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THE QUALITY AND PROCESSING USEFULNESS OF CHOSEN POLISH CARROT CULTIVARS

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Abstract. Carrot is one of the most important vegetables in Poland. It is the best carotenoid source in a human diet. Carrot is consumed in large quantities, thanks to continuous supply of fresh and storage roots as well as wide choice of processed products on a food market. Also consumer demands increase with regard to carrot quality and biological value. Polish breeders offer new carrot cultivars for processing. The choice of cultivar is the important factor under human control that may be used to improve carrot quality. The experiment was carried out at the University of Agriculture in Krakow, Poland, in the years 2009 and 2010, with carrot cultivars ('Askona F_1', 'DZE II F_1', 'Galicja F_1', 'Karioka F_1', 'Karotan', 'Rumba F_1', 'Afro F_1', 'Broker F_1', 'Kongo F_1', 'Korund F_1') to evaluate its morphological and chemical characteristics and processing usefulness. Root morphological features predisposed investigated cultivars to mechanical harvest and processing. Analyzed chemical characteristics allowed to point out genotypes of high biological value and low nitrates accumulation, such as 'Karioka F_1'. The source of frozen cube of the best quality were 'Karioka F_1', 'Rumba F_1', and 'Askona F_1', because of the lowest centrifugal leakage value. 'Karioka F_1' and 'Korund F_1' showed the greatest capacity for drying, because of the highest value of rehydration ratio. This shows that the comparison of the cultivars is necessary when the decision about the raw material selected for processing should be made. The parameters characterizing the minimally processed carrot cube quality were also correlated with morphological and chemical features of the roots. The equations allowing to predict the processing indices as the function of independent morphological and chemical variables were proposed with a use of the multiply regression method.

Key words. *Daucus carota*, processing, carotenoids

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INTRODUCTION

Carrot is a vegetable species of high economical value. Raw and processed carrot is a valuable diet component recommended in human nutrition, because of high level of β-carotene, fiber, essential micronutrients and functional ingredients. Raw carrot contains 12% of dry matter, 4.5 g · 100 g^{-1} of total sugars and 8.2 mg · 100 g^{-1} of β-carotene [USDA National Nutrient Database, 2012]. The consumption of carrot and carrot products increases steadily due to its recognition as an important source of natural antioxidants having anticancer activity [Sharma et al. 2011]. Seljåsen et al. [2012] reported, that the most important factor under human control that may be used to improve carrot quality is choosing the optimal variety. The content of carotenoids is the primary determinant of the biological value of carrot. The major carrot carotenoids, α- and β-carotene, act as vitamin A precursors and antioxidants which have protective properties against certain forms of cancer and cardiovascular diseases [Basu et al. 2001]. Root colour is primarily affected by a cultivar, maturity, cultivation practices and environmental conditions [Fikselová et al. 2010]. The synthesis of carotenoids occurs in temperature of 5–30°C, and the best colour is reached by root maturing in 16–21°C, especially for 3 weeks before harvesting. The carotenoid content is enhanced by the large differences in temperature between night and day. Rosenfeld et al. [1998] found, that temperature was the most important factor determining the sensory and chemical quality of carrot, whereas for morphological features like root weight, root length and diameter measurements, light was more important than temperature. Vegetables are also important source of nitrates in a human diet. The nitrates level in carrot roots depended on fertilization, environmental factors, root maturity and a cultivar [Gajewski et al. 2009]. The permissible level of nitrates in vegetables for Polish market was defined only in a case of lettuce and spinach (2000–4000 mg $NO_3 \cdot kg^{-1}$ f.m.), and food for children (200 mg $NO_3 \cdot kg^{-1}$ f.m.) [Dziennik Ustaw 136, 2010].

