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COMPARISON OF THE CHEMICAL COMPOSITION AND MORPHOLOGICAL CHARACTERISTICS OF DIFFERENT CARROT VARIETIES

Vladimír Sitkey[1], Iveta Čičová[2], Peter Dočolomanský[1], Michaela Havrlentová[2], Eva Ivanišová[3,4], Elena Belajová[5]*

Address(es):
[1] Axxence Slovakia s.r.o., Mickiewiczova 9, Bratislava, Slovakia, SK-811 07.
[2] National Agricultural and Food Centre, Research Institute of Plant Production, Bratislavská 122, Piešťany, Slovakia, SK-921 01.
[3] Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Institute of Food Sciences, Tr. A. Hlinku 2, Nitra, Slovakia, SK-949 76.
[4] Slovak University of Agriculture in Nitra, Food Incubator SUA in Nitra s.r.o., AgroBioTech Research Centre, Tr. A. Hlinku 2, Nitra, Slovakia, SK-949 76.
[5] National Agricultural and Food Centre, Food Research Institute, Priemyselná 4, P. O. Box 31, Bratislava, Slovakia, SK-824 75.

*Corresponding author: eva.ivanisova@uniag.sk

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ABSTRACT

Carrot (*Daucus carota* L.) is a globally significant root vegetable, rich in bioactive and nutritional compounds. Carrot is a crop with a wide range of phenotypic variability including colour, shape, size, and other characteristics. The aim of this work was to determine and compare selected morphological traits and chemical composition of 24 carrot varieties grown under open field conditions in Slovakia. Altogether, 11 qualitative characteristics and 6 quantitative parameters were evaluated. The carrot roots were also analysed for essential chemical constituents including reducing sugars (fructose, glucose, saccharose), carotenoids, dietary fibre, dry matter, ash, and mineral compounds. A wide range of diversity in morphological characteristics and chemical composition indicates a high variability of studied varieties. The root length ranged from 59 to 205 mm, root diameter varied from 17.7 to 39.0 mm and root weight ranged from 21.0 to 74.8 g. Based on the measurement results, saccharose was the dominant sugar ranging from 1.89 to 4.67 g.100 g^{-1} of fresh weight, carotenoid content varied from 85.94 to 374.24 μg.g^{-1} of fresh weight, the amount of dietary fibre ranged from 25.67 to 36.02% of dry matter**.** Considerable differences were also observed in the content of macro and microelements [mg.100 g^{-1}] ranging as follows: P (17.5 - 52.0), K (110.0 – 337.0), Na (65.9 – 186.0), Fe (0.324 – 3.340), Cu (0.042 – 0.126), Zn (0.152 – 0.945) and Mn (0.062 – 0.189). The presented results can provide useful information for carrot growers and consumers in terms of morphological characteristics as well as the chemical composition of individual carrot varieties.

Keywords: carrot, chemical composition, *Daucus carota,* morphological characteristics

INTRODUCTION

Carrot (*Daucus carota* L.) belongs among the most valuable root vegetable crops cultivated and consumed throughout the world due to its pleasant flavour and taste, good digestibility and rich content of nutrients and bioactive compounds **(Ahmad *et al.*, 2019)**. Carrot roots are also one of the most reliable, affordable, and easy-to-handle biocatalysts for the enantioselective reduction of prochiral ketones, a widely used method for the preparation of chiral alcohols **(Costa and Omori, 2017)**. According to **FAOSTAT (2023)**, the global production of carrots (combined with turnips) reached 41.6 million tons in 2021, with China's share of 43.6%. Other important producers were Uzbekistan with a share of 7.5% and the United States of America with a share of 3.4%. Carrot consumption plays a positive role in the prevention of various health complications **(Bolton *et al.*, 2020).** In addition to the traditional culinary uses of raw and cooked carrots, this vegetable can be commercially processed into nutritional products such as juice, concentrate, dried powder, canned food, etc. Carrot pomace containing about 50% of *β*-carotene could profitably be utilized for the supplementation of products like cake, bread, biscuits, and the preparation of several types of functional products **(Sharma, *et al*., 2012)**.
Carrot is a biennial crop related to the Apiaceae Lindl. family, cultivated since ancient times. The plant probably originated in Iranian plateau, then it spreads to all Asia, Europe, North Africa, and the Mediterranean region **(Stolarczyk and Janick, 2011; Sharma and Sharma, 2020)**. The earliest cultivated carrots were yellow and purple-fleshed cultivars. Currently, orange carrots are becoming more popular and more widely cultivated in the world. The first orange kitchen varieties were developed during 17th –18th century in the Netherlands **(Stolarczyk and Janick, 2011)**. The length of vegetation period depends on the used variety. Fast-growing cultivars mature within 90 days of sowing the seed, while slower-maturing cultivars need a longer ripening period of 120 days (**Shakheel *et al.*, 2017**).
There is significant diversity in both phenotype and chemical composition within different carrot genotypes **(Luby *et al.*, 2016; Bhandari, *et al.*, 2023)**. Carrots are found in many colours, including white, yellow, orange, red, purple and deep purple/black **(Sharma and Sharma, 2020; Iorizzo *et al.*, 2020; Sun, *et al.*, 2009; Montilla, *et al.*, 2011)**. Such alteration of root colour is associated with the accumulation of various combinations of anthocyanin and carotenoid pigments. Purple or black carrots are rich in anthocyanins, orange carrots contain high levels of β-carotene and α-carotene (both provitamin A carotenoids), red carrots are rich in lycopene, yellow carrots predominantly accumulate xanthophylls (especially lutein) and white-rooted carrots with nearly undetectable levels of the previous pigments **(Valerga, *et al.*, 2023)**. Carotenoid content in different genotypes of carrot varies significantly in the outer and inner tissues and is highly correlated with root colour **(Bhandari, *et al.*, 2023)**. Carrots, as a source of anthocyanins, have the potential to produce natural colorants, the global market of which was expected to grow more than 7% annually between 2017 and 2022 **(Iorizzo *et al.*, 2020)**. Total sugar content in crops is a function of genetic, nutritional, environmental, and developmental factors **(Nookaraju *et al.*, 2010)**. Sweetness, depending on the level of soluble sugars such as glucose, fructose and saccharose, is a major determinant of fruit and vegetable quality and marketability **(Kjellenberg, 2007)**. Carrot roots also contain high quantities of other bioactive compounds like vitamins, antioxidants, polyphenols, mineral compounds, and dietary fibres **(Singh, *et al*., 2021)**. Carrot phytochemicals can play a significant role in the prevention and degenerative disorders like diabetes, cancer, and cardiovascular diseases **(Sharma *et al.*, 2012; Sharma and Sharma, 2020)**.
The main objective of this study was to examine and compare 24 carrot varieties in terms of phenotypic traits and chemical composition, such as the content of reducing sugars (saccharose, glucose fructose), fibre, carotenoids, micro- and macroelements, to obtain a more comprehensive view on this topic.

MATERIALS AND METHODS

Field experiments

The plant material was grown on the field experimental plots of the Research Institute of Plant Production - National Agricultural and Food Centre, Piešťany, Slovakia (RIPP). The latitude and longitude of the experimental field were 48° 35' 6.4" N, 17° 48' 46" E; altitude of 163 meters. This location belongs to the maize production area, with mild winters and warm summers. The overall character of the climate is slightly variable. The climatic region is characterized as warm, slightly dry, basin-like, the sum of temperatures above 10 °C is 3000–2500 °C. According to the long-term observations, the average annual temperature is 9.2 °C and the average annual precipitation is 595 mm. The soil on the plot is clayey-loamy, with a content of clayey parts of around 50%, with a humus content in the topsoil of 18 – 20 g.kg^{-1}, with a low phosphorus content and a medium supply of humus and nitrogen, and with a neutral soil reaction. The depth of topsoil is approx. 300 mm, over the layer of the gravel. The main components of the soil, determined by the Agrochemical Laboratory of RIPP, were as follows: dry matter 97.09%; pH 7.04; *phosphorus* 63.8 mg.kg^{-1}; total nitrogen 0.209%; organic carbon 2.107%; humus 3.529%; magnesium 716 mg.kg^{-1}, calcium 4066 mg.kg^{-1}.

