volume, SV – specific volume.

CONCLUSIONS

It has been shown that genotype was the main determinant of the biological value of the investigated Polish carrot breeding lines and cultivars, which were characterized by high quality and processing usefulness. 'NOE 606' formed roots of attractive shape, cylindrical with a small core. 'N04' was the cultivar with the highest biological value according to the analyzed chemical characteristics, especially with its high content of dry matter, soluble sugars, carotenoids and soluble solids, and low accumulation of nitrates. 'NOE 808' produced frozen cube of the best quality; N04', 'A02' and 'NOE 606' showed the greatest suitability for drying. Root length was positively correlated with carotenoid content, but negatively with nitrate level. The investigated Polish-bred carrot genotypes showed statistically significant differences in morphological and chemical features and in parameters characterizing minimally processed product quality, making it possible to choose the best material for particular types of use.

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REFERENCES

ARSCOTT S.A., TANUMIHARDJO S.A. (2010). Carrots of many colors provide basic nutrition and bioavailable phytochemicals acting as a functional food. Comprehensive Rev. Food Sci. Food Safety 9(2): 223–239.

BAYSAL T., ICIER F., ERSUS S., YILDIZ H. (2003). Effects of microwave and infrared drying on the quality of carrot and garlic. Eur. Food Res. Technol. 218: 68–73

CHANDLER L.A., SCHWARTZ S.J. (1988). Isomerization and losses of trans-β-carotene in sweet potatoes as affected by processing treatments. J. Agric. Food Chem. 36: 129–133.

Da SILVA E.A., VIEIRA M.A., VIEIRA E.A., DE MELLO R.D., AMBONI C., AMANTE E.R., TEIXEIRA E. (2007). Chemical, physical and sensory parameters of different carrot varieties (*Daucus carota* L.). J. Food Process Eng. 30: 746–756

Dziennik Ustaw 136 (2010). Obwieszczenie Marszałka Sejmu Rzeczypospolitej Polskiej z dnia 29 czerwca 2010 r. w sprawie ogłoszenia jednolitego tekstu ustawy o bezpieczeństwie żywności i żywienia. Poz. 914.

FIKSELOVÁ M., MAREĈEK J., MELLEN M. (2010). Carotenes content in carrot roots (*Daucus carota* L.) as affected by cultivation and storage. Veg. Crops Res. Bull. 73: 47–54.

GAJEWSKI M., WĘGLARZ Z., SEREDA A., BAJER M., KUCZKOWSKA A., MAJEWSKI M. (2009). Quality of carrot grown for processing as affected by nitrogen fertilization and harvest term. Veg. Crops Res. Bull. 70: 135–144.

HUSSAIN S.I., HADLEY P., PEARSON S., HIDAYATULLAH (2008). Genetic variability of carrots. I. Effect of sowing dates on quality and growth characteristic in carrot (*Daucus carota* L.) cultivars. Pakistan J. Agric. Res. 21(1–4): 54–64.

KIDMOSE U., HANSEN S.L., CHRISTENSEN L.P., EDELENBOS M., LARSEN E., NØRBÆK R. (2004). Effects of genotype, root size, storage, and processing on bioactive compounds in organically grown carrots (*Daucus carota* L.). J. Food Sci. 69(9): 388–394.

KIM J.E., RENSING K.H., DOUGLAS C.J., CHENG K.M. (2010). Chromoplast ultrastructure and estimated carotene content in root secondary phloem of different carrot varieties. Planta 231: 549––558.

LICHTENTHALER H.K., WELLBURN A.R. (1983). Determinations of total carotenoids and chlorophylls a and b in leaf extracts by different solvents. Biochem. Soc. Trans. 11: 591–592.

MAYOR L., SERENO A.M. (2004). Modelling shrinkage during convective drying of food materials: a review. J. Food Eng. 61: 373–386.

METZGER B.T., BARNES D.M. (2009). Polyacetylene diversity and bioactivity in orange market and locally grown colored carrots (*Daucus carota* L.). J. Agric. Food Chem. 57(23): 11134–11139.

NAHIMANA H., MUJUMDAR A.S., ZHANG M. (2011). Drying and radial shrinkage characteristics and changes in color and shape of carrot tissues (*Daucus carota* L.) during air drying. Afr. J. Biotechnol. 10(68): 15327–15345.

PANYAWONG S., DEVAHASTIN S. (2007). Determination of deformation of a food product undergoing different drying methods and conditions via evolution of a shape factor. J. Food Eng. 78(1): 151–161.