Processing of carrot into wide spectrum of products (frozen cube, canned slices, juice, concentrate, pickle, preserve, etc.) make this important vegetable available throughout the year. The requirements of processing industry with regard to product quality are very high. Genotypes grown for processing should be characterized by low nitrate content, high carotenoid and sugar level, and good parameters characterizing minimally processed product like frozen or dried cube, i.e. centrifugal leakage or rehydration ratio [Gajewski et al. 2009]. Dehydration of carrot is one of the most important methods of preservation for further develop of value added products throughout the year. Carrot is dehydrated in the form of slices, cubes and strips. The proper technology of dehydration let to obtain the dry product which retains good value, natural flavour, and cooking quality of fresh material [Sablani 2006]. Hot-air drying is the most widely used method for production of dehydrated carrot. This method was found to be the most effective in preserving the attractive colour of final product [Baysal et al. 2003]. Degradation and isomerization of α- and β-carotene occur during thermal heating; however, a mild heat treatment, for example steam blanching, was reported as a method preserving carotenoids content on the greatest level. On the contrary, a more severe heat treatment may result in carotenoid degradation [Chandler and Schwartz 1988]. During frozen storage, α- and β-carotenes are rather stable [Kidmose and Martens 1999]. Kidmose et al. [2004] found no significant differences in the content of these pigments between the raw and blanched carrot samples after 4 months of frozen storage. The poured volume characterizes the possibility of dehydrated carrot storage and packaging. The specific volume quantifies dry product porosity and rehydrating properties. High rehydration ratio shows the high possibilities of tissue structure reconstruction after drying. The low rehydration ratio is the commonly reported problem with dehydrated carrot products [Baysal et al. 2003].

Attempts have been made to correlate the chemical and processing quality of carrots with morphological parameters. Kumar et al. [2010] proposed two models predicting average root weight on the basis of leaf length, shoulder thickness, crown diameter, marketable root yield per plot, forking, and cracking percentage; and marketable root yield – on the basis of shoulder thickness, crown diameter, root weight, and cracking percentage. Dry matter, soluble solids, sugars and total titratable acids were relevant for predicting the sensory quality of raw carrot [Varming et al. 2004].

The aim of the present study was to investigate the quality of Polish carrot cultivars and usefulness for minimally processed carrot cube production. The morphological and chemical features were assessed together with minimally processed carrot cube quality, evaluated by centrifugal leakage of deep frozen product, rehydration ratio, poured and specific volume of dehydrated product. The possible interaction effects between analyzed parameters were also estimated.

MATERIAL AND METHODS

Experiment design. The experiment was carried out at the University of Agriculture in Krakow, Poland in the years 2009 and 2010, with carrot (*Daucus carota* L.) cultivars: 'Askona F_1', 'DZE II F_1', 'Galicja F_1', 'Karioka F_1', 'Rumba F_1' (Polska Hodowla i Nasiennictwo Ogrodnicze POLAN Sp. z o.o., Poland), 'Afro F_1', 'Broker F_1', 'Kongo F_1', 'Korund F_1' (PlantiCo Hodowla i Nasiennictwo Ogrodnicze, Poland). 'Karotan' (Rijk Zwaan) was also used as a standard.

The sowing was performed on 18 April 2009 and 23 April 2010. Seeds were treated with Thiuram (Organica-Azot, Jaworzno, Poland). Plants were cultivated on standard ridges in two rows in spacing 8 × 4 cm. Distance between centre of ridges was 67.5 cm, and the height of a ridge was 30 cm. The soil was classified as a typical brown type, grey brown subtype of stabilised fluvial alluvium, silt loam laying on medium-heavy soil, underlain by very fine sandy soil.

The experimental plot of 3 m^2 included 150 plants. The fertilizers were applied to maintain the content of available nutrient forms on a level recommended for the investigated species, calculated on a base of the soil analysis, which showed pH (H_2O) – 6,2; organic carbon content of 2%; and nutrient content ($mg \cdot dm^{-3}$; in 2009 and 2010, respectively): $N\text{-}NH_4$ – 23.2 and 29.7; $N\text{-}NO_3$ – 21.0 and 85.7; P – 47.5 and 48.0; K – 191 and 217; Mg – 84 and 126; Ca – 778 and 455. The nutrients were applied in a dose: N – 35 + 35 $kg \cdot ha^{-1}$ before sowing in a form of nitrochalk and in June 2009 in a form of ammonium nitrate, P – 40 $kg \cdot ha^{-1}$ in a form of triple superphosphate in autumn 2008 and 2009.