Plant material

The seed material used in the experiments consisted of twenty-four carrot varieties commercially available and grown in Slovakia. Basic information on carrot varieties and seed suppliers is summarized in Table 1.

Table 1 Characterization of cultivated varieties

Sample No.	Variety	Earliness	Type	Supplier	Supplier code
1	Marion F1	early	Nantes	Dobrá semena	2195
2	Cascade F1	mid-early	Chantenay	Dobrá semena	2211
3	Naomi	early	Nantes	Moravoseed Slovakia	2657
4	Aron F1	very early	Nantes	Dobrá semena	2152
5	Katrin	mid-early	Chantenay	Moravoseed Slovakia	3263
6	Karotela	early	Nantes	Moravoseed Slovakia	2976
7	Nantes 3	early	Nantes	Semenárstvo s.r.o.	12203
8	Stupická k rychlení	very early	Nantes	Osiva Moravia	10419
9	Chamare	mid-early	Chantenay	SEMO	2231
10	Calibra F1	very early	Nantes	SEMO	2260
11	Lenka	early	Nantes	SEMO	2222
12	Kráska	mid-early	Berlicum	SEMO	2207
13	Jitka F1	early	Berlicum	SEMO	2262
14	Vanda	early	Nantes	SEMO	2203
15	Maxima F1	late	Danvers	SEMO	2271
16	Nectar F1	early	Nantes	SEMO	2209
17	Olympus	late	Flakkeer	Dobrá semena	2207
18	Bolero F1	early	Berlicum/Nantes	Vilmorin	632
19	Maestro F1	mid-late	Nantes	Vilmorin	PP34
20	Olympia	late	Flakkeer	Semenárstvo s.r.o.	12205
21	Sugarsnax 54 F1	mid-late	Nantes x Imperator	Garden Seeds BV	0476
22	Tendersweet	early	Imperator	Farma Lekvárik	zel5ts
23	Purple Elite F1	early	Imperator	Garden Seeds BV	0481
24	Katlen	late	Berlicum	SEMO	2247

The carrot seeds were sown in the experimental site on 7th of April 2022. The plants were grown under open field conditions, collected manually at a at a full maturity stage and immediately used for experiments. Based on the suppliers' information, a more detailed description of the tested varieties is as follows:

Marion F1 is an early Nantes type, root length 15 – 17 cm, cylindrical shape having blunt tip, rich orange colour with no green shoulders, vegetation period 90 – 95 days. **Cascade F1** is mid - early hybrid of Chantenay type, root length up to 22 cm that does not crack in the ground, conical shape, orange colour, vegetation period of 90 to 130 days. One of the tastiest carrots, juicy and sweet, very balanced in shape and size. **Naomi** is an early Nantes-type variety, suitable for early spring and field cultivation, root length 16 – 18 cm, cylindrical shape with a fine, smooth surface, orange colour, vegetation period of 90 days, the top of root does not turn green or purple. The pulp is sweet, soft and intensely orange-coloured. **Aron F1** is a very early carrot hybrid variety similar to Nantes type, root length up to 10 cm having an unusual half-long stumpy shape, cylindrical with a blunt tip, orange-coloured, vegetation period of 75 to 85 days, the tops do not turn green or purple. **Katrin** is a mid-early carrot variety of Chantenay type, root length 10 – 13 cm, conical with a blunt tip with length, orange colour, vegetation period is 125 –130 days. **Karotela** is an early variety of the Nantes type, root length up to 14 cm, conical, having an intense orange colour, vegetation period of 100 to 110 days. **Nantes 3** is mid-early Nantes-type, root length 16 – 20 cm, cylindrical shape, intense orange colour, vegetation period of 115 to 125 days. It is a traditional, very high-quality variety intended for direct consumption from summer to autumn and for industrial processing. **Stupická k rychlení** is an early variety of Nantes type, root length 13 – 15 cm, intense orange colour, vegetation period 93 – 98 days. It is one of the best early varieties of Nantes type. **Chamare** is a mid-early variety of Chantenay type, root length approximately 10 cm, robust, short and wide, broadly conical in shape and bluntly pointed, intense orange skin and darker medium red pulp, vegetation period starts on average from 70 days after sowing. It belongs to a less traditional variety, suitable for juicing and fresh market. **Calibra F1** is a very early carrot hybrid of Nantes type, root length 18 – 23 cm, slightly conical shape, with high resistance for bundling, orange colour, vegetation period 90 days. **Lenka** is an early variety of the Nantes type, root length 15 – 18 cm, cylindrical, longer, and thinner with blunt tip, good orange colour intensity, vegetation period of 90 to 125 days. **Kráska** is mid-early hybrid variety of Berlicum type, root length 18 – 20 cm, long, thin cylindrical shape with blunt tip, good orange colour, vegetation period 134 days. **Jitka F1** is an early, high-yielding hybrid carrot of Berlicum type, root length 18 – 22 cm, cylindrical, smooth blunt roots of orange red colour, vegetation period 135 days. Recommended for fresh consumption. **Vanda** is an early variety of Nantes type, root length 16 – 20 cm, cylindrical, blunt roots of bright orange colour, vegetation period 115 – 120 days. **Maxima F1** hybrid of Danvers type is an extra-large, late, storable carrot for industrial processing. The conical root is 25 – 30 cm long, vegetation period 150 – 180 days. This variety stands out for its high yield and uniformity, it has a high dry matter content and healthy, non-green tops. Despite its size, it provides a delicious and sweet pulp. **Nectar F1** is an early hybrid of Nantes type, root length 18 – 20 cm, cylindrical, blunt-ended, orange colour, vegetation period 105 – 120 days. Flavourful, long and are straight and uniform. **Olympus** is late, high-yielding variety of Flakkeer type, root length 23 – 25 cm, long, conical, orange-red colour, vegetation period 160 – 170 days. Intended for direct consumption, canning and especially for long-term storage. **Bolero F1** is a mid-early hybrid of Berlicum/Nantes variety, root length 18 – 20 cm, cylindrical, bright-orange colour, vegetation period of 110 to 120 days. The pulp contains approximately 8% sugar and 12% dry matter. Due to its excellent storability, it belongs to the most popular carrot varieties. **Maestro F1** is medium to late variety of Nantes type, root length 18 – 20 cm, cylindrical shape with a blunt tip, bright-orange colour, vegetation period is 120 – 130 days. **Olympia** is a very late variety of Flakkeer type, root length 16 cm, almost cylindrical, narrowed at the bottom, orange-red colour, harvest maturity is after 180 – 185 days. It is a very fertile variety with a high content of sugars and *beta*-carotene. **Sugarsnax 54 F1** is an extra sweet variety of Imperator type, root length 25 cm, long, tapered, cylindrical, contains high levels of beta carotene giving them a rich orange colour, harvest maturity after 63 days. **Tendersweet** is an early Imperator type variety, root length 22 – 25 cm, straight, tapering, deep orange colour, the period from germination *to technical ripeness is after 75 days*. **Purple Elite F1** is an early hybrid variety of Imperator type, root length 18 cm, longer, slender roots with a sharp taper from top to bottom, with a deep purple colour on the outside and attractive orange flesh on the inside, enabling the anthocyanins to be stored well, harvest maturity is after 75 days. **Katlen** is a late to very late variety of Berlicum type, root length 16 – 17 cm, long mostly, cylindrical, having a blunt tip, medium intense orange external and internal colouring, vegetation period of 160 to 170 days. This variety is intended for autumn cultivation suitable for direct consumption, industrial processing and for long-term storing.

Evaluation of qualitative and quantitative morphological parameters

The qualitative traits evaluated in this study included green colour intensity of leaf, anthocyanin colouration of petiole, root shape on longitudinal section, root surface, root shape, root type grouping, root tapering, stem hairiness, flesh colour distribution in transverse section, stem growth habit and root branching. These parameters were evaluated visually - according to the international **classificator UPOV (2004)** and descriptor **IPGRI (1998)**.

To determine quantitative parameters, five plants were selected, and the following traits were evaluated: root length (mm), root diameter (mm), root weight (g), leaf length (mm), width of crown (mm), number of leaves per plant. The measured values represent mean ± standard deviation (n = 5).