POKLUDA R. (2008). Content of dry matter, carotenoids and reducing sugars in selected vegetables. Ann. UMCS 18(1), Sectio EEE: 1–9.

RATTI C. (1994). Shrinkage during drying of foodstuffs. J. Food Eng. 23: 91–105.

RODRIGUEZ-CONCEPCION M., STANGE C. (2013). Biosynthesis of carotenoids in carrot: An underground story comes to light. Archiv. Biochem. Biophys. 539(2): 110–116.

SĘKARA A., KALISZ A., CEBULA S., GRABOWSKA A. (2012). The quality and processing usefulness of chosen Polish carrot cultivars. Acta Sci. Pol., Hortorum Cultus 11(5): 101–112.

SELJASEN R., KRISTENSEN H.L., LAURIDSEN C., WYSS G.S., KRETZSCHMAR U., BIRLOUEZ-ARAGONEE I. (2013). Quality of carrots as affected by pre- and postharvest factors and processing. J. Sci. Food Agric. 20(93): 2611–2626.

SHARMA K.D., KARKI S., THAKUR N.S., ATTRI S. (2011). Chemical composition, functional properties and processing of carrot – a review. J. Food Sci. Technol. 49(1): 22–32.

SINGH D.P., BELOY J., MCINERNEY J.K., DAY L. (2012). Impact of boron, calcium and genetic factors on vitamin C, carotenoids, phenolic acids, anthocyanins and antioxidant capacity of carrots (*Daucus carota*). Food Chem. 132: 1161–1170

TRAJER J., ŚWIDERSKI A. (2009). Using cluster analysis for examining carrot varieties diversity. Annals of Warsaw University of Life Sciences – SGGW, Agriculture 54: 71–76.

YEMM E.W., WILLIS A.J. (1954). The estimation of carbohydrates in plant extracts by anthrone. Biochem. J. 57(3): 508–514.

ZGÓRSKA K., GRUDZIŃSKA M. (2009). Rozmieszczenie azotanów w różnych częściach wybranych warzyw i w bulwach ziemniaka. Biul. Nauk. 30: 103–108.

Streszczenie: *Ocena wartości odżywczej i przydatności przetwórczej wybranych odmian marchwi polskiej hodowli – badania wstępne.* W krajach wysokorozwiniętych istnieje obecnie duże zapotrzebowanie na wysokiej jakości produkty warzywne, przygotowane w formie gotowej do spożycia. Marchew należy do najważniejszych gospodarczo warzyw w Polsce ze względu na wysoką jakość biologiczną i dużą wartość przetwórczą. Hodowla marchwi w Polsce jest ukierunkowana na tworzenie nowych odmian spełniających wysokie wymagania rynku warzyw świeżych i przemysłu przetwórczego. Celem prezentowanych badań była ocena jakości polskich linii hodowlanych i odmian marchwi pod względem przydatności produkcji minimalnie przetworzonego produktu, jakim jest mrożona i suszona kostka. Eksperyment przeprowadzono w latach 2008 i 2009 na Uniwersytecie Rolniczym w Krakowie. Obiektem badań były linie hodowlane i odmiany marchwi polskiej hodowli (‘A02’, ‘B01’, ‘Drako F_1’, ‘F03’, ‘N04’, ‘NOE 606’, ‘NOE 808’). Oceniono cechy morfologiczne i chemiczne korzeni oraz jakość minimalnie przetworzonej kostki marchwiowej. ‘NOE 606’ wytworzyła korzenie

o cylindrycznym kształcie i małym udziale rdzenia w średnicy korzenia. ‘N04’ charakteryzowała największa wartość biologiczna, określona na podstawie składu chemicznego korzeni, szczególnie wysokiego poziomu suchej masy, cukrów rozpuszczalnych, karotenoidów, ekstraktu oraz słabej akumulacji azotanów. ‘NOE 808’ była najlepszym surowcem do produkcji mrożonej kostki najwyższej jakości. ‘N04’, ‘A02’ i ‘NOE 606’ wykazały największą przydatność do suszenia. Długość korzenia spichrzowego była pozytywnie skorelowana z zawartością karotenoidów, ale negatywnie – z poziomem azotanów. Wykazano również korelacje między pozostałymi z analizowanych parametrów. Genotypy marchwi polskiej hodowli charakteryzowała bardzo duża wartość biologiczna, a istotne różnice w poszczególnych parametrach opisujących jakość materiału świeżego i minimalnie przetworzonego mogą posłużyć do wytypowania linii dedykowanych do konkretnego sposobu wykorzystania na rynku warzywnym.