Data concerning the mean month temperature and sum of rainfall during vegetation seasons are presented in Table 1. The sum of rainfall was considerably higher in the second year of the study for all months except June. Mean air temperature was similar in both years. In 2009 April, May, July, August and September were characterized by higher maximum, and lower minimum temperatures as compared to similar months in 2010.

Table 1. Sum of rainfall, mean, maximum and minimum temperature values in the experimental years
Tabela 1. Suma opadów oraz średnia, maksymalna i minimalna temperatura w latach badań

Month Miesiąc	2009				2010			
	temperature temperatura (°C)			sum of rainfall suma opadów (mm)	temperature temperatura (°C)			sum of rainfall suma opadów (mm)
	mean średnio	max.	min.		mean średnio	max.	min.	
April Kwiecień	11.9	22.2	1.7	1	8.5	14.3	3.3	37
May Maj	13.3	20.5	6.6	91	12.8	16.8	9.4	302
June Czerwiec	15.5	20.8	10.5	128	17.6	22.6	12.1	122
July Lipiec	19.5	26.6	13.1	83	20.9	26.5	15.1	110
August Sierpień	18.9	27.4	12.0	53	18.7	24.6	13.5	138
September Wrzesień	15.1	23.4	8.0	35	12.4	17.1	8.4	92

The manual harvest was performed on 28 September 2009 and 22 September 2010. Directly after harvest the root length, diameter 1 cm below top, weight and core diameter were assessed on 20 roots in three replications.

Chemical analysis. Directly after harvest roots were subjected to analysis, all laboratory analysis 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 obtained. The total soluble sugars were determined by anthrone method [Yemm and Willis 1954]. The total carotenoid content was determined by the modified Lichtenthaler and Wellburn [1983] method after ethanol extraction, at 470 nm, with Helios Beta spectrophotometer (Thermo Fisher Scientific Inc., USA). Nitrate ions content in plant material were determined using Orion® ion selective pH meter 920A (Thermo Electron Corp., USA) after extraction in 0.02M $Al_2(SO_4)_3$ $18H_2O$. The content of soluble solids in the juice was determined with a digital refractometer and expressed in °Bx.

Processing usefulness assessment. Washed and pilled roots were cut to cube (10 × 10 × 10 mm). The cube was carefully mixed, blanched (95°C / 4 min), cooled to

20°C and drained. Three 400-g samples from each genotype were stored in polyethylene bags (-20°C / 4 weeks) in a laboratory deep freezer 2 MXP300 (Danfoss, Denmark). The centrifugal leakage was assessed as the percentage decrease of defrost material mass, after centrifuging of samples (2 thousands g / 10 min / 20°C) with the centrifuge MPW-351 (MPW Med, Poland).

Three 400-g samples from each genotype were convective drained (50°C / 12 h) in drying oven (Binder, Germany). Dried samples were stored in polyethylene bags (20°C / 4 weeks) until rehydration. Randomly chosen 20 pieces of the dried sample were weighed (M1) and placed in a glass with 100 ml distilled water at 20°C and allowed to rehydrate for 24 hours, the surplus water was removed with absorbent paper, then samples were weighed (M2). The rehydration ratio (R) was determined as a water absorbed (g) by 1 g of dried material and 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 amount of sample (M) was poured into the glass measured cylinder and the total volume was evaluated by reading the scale of cylinder (V1). The poured volume was calculated using equation: Vp = V1/M. A known amount 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 equation: Vs = V2/M. The data were expressed as the volume of sample (dm^3) per 1 kg.

All data obtained were subjected to one-way ANOVA, and the differentiation of the means was compared by the Tukey test at $p = 0.05$. Simple correlation coefficients were calculated between investigated quality parameters at $p \leq 0.05$. The equations allowing to predict the processing indices as the function of independent morphological and chemical variables was proposed with a use of a multiply regression method.