Chemical Analysis

Uniform roots (five per variety) were selected and washed with tap water to remove soil and other impurities, and representative samples from each set of five roots were taken for subsequent analysis.

Chemicals

All standards and basic chemicals were purchased by Merck.

Determination of reducing sugars (glucose, fructose, saccharose)

Carrot roots were homogenized in a high-speed blender (Retsch Grindomix GM 200, Haan, Germany) at 8000 rpm for 20 seconds and 5.0 to 7.0 g of homogeneous sample was weighed into a plastic centrifuge tube with a cap and 15 mL of deionized water was added. The content was mixed on an orbital mixer OS-20 (Biosan, Riga, Latvia) at 250 rpm for 10 min and then in an ultrasonic bath UC 005 AJ1 (Tesla, Praha Strašnice, Czechoslovakia) for another 10 min. The sample was finally centrifuged at 14,000 rpm (model 2-16KC, Sigma Laborzentrifugen, Osterode, Germany) for 10 min. An aliquot volume of the supernatant was filtered through a syringe microfilter (regenerated cellulose/polypropylene, pore size of 0.45 μm, 13 mm diameter) and analysed by an HPLC model PU 4003 (Pye Unicam, Cambridge, UK) equipped with a refractometric detector RID-10A (Shimadzu, Tokyo, Japan). Chromatographic separation of sugars took place following conditions: Column Kromasil 100-5NH2 250 mm x 4.6 mm i.d. (EKA Chemicals, Bohus, Sweden); mobile phase acetonitrile: water, 80:20, v/v; mobile phase flow rate 1.35 mL.min^{-1}; sample injection 20 μL; column temperature laboratory; RID cuvette temperature 40 °C. Each sample was processed in this procedure at 2 different weights. The results were evaluated by the software CSW version 1.7. (DataApex, Prague, Czech Republic) according to the internal calibration procedure and are expressed as an arithmetic mean with the corresponding standard deviation in g.100 g^{-1} of fresh product. To construct the calibration curve, the following stock solution of standards were used: fructose 10.112 g.L^{-1}; glucose 10.052 g.L^{-1}; saccharose 10.054 g.L^{-1}.

Statistical analysis

Each sample was analysed minimally in duplicate and results are reported as mean concentration ± standard deviation. Excel XP Software (Microsoft, Redmond, Washington, USA) was used for the construction of calibration graphs as well as for the determination of differences between means by analysis of variance (ANOVA). In this analysis, the difference was taken as significant at $p < 0.05$ (95% confidence level).
Standard deviation of the individual sugar content (fructose, glucose, and saccharose) was calculated using the formula:

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^{n}(\bar{x}-x_i)^2}{n-1}} \quad (1)$$

where: σ_x – standard deviation; n – the number of data points in the data set; x_i – value of the ith point in the data set; $\bar{x}$ – the mean value of the data set.

Standard deviation of the total sugar content (expressed as the sum of fructose, glucose, and saccharose concentrations) was calculated using the formula:

$$\sqrt{\sigma_F^2 + \sigma_G^2 + \sigma_S^2} \quad (2)$$

where σ_T is standard deviation of the total sugar content and σ_F, σ_G, σ_F are standard deviations of individual sugars (fructose, glucose and saccharose).

Measurement of Brix in carrot juice

Juicer Delos, model SE-1 (The House of Eden Food, Farnham, UK) was used for juice preparation. The carrot juice samples were analysed for ºBrix, immediately after the carrots were juiced, using an ATC-1E hand-held refractometer (ATAGO, Tokyo, Japan). This procedure was performed in triplicate for each sample of carrot juice.

Total carotenoid content

Total carotenoid content was determined according to **STN 56 0053: 1986** at the wavelength of the absorption maximum for the dominant carotenoid which was β-carotene. All measurements were repeated two times.
An amount of 1 g of sample was homogenized in the mortar with sea sand, and repeatedly extracted with 10 mL acetone until the sample became colorless. The extract was filtered using a Whatman filter paper and used for the detection of total carotenoid content.
Petroleum ether was pipetted into a separating funnel with teflon stopcock. The acetone extract of sample and distilled water were added by flowing along the walls of the funnel. The mixture was allowed to separate into two phases, and the aqueous phase was discarded. The petroleum ether phase was washed 2 times with distilled water to remove residual acetone. The petroleum ether phase was collected in a 50 ml volumetric flask by passing the solution through a small funnel containing 5 g of anhydrous sodium sulfate to remove residual water. The absorbance of sample at 445 nm was detected spectrophotometrically. The volumetric flask was then made up to volume with petroleum ether, and the total carotenoid content was determined from the molar absorption coefficient of β-carotene.
The concentration (μg.g^{-1}) of carotenoids was calculated according to the following formula:

$$\text{TCC } (\mu g.g^{-1}) = \frac{A.r.V.10}{E.n} \quad (3)$$

where: TCC - total carotenoid content; A - absorbance at 445 nm; r - sample dilution; E - molar absorption coefficient $E_{1cm}^{1\%}$ = 2620; n - sample weight

Determination of total dietary fibre

The total dietary fibre was analysed according to the modified method for determining total dietary fibre in accordance with **AACC method 32-07 (AACC 1991)** and **AOAC method 991.43 (AOAC 2017)**. For the analysis of total dietary fibre by means of the enzymatic-gravimetric method, we used the kit purchased by Megazyme (Wisklow, Ireland). This method is applicable to cereal grains, fruits and vegetables, cereal and fruit and food products.

The dry matter determination

The dry matter content was determined by drying sample at 105°C until constant weight was attained, using ADAM, model AMB 50, Moisture Determination Balance (Adam Equipment, Milton Keynes, UK).

Determination of ash content

The ash content was determined by gravimetric method as the residue on ignition, after burning the dry sample in a muffle furnace A9X (ANETA, Trenčianska Teplá, Slovakia), at 550 ºC, expressed as a percentage by mass of the dried sample.

Determination of metal contents

The metal contents (Cu, K, Na, Mn, Fe, Zn) were determined using flame atomic absorption spectrometer AAS Varian AA240FS, GTA120 (Varian Medical Systems, Palo Alto, California, USA), after mineralization of the sample by boiling in concentrated nitric acid and 30% hydrogen peroxide.

Determination of total phosphorus

The phosphorus content was determined by the spectrophotometric method **(Boltz and Mellon, 1948)**, using a Skalar Segmented flow analyser SUN PLUS (Skalar Inc., Breda, The Netherlands), after sample mineralizing by boiling in a mixture of concentrated sulfuric acid with selenium and 30% hydrogen peroxide. The content of phosphorus in mineralizate was determined by measuring the intensity of molybdenum blue coloration after the reduction of ammonium molybdate phosphate.

RESULTS AND DISCUSSION

Physical parameters

As weather conditions influence growth, maturity and quality of carrots, the temperatures and precipitations were recorded during the monitored year 2022.

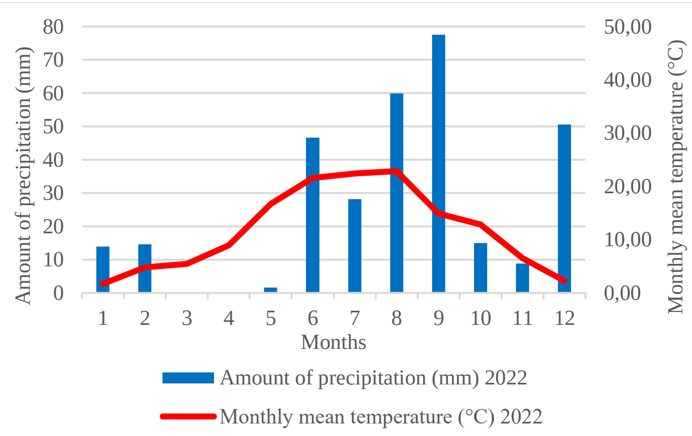

Figure 1 The amount of precipitations and monthly mean temperatures during 2022

The corresponding data are presented in the Figure 1. The results show that the course of temperatures was favourable for the growth of carrots, as the optimum temperatures for achieving good carrot quality range from 16 to 21 ºC **(Tesfaendrias *et al*., 2011)**, which will ensure that the roots also develop the best colour and flavour.