RESULTS AND DISCUSSION

According to processing industry requirements the most valuable are carrot cultivars with uniform and cylindrical roots, with regard to the reduction of refuses. The root diameter should not exceed 3.5 cm. The investigated carrot genotypes formed roots with length of 17.5–20.8 cm, weight of 132.5–242.5 g, root diameter 2.94–3.84 cm, and core diameter 37.8–57.8% of root diameter (tab. 2). ‘Galicja F_1’, ‘Karioka F_1’ i ‘DZE II F_1’ had significantly longer roots than standard cultivar ‘Karotan’. Roots of all examined cultivars with the exception of ‘Askona F_1’ had significantly smaller core diameter than ‘Karotan’. Da Silva et al. [2007] evaluated four carrot cultivars in terms of its chemical and organoleptic features. The correlation coefficients between the root cylindrical form and the attributes of internal and external colors, minerals, total and insoluble alimentary fibers were close to 1.0. In present work, carrot roots were characterized by a shape from cylindrical to conical; a greater root diameter indicated shape closed to cone. The root diameter, like root length and weight *were positively correlated with* dry matter, soluble sugars and soluble solids content (tab. 5). The significant correlation between the height of a rosette and diameter of a root, diameter of a core and root crop, the leaf number in a rosette and diameter of a root were shown by Butov [2010]. The

Table 2. Root morphological indices (means for 2009–2010)
Tabela 2. Parametry morfologiczne korzeni (średnia z lat 2009–2010)

Cultivar Odmiana	Root length Długość korzenia (cm)	Root diameter Średnica korzenia (cm)	Root weight Masa korzenia (g)	Core diameter (% of root diameter) Średnica rdzenia (% średnicy korzenia)
Afro F_1	18.8 ac	3.11 a	152.0 c	40.1 ab
Askona F_1	19.7 b-d	3.84 d	227.0 f	57.5 c
Broker F_1	18.6 ab	3.41 bc	153.7 c	47.9 b
DZE II F_1	20.4 cd	3.55 cd	242.5 g	44.6 b
Galicja F_1	20.8 d	3.34 bc	200.3 e	50.6 b
Karioka F_1	20.4 cd	3.11 ab	146.5 bc	37.8 a
Karotan	18.2 ab	3.18 a-c	171.5 d	57.8 c
Kongo F_1	19.8 b-d	3.22 a-c	140.5 ab	50.3 b
Korund F_1	18.9 ab	3.36 bc	132.5 a	49.3 b
Rumba F_1	17.5 a	2.94 a	142.8 b	46.2 b
Mean – Średnio	19.29	3.304	170.93	48.62

genotypes with a great number of leaves are predisposed to mechanical harvest. The small core is preferred on a fresh vegetable market because of worse taste and lower biological value of core as compared to cortex. Nahimana et al. [2011] reported, that the cortex of fresh and dried carrot had better color due to its high chroma and low whitening index compared to the core tissue. Higher carotenoid amounts were also recorded in cortex. Zgórska and Grudzińska [2009] found more than ten times greater nitrates level in carrot core as compared to cortex. Present results do not confirm the correlations between core diameter and chemical composition of carrot roots (tab. 5). The parameters characterizing the processing capacity of carrot were also correlated with morphological root features. Centrifugal leakage was inversely proportional to root length, weight and diameter and directly proportional to core diameter. In opposite, rehydration ratio was positively correlated with root length, weight and diameter and negatively with core diameter. The positive dependence was found between root length and poured volume, and root weight and specific volume of dry cube. The negative correlation was found between core diameter and poured volume of dry cube.

The level of dry matter in investigated carrot genotypes ranged between 9.70 and 12.46% f.m., 10 evaluated genotypes formed seven statistically different groups, as shown in Table 3, and 'Karioka F_1' and 'Askona F_1' contained the highest level of dry matter, significantly higher than 'Karotan'. The present results were similar with reported by Fikselová et al. [2010] for 4 carrot cultivars grown in Slovakia and with data reported by USDA National Nutrient Database [2012]. Carrot genotypes of different root colour and shape, cultivated in Poland, were characterized by mean dry matter content of 11.3%, measured directly after harvest [Gajewski et al. 2010]. There was a significant effect of genotype on the soluble sugars content in carrot roots, which was contained in a range 4.43–6.22 $mg \cdot 100g^{-1}$ f.m. (tab. 3), with greatest values for 'Karioka

F_1', 'Karotan', 'Askona F_1', and 'Kongo F_1'. Investigated cultivars were characterized by soluble solids content of 8.07–10.02 °Brix. Only 'Karioka F_1' was characterized by higher soluble solids content than 'Karotan'. The given values were comparable with the results of Da Silva et al. [2007], but cited authors found no statistical differences in this parameter between investigated cultivars.