Evaluation of the morphological characteristics

In the Table 2 are presented the results of the morphological evaluation of 24 carrot varieties in 2022.

Table 2 Morphological parameters of different varieties of *Daucus carota* in 2022

No.	Variety	Root length [mm]	Root diameter [mm]	Root weight [g]	Leaf length [mm]	Width of crown [mm]	Number of leaves per plant	Anthocyanin colouration of petiole anthocyanin
1	Marion F1	146.0±21.6	29.7±2.0	66.4±14.9	316.0±23.5	14.25±2.99	8.2±0.6	1
2	Cascade F1	109.0±23.7	35.2±5.2	55.5±12.4	243.0±66.5	8.50±1.29	7.0±1.1	1
3	Naomi	115.0±36.8	24.5±6.2	45.9±14.9	283.0±51.7	10.50±1.29	7.0±1.7	1
4	Aron F1	86.0±15.1	39,0±3.3	51.0±8.9	254.0±16.7	11.50±2.65	7.4±1.5	1
5	Katrin	93.0±16.7	30.2±1.9	47.5±8.5	302.0±22.8	12.00±2.94	10.0±1.6	1
6	Karotela	127.0±22.6	30.3±2.0	37.4±6.7	388.0±31.9	12.00±2.16	8.8±1.5	1
7	Nantes 3	104.0±18.0	18.7±1.4	31.1±5.5	312.0±33.0	6.25±1.26	5.8±1.5	1
8	Stupická	90.7±28.2	23.2±2.3	25.8±8.0	228.0±59.3	5.75±1.29	6.6±2.3	1
9	Chamare	59.0±12.2	27.3±5.1	24.7±5.1	200.0±22.6	4.25±1.26	5.2±1.4	1
10	Calibra F1	112.0±22.9	17.7±2.3	25.2±5.3	258.0±48.7	7.50±1.91	7.4±1.2	1
11	Lenka	116.0±13.6	21.3±4.6	26.2±3.1	243.0±29.9	8.50±2.08	7.6±1.4	1
12	Kráska	122.0±28.6	18.5±2.4	21.0±5.0	247.0±56.5	7.25±1.89	7.4±2.1	1
13	JitkaF1	119.0±13.5	28.3±3.4	37.8±4.3	206.0±11.9	10.25±2.87	8.4±1.7	1
14	Vanda	114.0±27.3	26.8±4.5	42.4±10.1	260.0±31.6	8.50±1.29	7.6±0.5	1
15	Maxima F1	152.0±25.2	35.2±2.3	67.1±11.4	248.0±34.0	12.00±2.94	7.4±1.9	1
16	Nectar F1	140.0±19.9	25.2±5.5	49.8±7.5	227.0±35.6	10.50±1.29	7.6±1.5	1
17	Olympus	136.0±18.6	28.8±1.2	41.9±5.9	236.0±40.7	10.25±0.96	11.0±2.3	1
18	Bolero F1	126.0±18.4	20.5±6.4	34.1±5.2	277.0±35.6	12.00±2.16	10.4±2.4	1
19	Maestro F1	130.0±22.8	25.7±2.9	26.7±4.8	269.0±36.5	6.25±0.96	9.8±2.1	9
20	Olympia	152.0±27.3	26.3±3.1	32.5±9.9	287.0±29.8	7.25±1.26	8.8±2.4	1
21	Sugarsnax54 F1	182.0±21.6	24.5±3.1	41.5±4.9	259.0±22.6	9.75±0.96	9.2±2.3	1
22	Tendersweet	166.0±18.4	29.8±2.2	71.2±8.3	274.0±11.0	8.75±1.71	7.8±0.8	1
23	Purple Elite	205.0±28.3	34.2±4.4	74.8±10.3	351.0±16.7	11.50±1.29	9.4±1.5	9
24	Katlen	147.0±16.9	28.0±1.2	45.0±5.5	348.0±28.6	11.50±1.29	8.6±1.6	1

Table 2 Morphological parameters of different varieties of *Daucus carrota* in 2022 (continued)

No.	Variety	Green colour intensity of leaf	Root shape on a longitudinal section	Root surface	Root shape	Root type grouping	Root tapering	Stem hairiness	Flesh colour distribution in transverse section	Stem growth habit
1	Marion F1	5	4	4	4	3	3	3	2	7
2	Cascade F1	5	3	1	3	4	3	3	3	7
3	Naomi	5	5	3	4	3	3	3	2	7
4	Aron F1	5	3	1	3	3	1	3	2	7
5	Katrin	5	3	3	3	4	1	3	3	7
6	Karotela	5	5	3	5	3	3	3	3	7
7	Nantes 3	5	4	3	5	3	1	5	3	7
8	Stupická	5	3	1	3	3	1	5	2	7
9	Chamare	5	3	3	3	4	1	5	2	7
10	Calibra F1	5	4	3	5	3	1	5	2	7
11	Lenka	5	4	3	5	3	1	5	2	7
12	Kráska	5	5	1	5	7	1	5	2	3
13	JitkaF1	5	4	1	3	7	1	5	2	7
14	Vanda	5	4	1	4	3	1	3	2	7
15	Maxima F1	5	4	3	3	5	1	5	2	7
16	Nectar F1	5	4	1	4	3	1	5	2	7
17	Olympus	5	4	3	5	8	1	5	3	7
18	Bolero F1	5	4	3	5	7	1	5	2	7
19	Maestro F1	5	4	1	4	3	1	5	2	7
20	Olympia	7	4	3	5	8	1	5	2	7
21	Sugarsnax54 F1	5	4	1	5	3x1	1	5	2	7
22	Tendersweet	5	5	1	5	1	3	5	2	7
23	Purple Elite	7	4	1	5	1	3	5	3	7
24	Katlen	7	4	3	5	7	1	5	2	7

<u>Leaf intensity of green colour</u>: 3 – light, 5 – medium, 7 – dark; <u>Leaf anthocyanin colouration of petiole</u>: 1 – absent, 9 – present; <u>Root shape in longitudinal section</u>: 1 – circular, 2 – obovate, 3 – obtriangular, 4 – narrow obtriangular, 5 – narrow obtriangular/to narrow oblong, 6 – narrow oblong; <u>Root surface</u>: 1 – smooth, 2 – coarse, 3 – dimpled, 4 – ridged; <u>Root shape</u>: 1 – round, 2 – obovate, 3 – obtriangular, 4 – oblong, 5 – tapering; <u>Root type grouping</u>: 1 – Imperator, 2 – Gold Pak, 3 – Nantes, 4 – Chatenay, 5 – Danvers, 6 – Amsterdam, 7 – Feonia-Berlicum, 8 – Flakker, 9 – Paris; <u>Root tapering</u>: 0 – absent, 1 – slight, 2 – intermediate, 3 – acute; <u>Stem hairiness</u>: 3 – sparse, 5–intermediate, 7 – dense; <u>Flesh colour distribution in transverse section</u>: 1 – indistinctly uniform throughout outer and inner cores; 2 – colour in two distinct outer and inner cores; 3 – colour radially distributed in stellate pattern; 4 – colour radially distributed from inner core; <u>Stem growth habit</u>: 3 – prostrate, 5 – semierect, 7 – erect; <u>Leaf division</u>: 3 – fine, 5 – medium, 7 – coarse;

The root length of individual varieties ranged from 59 mm (Chamare) to 205 mm (Purple Elite F1). The root diameter ranged from 17.7 mm (Calibra F1) to 39.0 mm (Aron F1). The root weight ranged from 21.0 g (Kráska) to 74.8 g (Purple Elite F1). The leaf length ranged from 200 mm (Chamare) to 388 mm (Karotela). In addition to the size, the Purple Elite F1 variety was very interesting with its deep purple skin contrasting nicely with the beautiful yellow core, and the bright colouring of the leaves. These findings are following the results of other authors. **Sharma and Sharma (2020)** concluded that the root weight observed in orange carrots was 84.14 g and root length 16.53 cm. **Tadele (2016)** reported range of fresh root weight of 73.33 – 182.33 g and the root length from 11.57 to 20.3 cm, significantly influenced by intra- row spacing. **Ali *et al*. (2021)** mentioned range of fresh root weight from 104 to 185 g and root length from 13.8 to 25.0 cm. Width of crown ranged from 4.25 (Chamare) to 14.25 mm (Marion F1). **Kumar *et al*. (2011)** reported a mean value of 15.79 mm for crown diameter of 30 carrot genotypes representing different European types. The leaf length varied from 200 mm (Chamare) to 388 mm (Karotela). **Kiran *et al*. (2022)** reported leaf length ranged from 15.7 to 17.33 cm without fertilizing and from 36.77 to 38.17 cm using combination of NPK and organic manure.