Table 3. Root biochemical indices (means for 2009–2010)
Tabela 3. Parametry biochemiczne korzeni (średnia z lat 2009–2010)

Cultivar Odmiana	Dry matter Sucha masa (%)	Soluble sugars Cukry rozpuszczalne (mg·100 g^{-1} f.m.)	Carotenoids Karotenoidy (mg·100 g^{-1} f.m.)	Nitrates Azotany (mg NO_3^-·kg^{-1} f.m.)	Soluble solids Ekstrakt (°Brix)
Afro F_1	10.34 b	5.05 c	15.11 b-d	393.6 c	8.15 a
Askona F_1	11.47 f	5.76 e	16.18 d	400.8 e	9.03 cd
Broker F_1	11.06 e	5.19 cd	15.48 cd	512.9 g	8.97 c
DZE II F_1	9.70 a	4.43 a	13.55 a	304.9 b	8.07 a
Galicja F_1	10.70 c	5.17 cd	14.03 ab	571.9 h	8.18 a
Karioka F_1	12.46 g	6.22 f	21.02 f	194.7 a	10.02 e
Karotan	11.12 e	5.84 e	14.25 ac	407.7 e	9.20 d
Kongo F_1	10.89 d	5.71 e	15.17 b-d	302.1 b	9.00 cd
Korund F_1	11.08 e	4.77 b	18.67 e	495.3 f	8.92 c
Rumba F_1	10.66 c	5.36 d	16.25 d	337.9 d	8.47 b
Mean – Średnio	10.947	5.351	15.972	392.20	8.800

Carrot is one of the best sources of carotenoids. In a present study, carotenoid content differed significantly among investigated cultivars and ranged between 13.55 and 21.02 mg·100 g^{-1} f.m. (tab. 3), and was the greatest for 'Karioka F_1' and 'Korund F_1'. Cultivars 'DZE II F_1', 'Galicja F_1', 'Afro F_1' , 'Kongo F_1' and 'Broker F_1', similarly like 'Karotan', were characterized by the lowest carotenoid content in roots. The differences in carotenoid content between carrot cultivars were widely documented in literature [Karklelienė et al. 2008, Matějková and Petříková 2010, Fikselová et al. 2010]. Kidmose et al. [2004] found no significant effect of root size on the content of α- and β-carotene in carrot, even though the contents seemed to decrease with increasing root size. In present experiment root length but not weight was positively correlated with carotenoid content. The investigated carrot cultivars were characterized by nitrate content of 194.7–571.9 mg NO_3^-·kg^{-1} f.m. (tab. 3), the lowest for 'Karioka F_1'. Presented values were comparable with reported by Zagórska and Grudzińska [2009], but higher that given by Gajewski et al. [2009].

Carrot cube is a valuable component of frozen vegetable products. The frozen carrot cube quality is mainly determined by low cell sap leakage during defrosting. In a present study, the significant differences were found between investigated genotypes in centrifugal leakage values (tab. 4). 'Karioka F_1', 'Rumba F_1', and 'Askona F_1' were sources of frozen cube of the best quality because of the lowest centrifugal leakage value, testifying the small destruction of cells as a result of frosting. The centrifugal

Table 4. Processing indices of deep frozen and dry carrot cube (means for 2009–2010)
Tabela 4. Parametry przetwórcze suszonej i mrożonej kostki marchwiowej (średnia z lat 2009–2010)

Cultivar Odmiana	Centrifugal leakage Wyciek wirówkowy (%)	Rehydration ratio Współczynnik rehydratacji ($g H_2O \cdot g^{-1}$)	Poured volume Objętość nasypowa ($dm^3 \cdot kg$ d.m.)	Specific volume Objętość właściwa ($dm^3 \cdot kg$ d.m.)
Afro F_1	14.8 cd	4.19 b	2.25 a-c	0.74 bc
Askona F_1	12.3 b	5.40 d	2.19 a	0.75 bc
Broker F_1	15.1 d	5.31 d	2.21 a	0.62 a
DZE II F_1	13.5 bc	5.00 c	2.56 e	0.78 c
Galicja F_1	15.9 de	5.51 d	2.29 a-d	0.69 a-c
Karioka F_1	10.5 a	5.88 f	2.98 f	0.60 a
Karotan	19.8 f	3.65 a	2.23 ab	0.67 ab
Kongo F_1	14.9 cd	4.33 b	2.48 c-e	0.66 ab
Korund F_1	16.6 e	5.67 ef	2.49 de	0.69 a-c
Rumba F_1	12.1 b	4.92 c	2.44 b-e	0.78 c
Mean – Średnio	14.55	4.986	2.413	0.700