According to the descriptors used in this study, *green colour intensity* of *leaf was mainly medium, excluding varieties* Olympia, Purple Elite F1 and Katlen with dark intensity of green colour of leaf. Leaf anthocyanin coloration of petiole was mostly absent in the observed varieties, except for the varieties Purple Elite F1 and Maestro F1. Root shape on a longitudinal section was mainly obtriangular, narrow obtriangular, and narrow obtriangular/to narrow oblong. Regarding the root surface, a various appearance was observed: smooth, coarse, dimpled, and ridged. The root shape was obtriangular, oblong, or tapering. The root type grouping of the studied varieties was very diverse and included Imperator, Nanntes, Chatenay, Danvers, Feonia-Berlicum and Flakker types. Root tapering was mostly slight, or acute. The average number of leaves per plant ranged from value 5 to 11. The hairiness observed on the stems was mostly intermediate or sparse. The stem growth habit scale was erect in all varieties, except for Kráska variety with a prostrate habit. The flesh colour distribution in transverse section had 2 variants, either it was the colour of two different outer and inner cores, or the colour radially distributed in a stellate pattern.

Figure 2 illustrates the evaluation of the flesh colour distribution in transverse section of 24 tested carrot root varieties.

The results show that there was a wide range of variability in almost all traits, except for no occurrence of branching and top greening.

Figure 2 Flesh colour distribution in transverse section of 24 tested carrot root varieties.

Evaluation of the chemical composition of carrot varieties

Sugar content

The content of fructose, glucose and sucrose as basic components of sugars was determined in 24 carrot varieties. In addition, the refraction of carrot juice was measured to find out the possibility of predicting the reducing sugar content based on the refraction. In **Table 3** are presented the results of the analysis.

The content of individual sugars ($g.100\ g^{-1}$) ranged from 0.296 (Karotela) to 2.009 (Katlen) for fructose; from 0.325 (Marion F1) to 2.504 (Katlen) for glucose; and from 1.888 (Naomi) to 4.674 (Bolero F1) for saccharose. The total content of reducing sugars expressed as the sum of fructose, glucose and saccharose content ranged from 3.509 (Naomi) to 8.131 (Katlen). The results showed that saccharose was the dominant sugar, which follow the findings of **Yusuf *et al.* (2021)**, who reported ranges of 0.25 – 3.78 $g.100\ g^{-1}$ for fructose, 0.79 – 4,09 $g.100\ g^{-1}$ for glucose and 0.31 – 9.68 $g.100\ g^{-1}$ for saccharose. **Augspole *et al*. (2012)** reported range ($g.100\ g^{-1}$) from 4.03 to 7.99 for total sugars, 1.11 – 1.40 for fructose, 1.12 – 1.87 for glucose and 1.81 – 4.82 for saccharose. Other authors declared lower values of sugar content. **Sharma and Sharma (2020)** reported the content of reducing sugars of 2.04 ± 0.07% and 2.10 ± 0.04% for orange carrot and for purple carrot, respectively. **Benamor (2020)** determined the individual sugar contents on a dry weight basis as follows: 96.9 – 245.47 $mg.100\ g^{-1}$ for glucose, >119 – 252.03 $mg.100\ g^{-1}$ for fructose and 46.2 – 123.95 $mg.100\ g^{-1}$ for saccharose. The total sugar content expressed as the sum of the individual sugars, varied from 3.509 to 8.131 $g.100\ g^{-1}$ of dry weight. **Bajaj *et al.* (1980)** reported the content of reducing sugars ranged from 0.67 to 9.93%.

According to gained results, the variety Katlen contains the highest content of reducing sugars (8.131 $g.100\ g^{-1}$), followed by varieties Vanda (7.189 $g.100\ g^{-1}$), Maestro F1 (6.853 $g.100\ g^{-1}$) and Sugarsnax 54 F1 (6.704 $g.100\ g^{-1}$). Purple Elite F1 variety demonstrated also high content of total sugar 6.305 $g.100\ g^{-1}$, but it is much less compared to 11.24 $g.100\ g^{-1}$ published by **Yusuf *et al.*** (2021). The lowest sugar content (below 4.0 $g.100\ g^{-1}$) was found in varieties Naomi, Cascade F1, Calibra F1, Marion F1 and Katrin. This work did not confirm the high sugar content of 8.2% in the Cascade F1 variety reported by **Ayupov *et al.* (2019)**, since only 3.169 $g.100\ g^{-1}$ was determined.

Table 3 also shows the results of measuring ºBrix in fresh carrot juice. The measured values ranged from 8.85 to 12.05 ºBrix, which is a slightly larger interval compared to the work of **Stefl (2017)**, who reported values from 8.3 to 10.2 ºBrix. Comparing the results obtained from ºBrix measurements and HPLC analyses of the sugar content, we can conclude that the ºBrix corresponds only approximately to the true sugar content, and therefore the measurement of refraction can only be used as an indicative method for estimating the sugar content. For example, the lowest values of both, sugar content (3.509 $g.100\ g^{-1}$) and ºBrix (8.85) were measured for the Naomi variety, but inconsistently, the highest ºBrix of 12.05 was measured for the Karotela variety, which contained only 4.383 $g.100\ g^{-1}$ of reducing sugars. Similar discrepancies were also found in the Kráska variety, in which a high ºBrix value of 12.0 was measured, but it contained only 5.113 $g.100\ g^{-1}$ of reducing sugars. Based on previous work **(Niari *et al.*, 2012)**, it can be assumed, that when predicting the content of reducing sugars in carrots based on the ºBrix, it would probably be necessary to take the water content in carrot juice into account as well.

Carotenoid content

Table 4 shows the content of carotenoids and total dietary fibre in the roots of tested carrot varieties. The content of carotenoids on a fresh *weight* basis varied in a wide interval, depending on the cultivated varieties, from 85.94 (Purple Elite F1) to 374.24 $\mu g.g^{-1}$ (Chamare). **Benamor et al**. **(2020)** determined higher values of carotenoids, ranged between 155.74 and 511.44 $\mu g.g^{-1}$ of dry weight. **Ma et al. (2020)** reported carotenoid contents ranged from 60 to 540 $\mu g.g^{-1}$ of dry weight. **Mech-Nowak et al. (2012)** reported the content of total carotenoids in the cultivars with orange roots ranged from 12.29 to 48.6 $mg.100\ g^{-1}$ of fresh weight and 3.46 $mg.\ 100\ g^{-1}$ of fresh weight for the purple roots with yellow core. **Matějková & Petříková (2010)** reported carotenoid contents ranged from 77 to 95 $mg.kg^{-1}$ for Kráska variety, from 60 to 92 $mg.kg^{-1}$ for Stupická k rychlení variety, and from 97 to 141 $mg.kg^{-1}$ for Olympia variety. Our results for mentioned above varieties were higher: 168,43 $\mu g.g^{-1}$ (Kráska), 216.75 $\mu g.g^{-1}$ (Stupická k rychlení), and 198.49 $\mu g.g^{-1}$ (Olympia). **Bozalan (2011)** reported the content of carotenoids in Maestro F1 variety ranged from 58.15 to 87.36 $\mu g.g^{-1}$, which is a lower value compared to 230.96 µg.g-1 measured in this work.

Dietary fibre

As can be seen from Table 4, the content of total dietary fibre on a *dry weight* basis varied from 25.67% (Katrin) to 36.02% (Purple Elite F1), which is consistent with data published by **Augspole *et al.* (2012)** who determined the dietary fibre content in carrots ranged from 25.78 to 34.25 $g.100\ g^{-1}$ in Nantes hybrids.

Table 3 ºBrix and sugar content in 24 carrot tested varieties in 2022

No.	Variety	ºBrix	Fructose	Glucose	Saccharose	Total sugars*
			[g.100 g^{-1}]			
1	Marion F1	9.87	0.328 ± 0.005	0.325 ± 0.016	3.153 ± 0.148	3.806 ± 0.149
2	Cascade F1	9.45	0.608 ± 0.029	0.784 ± 0.029	2.227 ± 0.014	3.619 ± 0.043
3	Naomi	8.85	0.621 ± 0.025	1.000 ± 0.020	1.888 ± 0.077	3.509 ± 0.083
4	Aron F1	10.15	0.297 ± 0.004	0.623 ± 0.017	3.146 ± 0.121	4.066 ± 0.122
5	Katrin	9.70	0.771 ± 0.026	1.222 ± 0.033	1.978 ± 0.078	3.971 ± 0.089
6	Karotela	12.05	0.296 ± 0.001	0.430 ± 0.007	3.657 ± 0.125	4.383 ± 0.125
7	Nantes 3	10.40	0.630 ± 0.016	0.827 ± 0.019	3.035 ± 0.106	4.492 ± 0.109
8	Stupická k rychlení	10.25	0.570 ± 0.014	0.957 ± 0.037	2.961 ± 0.110	4.488 ± 0.117
9	Chamare	8.95	0.752 ± 0.019	0.913 ± 0.038	2.821 ± 0.035	4.486 ± 0.055
10	Calibra F1	10.70	0.545 ± 0.023	0.661 ± 0.032	2.549 ± 0.135	3.755 ± 0.141
11	Lenka	10.60	0.613 ± 0.030	0.620 ± 0.024	3.337 ± 0.069	4.570 ± 0.079
12	Kráska	12.00	0.594 ± 0.004	0.484 ± 0.004	4.035 ± 0.028	5.113 ± 0.029
13	Jitka F1	11.70	0.975 ± 0.028	1.174 ± 0.037	3.816 ± 0.126	5.965 ± 0.134
14	Vanda	11.55	1.679 ± 0.076	2.138 ± 0.008	3.372 ± 0.119	7.189 ± 0.141
15	Maxima F1	10.95	0.945 ± 0.009	1.049 ± 0.052	4.598 ± 0.219	6.592 ± 0.225
16	Nectar F1	10.65	1.651 ± 0.081	1.932 ± 0.011	3.103 ± 0.130	6.686 ± 0.154
17	Olympus	9.35	1.183 ± 0.042	1.351 ± 0.055	2.805 ± 0.123	5.339 ± 0.141
18	Bolero F1	10.95	1.060 ± 0.032	1.060 ± 0.031	4.674 ± 0.229	6.794 ± 0.233
19	Maestro F1	11.10	1.538 ± 0.034	1.583 ± 0.042	3.732 ± 0.143	6.853 ± 0.153
20	Olympia	11.35	1.400 ± 0.054	1.624 ± 0.035	3.133 ± 0.087	6.157 ± 0.108
21	Sugarsnax 54 F1	10.35	1.302 ± 0.063	1.551 ± 0.025	3.851 ± 0.110	6.704 ± 0.129
22	Tendersweet	10.00	1.236 ± 0.007	1.483 ± 0.041	2.740 ± 0.045	5.459 ± 0.061
23	Purple Elite F1	11.25	1.922 ± 0.025	2.161 ± 0.078	2.222 ± 0.073	6.305 ± 0.110
24	Katlen	11.40	2.009 ± 0.003	2.504 ± 0.055	3.618 ± 0.152	8.131 ± 0.162

*expressed as a sum of fructose, glucose and saccharose concentrations; values represent mean ± standard deviation (n = 2)

Table 4 The content of carotenoids and total fibre in 24 carrot varieties in 2022.

No.	Variety	Carotenoids [μg.g^{-1}]	Total dietary fibre content in dry matter [%]
1	Marion F1	258.82 ± 0.73	28.17 ± 0.23
2	Cascade F1	252.47 ± 0,04	30.00 ± 2.05
3	Naomi	193.06 ± 1.29	28.70 ± 0.99
4	Aron F1	249.20 ± 2.15	27.34 ± 0.00
5	Katrin	268.80 ± 2.00	25.67 ± 0.81
6	Karotela	236.38 ± 2.09	31.84 ± 0.22
7	Nantes 3	226.59 ± 0.51	29.66 ± 0.23
8	Stupická k rychlení	216.75 ± 0.39	28.77 ± 0.71
9	Chamare	374.24 ± 0.14	29.32 ± 0.42
10	Calibra F1	216,57 ± 0,06	32.98 ± 0.20
11	Lenka	201.04 ± 1.74	29.69 ± 0.42
12	Kráska	168.43 ± 0.24	32.19 ± 0.13
13	Jitka F1	168,30 ± 0,06	31.54 ± 0.71
14	Vanda	174.49 ± 0.10	33.66 ± 0.03
15	Maxima F1	252.86 ± 0.11	30.68 ± 1.88
16	Nectar F1	184.35 ± 0,09	32.96 ± 1.36

Continue Table 4

17	Olympus	196.23 ± 1.12	31.49 ± 0.13
18	Bolero F1	220.23 ± 0.18	29.78 ± 0.30
19	Maestro F1	230.96 ± 0.10	30.19 ± 1.27
20	Olympia	198.49 ± 0.13	32.31 ± 0.42
21	Sugarsnax 54 F1	201.77 ± 0.03	29.34 ± 0.78
22	Tendersweet	184.37 ± 0.05	35.32 ± 0.42
23	Purple Elite F1	85.94 ± 0,03	36.02 ± 0.57
24	Katlen	206.61 ± 0.84	31.86 ± 0.06

values represent mean ± standard deviation (n = 2)

Dry matter content

Based on root composition analysis (Table 5), we found that the dry matter content varied in 2022 from 10.3% (Naomi) to 20.3% (Cascade F1). **Yusuf *et al.* (2021)** published the mean dry matter contents of the carrots ranged from 10.9 to 16.4%. **Yadav (2020)** reported a range of dry matter from 11 to 14%. The high content (15.4%) of dry matter of the variety Cascade F1 was also mentioned by **Rima (2020)**, ranged from 11.49 to 17.34%. Due to its high dry matter content, the Cascade F1 variety is particularly suitable for freezing and drying.

Table 5 Content of dry matter, ash, micro and macroelements in 24 carrot varieties in 2022

No.	Variety	Dry matter	Ash	P_{tot}	Cu	K	Na	Mn	Fe	Zn
		[%]	[%]	[mg.100 g^{-1}]						
1	Marion F1	13.9	0.87	32.7	0.093	176	124.0	0.124	0.813	0.268
2	Cascade F1	20.3	1.66	52.0	0.126	320	186.0	0.189	3.340	0.536
3	Naomi	10.3	0.72	17.5	0.045	110	80.9	0.065	1.700	0.945
4	Aron F1	11.5	0.79	25.0	0.071	147	111.0	0.087	0.693	0.157
5	Katrin	10.9	0.69	21.6	0.057	126	65.9	0.062	0.648	0.250
6	Karotela	13.8	0.93	31.1	0.085	196	92.7	0.081	0.707	0.293
7	Nantes	13.7	1.02	30.1	0.061	190	110.0	0.098	0.672	0.191
8	Stupická k rychlení	11.7	0.88	30.3	0.063	170	114.0	0.095	0.742	0.279
9	Chamare	10.8	0.86	17.7	0.042	128	96.0	0.072	0.722	0.152
10	Calibra F1	12.0	1.07	35.2	0.089	272	108.0	0.113	0.614	0.247
11	Lenka	10.6	0.85	29.1	0.042	161	100.0	0.117	0.559	0.220
12	Kráska	12.5	0.99	30.5	0.062	192	88.7	0.075	0.324	0.274
13	Jutka F1	13.3	1.06	33.8	0.052	275	69.4	0.087	0.378	0.236
14	Vanda	12.9	1.06	37.1	0.067	232	124.0	0.089	0.544	0.218
15	Maxima F1	14.8	1.22	43.7	0.079	305	83.4	0.086	0.560	0.332
16	Nectar F1	11.8	1.1	29.6	0.056	178	143.0	0.082	0.502	0.196
17	Olympus	13.1	1.04	35.9	0.068	198	115.0	0.104	0.514	0.259
18	Bolero F1	14.4	0.98	43.6	0.085	267	104.0	0.127	0.588	0.376
19	Maestro F1	12.3	0.96	29.2	0.064	229	129.0	0.086	0.534	0.220
20	Olympia	14.5	1.24	44.4	0.117	337	114.0	0.137	0.539	0.338
21	Sugarsnax 54 F1	12.3	1.15	41.6	0.091	295	116.0	0.077	0.651	0.262
22	Tendersweet	11.6	0.84	29.5	0.062	218	76.8	0.081	0.374	0.180
23	Purple Elite F1	11.1	1.06	34.5	0.068	225	111.0	0.100	0.788	0.213
24	Katlen	14.5	1.05	39.1	0.087	262	82.0	0.132	0.416	0.302

Ash

The ash content (Table 5) varied from 0.69% (Katrin) to 1.66% (Cascade F1), which is in good agreement with data published previously. **Bajaj *et al.* (1980)** reported a range of ash content 0.22 – 0.81%, and **Yusuf, *et al.* (2021)** determined the range of 0.74 – 1.42 %. **Yadav (2020)** reported ash content of 1.1%.