Table 5. Coefficients of correlation (r) between biochemical and processing parameters of carrot quality and morphological features, N = 60
Tabela 5. Współczynniki korelacji (r) pomiędzy biochemicznymi i przetwórczymi parametrami jakościowymi marchwi oraz parametrami morfologicznymi, N = 60

Specification Wyszczególnienie	Root length Długość korzenia	Root diameter Średnica korzenia	Root weight Masa korzenia	Core diameter Średnica rdzenia
Dry matter Sucha masa	0.71**	0.42**	0.49**	-0.10
Soluble sugars Cukry rozpuszczalne	0.71**	0.41**	0.55**	-0.05
Carotenoids Karotenoidy	0.48**	0.16	0.23	-0.31
Nitrates Azotany	-0.67**	0.43**	-0.64**	0.29
Soluble solids Ekstrakt	0.60**	0.40*	0.40*	-0.11
Centrifugal leakage Wyciek wirówkowy	-0.60**	-0.38*	-0.52**	0.39*
Rehydration ratio Współczynnik rehydratacji	0.52**	0.42**	0.45**	-0.34*
Poured volume Objętość nasypowa	0.35*	-0.02	0.03	-0.45**
Specific volume Objętość właściwa	0.27	0.39*	0.43**	0.04

* $p \le 0.01$, ** $p \le 0.001$

leakage value was the greatest for 'Karotan' among all investigated cultivars. The free leakage of cell sap was not observed for defrosted cube of all investigated cultivars. The centrifugal leakage was negatively correlated with features characterizing high biological value of carrot, i.e. dry matter, soluble sugars, carotenoids and soluble solids) and positively – with nitrates content. The prediction of the centrifugal leakage value can be made on a basis of the regression equation:

y = 19.7 – 1.10 · "Dry matter (%)" + 0.20 · "Core diameter (% of root diameter)" – – 0.02 · "Root weight (g)", $R^2 = 0.58$.

Rehydration is the process of dry material moistening. In most cases, dried foods are soaked in water before cooking or consumption, thus rehydration is one of the important quality criteria [Sagar and Kumar 2010]. Porosity, capillaries and cavities near the surface enhance the rehydration process. In practice, most of the changes during drying are irreversible and rehydration cannot be considered simply as a process reversible to dehydration [Lewicki 1998]. The high rehydration ratio of dry product is evidence of its

Table 6. Coefficients of correlation (r) between biochemical and processing parameters of carrot quality, N = 60
Tabela 6. Współczynniki korelacji (r) pomiędzy biochemicznymi oraz przetwórczymi parametrami jakościowymi marchwi, N = 60

Specification Wyszczególnienie	Centrifugal leakage Wyciek wirówkowy	Rehydration ratio Współczynnik rehydratacji	Poured volume Objętość nasypowa	Specific volume Objętość właściwa
Dry matter Sucha masa	-0.65**	0.50**	0.30	0.02
Soluble sugars Cukry rozposzczalne	-0.59**	0.37*	0.23	0.07
Carotenoids Karotenoidy	-0.64**	0.52**	0.55**	-0.15
Nitrates Azotany	0.68**	-0.39*	-0.27	-0.30
Soluble solids Ekstrakt	-0.65**	0.50**	0.30	0.02

* $p \le 0.01$, **$p \le 0.001$

possibilities of tissue structure regeneration after drying. In the present study, 1 g samples of dried material absorbed 3,65–5.88 g of water during rehydration (tab. 4). 'Karioka F_1' and 'Korund F_1' showed the greatest capacity for drying, because of the highest values of this parameter, and 'Karotan' – the lowest. Similar values of rehydration ratio were showed for air dried carrot slices at 25°C [Lin et al. 1998]. These results are in agreement with the data showed in Table 4. Cube of cultivars with a less dense structure had higher capacity to absorb water when reconstituted, what was also confirmed by Lin et al. [1998]. The rehydration ratio was directly proportional to dry matter, soluble sugars, carotenoids and soluble solids content in roots, and negatively – to nitrates content.