Minerals

Table 5 shows the contents of minerals in different varieties of carrots with significant differences. Phosphorus content varied from 17.5 (Naomi) to 52.0 mg.100 g^{-1} (Cascade F1), copper content ranged from 0.042 (Chamare and Lenka) to 0.126 mg.100 g^{-1} (Cascade F1), potassium content varied from 110 (Naomi) to 337 mg.100 g^{-1} (Olympia), sodium content varied from 65.9 (Katrin) to 186 mg.100 g^{-1} (Cascade F1), manganese content varied from 0.062 (Katrin) to 0,189 mg.100 g^{-1} (Cascade F1), iron content varied from 0.324 (Kráska) to 3.340 mg.100 g^{-1} (Cascade F1), and zinc content varied from 0.152 (Chamare) to 0.945 mg.100 g^{-1} (Naomi).
The comparison of the reached results with previously published works is presented in Table 6.

Table 6 Comparison of the mineral contents in carrot roots with previously published data

P_{tot} [mg.100 g^{-1}]	K	Na	Fe	Cu	Zn	Mn	References
25.0-53.0	240	40.00	0.40–2.20	0.020	0.200	*	Sharma (2012)
15.74–59.88	197.58–414.17	30.29–70.56	1.23–5.52	0.089–0.279	0.319–2.110	0.110–0.523	Bajaj (1980)
*	443–758	14.40–61.60	0.32–1.98	*	0.18–0.39	*	Nicolle et al. (2004)
*	1479–2400	55.80–494.00	1.50–13.40	*	*	*	Yusuf et al. 2021
17.5–52.0	126–337	65.90–186.00	0.324–3.340	0.042–0.126	0.152–0.945	0.062–0.189	This work

*Not measured

CONCLUSION

This study demonstrates significant differences in morphological characteristics and chemical composition between 24 carrot varieties grown in Slovakia, which indicate a high genetic variability of the studied material. According to the obtained results, the Katlen variety contained the highest amount of reducing sugars, followed by varieties Vanda, Maestro F1 and Sugarsnax 54 F1. Based on the gained results, we can also conclude that ºBrix corresponds to the actual sugar content only approximately, and therefore the refraction measurement can only be used as an indicative method for estimating the sugar content. The highest content of carotenoids was determined in the variety Chamare. The highest amount of total dietary fibre was determined in the variety Purple Elite F1. The highest dry matter content was determined in the Cascade F1 variety. The variety Cascade F1 also showed the highest content of ash, phosphorus, copper, sodium, manganese, and iron. The variety Olympia showed the highest content of potassium, and the variety Naomi showed the highest content of zinc. The presented results can provide useful information for carrot growers and consumers in terms of morphological characteristics as well as the chemical composition of the studied carrot varieties. Based on the preferences of agronomic parameters and the content of individual bioactive compounds, they can choose a suitable variety that meets their requirements.

Conflicts of interest: All authors declare no conflicts of interest.

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REFERENCES

AACC (1991). Method 32-07.01. Soluble, insoluble, and total dietary fiber in foods and food products. Approved October 16, 1991. ACC–International, Approved methods of analysis, 11th ed., St. Paul, Minnesota, USA.
AOAC (2017). Total, soluble and insoluble dietary fiber in foods. Method 991.43. Megazyme, Wicklow, Ireland.
Ahmad, T., Cawood, M., Iqbal, Q., Ariño, A., Batool, A., Tariq, R.M.S., Azam, M., & Akhtar, S. (2019). Phytochemicals in *Daucus carota* and Their Health Benefits-Review Article. *Foods*,8, 2424. https://doi.org/10.3390/foods8090424
Ali, M.B., Lehir, S.M., Bangulzai, B.A., Ahmed, S., Babar, M.A., Nadeem, M., Kadhif, M., Dawood, M., & Langove, A.G. (2021). Comparative study of growth and yield performance of various carrot cultivars under climatic conditions of Balochistan. *American Journal of Agriculture*, 3(1), 35 – 41. https://doi.org/10.47672/aja.786
Augspole, I., Rakcejeva, T., & Dukalska, L. (2012). Content of sugars, dietary fibre and vitamin C in hybrids of Nante carrots cultivated in Latvia. *Proceedings of the 18th annual international conference* "Research for rural development", Jelgava, Latvia. ISSN 1691-4031, Vol. 1, pp 137-142. https://doi.org/10.2478/prolas-2013-0054
Ayupov, D., Akhiyarov, B.G., Kuznetsov, I.Y., Ismagilov, R.R., Abdulvaleyev, R.R., Akhiyarova, L.M., Valitov, A.V., Davletshin, F.M., Abdulmanov, R.I., & Irgalina, R.S. (2019). Improving technology elements in multi-purpose carrot cultivation. *Bulgarian Journal of Agricultural Science*, 25 (Suppl. 2), 21-29. Available online at https://api.semanticscholar.org/CorpusID:231891949
Bajaj, K.L., Kaur, G. & Sukhija, B.S. (1980). Chemical composition and some plant characteristics in relation to quality of some promising cultivars of carrot (*Daucus carota* L.). *Plant Foods for Human Nutrition,* 30, 97–107. https://doi.org/10.1007/BF01099047
Benamor, J., Mezghani, N., Periago, M.J., Navarro-González, I., Elvira-Torales, L.I., Mezghani, N., Ouakrim, Y., & Tarchoun, N. (2020). Variations in the sugars and antioxidant compounds related to root colour in Tunisian carrot (*Daucus carota* subsp. *sativus*) landraces. Italian Journal of Food Science, 32(3), 654-673. Available online at https://itjfs.com/index.php/ijfs/article/view/1797
Bhandari, S.R., Choi, C.S., Rhee, J., Shin, Y.K., Song, J.W., Kim, S.-H., Kang, S., & Lee, J.G. (2023). Influence of Root Color and Tissue on Phytochemical Contents and Antioxidant Activities in Carrot Genotypes. *Foods,* 12, 120. https://doi.org/10.3390/foods12010120
Bolton, A., Klimek-Chodacka, M., Martin-Millar, E., Grzebelus, D., & Simon, P.W. (2020). Genome-Assisted Improvement Strategies for Climate-Resilient Carrots. In: Kole, C. (eds) Genomic Designing of Climate-Smart Vegetable Crops. Springer, Cham. https://doi.org/ 10.1007/978-3-319-97415-6_6
Boltz, D.F., & Mellon, M.G. (1948). Spectrophotometric determination of phosphorus as molybdiphosphoric acid. *Analytical Chemistry,* 20 (8), 749–751. https://doi.org/10.1021/ac60020a021
da Costa, M.R., & Omori, A.T. (2017). Acetophenone Bioreduction by Carrot Root. *Food Technology and Biotechnology,* 55 (2), 231–235. https://doi.org/10.17113/ftb.55.02.17.4789
FAOSTAT (2022). Production of carrots and turnips in 2022. Available online at: https://www.fao.org/faostat/en/#data/QCL
IPGRI (International Plant Genetic Resources Institute (1998). Descriptors for wild and cultivated Carrots (Daucus carota L.). International Plant Genetic Resources Institute, Rome, Italy, 65 p. ISBN 92-9043-392-2. Available online at: https://hdl.handle.net/10568/72729
Iorizzo, M., Curaba, J., Pottorff, M., Ferruzzi, M.G., Simon, P., & Cavagnaro, P.F. (2020). Carrot Anthocyanins Genetics and Genomics: Status and Perspectives to Improve Its Application for the Food Colorant Industry. *Genes (Basel)*, 11(8), 906. https://doi.org/10.3390/genes11080906
Kiran, M., Jilani, M.S., Waseem, K., Haq, F., Khan, M.S., Nadim, M.A., Rahman, K., & Hussain, K. (2022). Growth and yield enhancement of carrot through integration of NPK and organic manures. *Journal of Horticultural Sciences*, 17(2)2022, 341-346. https://doi.org/10.24154/jhs.v17i2.857.
Kjellenberg, L. (2007). Sweet and bitter taste in organic carrot. In: Introductory Paper at the Faculty of Landscape Planning, Horticulture and Agricultural Science. Swedish University of Agricultural Sciences, Alnarp, 1-46. Available online at: https://pub.epsilon.slu.se/ 3083/1/IntroLarsKj2007pdf.pdf
Kumar, R. , Vashisht, P. , Gupta, R. K. , Singh, M., & Kaushal, S. (2011) Characterization of European Carrot Genotypes Through Principal Components and Regression Analyses. *International Journal of Vegetable Science*, 17(1) 3-12. https://doi.org/10.1080/19315260.2010. 486021
Luby, CH., Dawson, J.C., & Goldman, I.L. (2016). Assessment and accessibility of phenotypic and genotypic diversity of Carrot (*Daucus carota* L. var. sativus) cultivars commercially available in the United States. PLoS ONE 11(12): e0167865. https://doi.org/10.1371/journal. pone.0167865
Ma, J., Chen, C., Ma, J., Ma, W., & Yang, J. (2020). Analysis of bioactive compounds and antioxidant capacities in different varieties of carrots. *Journal of Physics: Conference Series* 1549, 32054. https://doi.org/10.1088/1742-6596/1549/3/032054.
Matějková, J., & Petříková, K. (2010). Variation in content of carotenoids and vitamin C in carrots. *Notulae Scientia Biologicae,* 2 (4) 2010, 88-91. https://doi.org/10.15835/nsb245108
Mech-Nowak, A., Świderski, A., Kruczek, M., Łuczak, I. & Kostecka-Gugała, A. (2012). Content of carotenoids in roots of seventeen cultivars of Daucus carota L. *Acta Biochimica Polonica*, 59(1), 139-141. https://doi.org/10.18388/abp.2012_2190
Montilla, E.C., Arzaba, M.R., Hillebrand, S., & Winterhalter, P. (2011). Anthocyanin composition of black carrot (Daucus carota ssp. sativus var. atrorubens Alef.) cultivars Antonina, Beta Sweet, Deep Purple, and Purple Haze.

Journal of Agricultural and *Food Chemistry*, 59, 3385–3390. https://doi.org/10.1021/jf104724k

Niari, S.M., Rashidi, M., & Nazari, M. (2012). Prediction of Carrot Reducing Sugars Based on Brix and Water Content of Carrot During Cold Storage. *Middle-East Journal of Scientific Research*, 12(4),542-546. https://doi.org/10.5829/idosi.mejsr.2012.12.4.1701

Nicolle, C., Simon, G., Rock, E., Amouroux, P., Rémésy, C. (2004). Genetic Variability Influences Carotenoid, Vitamin, Phenolic, and Mineral Content in White, Yellow, Purple, Orange, and Dark-orange Carrot Cultivars. *Journal of the American Society for Horticultural Science*, 129(4), 523-529. https://doi.org/10.21273/JASHS.129.4.0523

Nookaraju, A., Upadhyaya, C.P., Shashank, K., Pandey, S.K., Young, K.E., Hong, S.J., Park, S.K., & Park, S.W. (2010). Molecular approaches for enhancing sweetness in fruits and vegetables. *Scientia Horticultur*ae, 127 (1), 1-15. https://doi.org/10.1016/j.scienta.2010.09. 014

Rima, S.S. (2020). Effect of potassium and earthing up on growth, yield and economic benefit of carrot. A Thesis for the degree of Masters of Science (MS), Faculty of Agriculture Sher-e-Bangla Agricultural University, Dhaka, Pakistan. Available online at: http:// eprints. oastmlibrary. com/id/eprint/201

Shakheel, M.B., Saliyan, T., Satish, S., & Hedge, H. (2017). Therapeutic Uses of Daucus carota: A Review. *International Journal* of *Pharma* and *Chemical Research*, 3(2), 138-143. Available online at http://www.ijpacr.com.

Sharma, K.D., Karki, S., Thakur, N.S., & Attri S. (2012). Chemical composition, functional properties and processing of carrot-a review. *Journal of Food Science and Technology,* 1, 22-32. https://doi.org/10.1007/s13197-011-0310-7

Sharma, S., & Sharma, K.D. (2020). Nutritional characteristics of different types of carrot. *International Journal of Chemical Studies*, 8(6), 2275-2278. https://doi.org/10.22271/chemi.2020.v8.i6ag.11111

Singh, M.N., Raunak Srivastava, R., & Yadav, I. (2021). Study of different varieties of carrot and its benefits for human health: A review. *Journal of Pharmacognosy and Phytochemistry*, 10(1), 1293-1299. https://doi.org/10.22271/phyto.2021.v10.i1r.13529

Stefl, H. H. (2017). Exploring the Nutritional Value of Carrots and Determining Attributes that are Favored by Consumers. Honors College. 455. Available online at https://digitalcommons.library.umaine.edu/honors/455

STN 56 0053: 1986. Determination of vitamin A and its provitamins. Praha: ÚNN, 1986.

Stolarczyk, J., & Janick, J. (2011). Carrot: history and iconography. *Chronica Horticulturae,* 51(2), 13-18. Available online at: https://www.actahort. org/chronica/pdf/ch5102.pdf

Sun, T., Simon, P.W., & Tanumihardjo, S.A. (2009). Antioxidant phytochemicals and antioxidant capacity of biofortified carrots (Daucus carota L.) of various colors. *Journal of Agricultural* and *Food Chemistry*, 57, 4142–4147. https://doi.org/10.1021/jf9001044

Tadele, S., & Selomon, T. (2016). Effect of intra spacing on yield and yield components of carrot (Daucus carrota L.sub sp. sativus). *Current Research in Agricultural Sciences*, 3(1), 1-6. https://doi.org/10.18488/journal.68/2016.3.1/68.1.1.6

Tesfaendrias, M.T., McDonald, M.R., & J. Warland, J. (2011). Consistency of long-term marketable yield of carrot and onion cultivars in muck (organic) soil in relation to seasonal weather. *Canadian Journal of Plant Science*. 90(5), 755-765. https://doi.org/10.4141/CJPS09175

UPOV (2004). Carrot, TG/49/7. International Union for the Protection of New Varieties of Plants, Geneva, Switzerland. Available online at https://www.upov.int/ edocs/mdocs / upov/en/tg/2004/tg_49_7_proj.3.pdf

Valerga, L, González, R.E., Pérez, M.B., Concellón, A., & Cavagnaro, P.F. (2023). Differential and Cultivar Dependent Antioxidant Response of Whole and Fresh-Cut Carrots of Different Root Colors to Postharvest UV-C Radiation. *Plants*, 12, 1297. https://doi.org/10.3390/ plants 12061297

Yusuf, E., Tkacz, K., Turkiewicz. I.P., Wojdyło, A., & Nowicka, P. (2021). Analysis of chemical compounds' content in different varieties of carrots, including qualification and quantification of sugars, organic acids, minerals, and bioactive compounds by UPLC. *European Food Research and Technology,* 247(12), 3053–3062. https://doi.org/10.1007/s00217-021-03857-0

Yadav, P. A. (2020). Review on different types of carrot and its chemical compositions. *IOSR Journal of Pharmacy*, series. I, 10(5), 32-39. Available online at https://iosrphr.org/papers/vol10-issue5/E1005013239.pdf