The following equation was proposed to predict the rehydration ratio with the use of the morphological and chemical features:

y = 1.61 + 0.99 · "Dry matter (%)" – 1.24 · "Soluble sugars (mg·100 g^{-1} f.m." –
– 0.04 · "Core diameter (% of root diameter)" + 0.01 · "Root weight (g)"; $R^2 = 0.53$.

The small poured volume of dried product increase the efficiency of its storage and packaging. The specific volume quantifies dry product porosity and rehydrating properties. Investigated genotypes were characterized by a poured volume of 2.19–2.98 dm^3·kg d.m. and specific volume of 0.60–0.78 dm^3·kg d.m. Dry cube of 'Kongo F_1', 'Korund F_1', 'DZE II F_1' and 'Karioka F_1' had a greater value of poured volume than 'Karotan'. Dry cube of 'DZE II F_1' and 'Rumba F_1' had was characterized by greater specific volume than 'Karotan'. In the present study, poured and specific volume could not be well predicted as the function of morphological and chemical variables because of precision (R^2) below 50%.

CONCLUSIONS

1. The statistically significant differences were found between investigated cultivars in morphological and chemical features, and parameters characterizing minimally processed product quality.
2. 'Karioka F_1' was the cultivar of the highest biological value according to analyzed chemical characteristics, especially high dry matter, carotenoids, soluble sugars and soluble solids content, and low nitrates accumulation.
3. 'Karioka F_1', 'Rumba' F_1, and 'Askona F_1' were sources of frozen cube of the best quality, and 'Karioka F_1' and 'Korund F_1' showed the greatest suitability for drying.
4. Root length and weight *were positively correlated with* dry matter, soluble sugars and soluble solids content, but negatively – with nitrates level.
5. Centrifugal leakage was negatively and rehydration ratio was positively correlated with *the* root length, weight, diameter, and with all analyzed chemical components with the exception of nitrates.
6. Most of the analyzed parameters characterizing processing usefulness of carrot can be predicted on a basis of morphological and chemical features.

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OCENA JAKOŚCI I PRZYDATNOŚCI PRZETWÓRCZEJ WYBRANYCH POLSKICH ODMIAN MARCHWI

Streszczenie. Celem badań była morfologiczna i biochemiczna charakterystyka oraz ocena przydatności przetwórczej odmian marchwi ‘Askona F_1’, ‘DZE II F_1’, ‘Galicja F_1’, ‘Karioka F_1’, ‘Karotan’, ‘Rumba F_1’, ‘Afro F_1’, ‘Broker F_1’, ‘Kongo F_1’ i ‘Korund F_1’. Badania przeprowadzono na Uniwersytecie Rolniczym w Krakowie w latach 2009 i 2010. Analiza cech morfologicznych korzeni pozwoliła na stwierdzenie, że badane odmiany są przydatne do mechanicznego zbioru. Na podstawie analizy parametrów biochemicznych korzeni wytypowano odmiany o wysokiej wartości biologicznej i małej tendencji do akumulacji azotanów. Mrożoną kostkę najlepszej jakości, o najmniejszym wycieku wirówkowym, otrzymano z korzeni odmian ‘Karioka F_1’, ‘Rumba F_1’ i ‘Askona F_1’. Odmiany ‘Karioka F_1’ i ‘Korund F_1’ cechowała najlepsza przydatność do produkcji suszu, oceniona na podstawie wartości współczynnika rehydratacji. Parametry charakteryzujące jakość minimalnie przetworzonej kostki marchwiowej były skorelowane z cechami morfologicznymi i biochemicznymi korzeni. Zaproponowano równania predykcji pozwalające prognozować parametry charakteryzujące jakość minimalnie przetworzonej marchwi jako funkcję niezależnych morfologicznych i biochemicznych zmiennych.

Słowa kluczowe: *Daucus carota*, przetwórstwo, karotenoidy

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