Chemical composition and some plant characteristics in relation to quality of some promising cultivars of carrot (*Daucus carota* L.)

K.L. BAJAJ, GURDEEP KAUR, and B.S. SUKHIJA

Department of Vegetable Crops, Landscaping and Floriculture, Punjab Agricultural University, Ludhiana-141004, India

Abstract. Twenty three cultivars of carrot (*Daucus carota* L.) roots consisting of fifteen local and eight exotic cultivars were analysed for various chemical constituents including dry matter, total soluble solids (TSS), β-carotene, total and reducing sugars, phenolics, phosphorus, zinc, manganese, copper, iron, sodium potassium and ash. In addition other characteristics such as days to maturity, root weight and length, flesh thickness, core diameter, number of forked and cracked roots per plot have been studied. Yellow carrots were found to have maximum root length, water soluble carbohydrates and minimum β-carotene content. The exotic cultivars were found to have higher TSS content than the local cultivars, while the latter cultivars had higher mineral contents than the former. However, on the average, dry matter content, total water soluble sugars, reducing and non-reducing sugars were found to be greater in exotic cultivars than in local ones, but β-carotene, phenols and phosphorus contents were greater in local cultivars. A significant positive correlation between β-carotene content, ash percentage and days to maturity was observed. A wide variation in chemical constituents and plant characteristics was observed indicating a high genetic variability in the material under study.

Introduction

Carrots (*Daucus carota* L.), which are a rich source of sugars and β-carotene, play a dominant role in the nourishment of infants and young children. Of all our vegetables, they are the best source of the important pro-vitamin A, β-carotene (Schuphan [17]). Carrots are extensively used in the food processing industry. They are frozen for use as mixed vegetables and also for re-manufacture into canned soups. They are also canned (whole, diced or sliced), dehydrated or used in juice manufacture (Pantastico [15]). The information pertaining to the chemical constituents of carrot (*Daucus carota* L.) and their relationship with the quality needs consideration especially for new cultivars. This communication reports the dry matter, TSS, phenols, β-carotene, carbohydrates, mineral constituents and other plant characteristics such as maturity period, root length and weight, core size, flesh thickness, and number of forked and cracked roots of some promising carrot cultivars. This information might be useful to consumers, breeders and food technologists.

Material and Methods

Seeds of twenty three cultivars of carrot were sown on September 23, 1978, in a randomised block design in four replications at the Vegetable Exper-

Qual Plant Plant Foods Hum Nutr 30:97–107(1980) 0377–3205/80/0302–0097$01.65.

imental Farm of the Punjab Agricultural University, Ludhiana. The names of cultivars with their source of procurement are given in Table 1 (a). The distances between ridges and plants were 30 cm and 7 cm respectively. The crop was given the recommended dose of fertilizers (100 kg N/ha, 50 kg P_2O_5/ha and 80 kg K/ha) and care was taken regarding irrigation and weed control. A random selection of ten plants (excluding border plants) in each strain per replication plot was made and observations were recorded for days to maturity, total soluble solids, root weight, root length, flesh thickness, core diameter, and number of forked and cracked roots.

For chemical analysis, uniform roots were uprooted at the optimum maturity stage. Five roots from each replication were selected at random, pooled and composite samples analysed in duplicate. The dry matter content was based on samples dried at 75 ± 2°C to a constant weight. The sugars were extracted exhaustively with hot water and estimated by the method of Yemm & Willis [19] using anthrone after clarification of the extract by the method of the A.O.A.C. [1]. Reducing sugars were estimated by the method of Noelting & Bernfield [14] using 3, 5 dinitrosalicytic acid. β-carotene was estimated by the method of A.O.V.C. [2]. Total phenolics were estimated from their 80% methanolic extract by the method of Swain & Hillis [18]. The minerals were extracted from the oven dried ground material by wet digestion with nitric acid: perchloric acid (4:1). Phosphorus from this extract was determined by vanadomolybdophosphoric-yellow method (Jackson [12]) whereas zinc, copper, manganese and iron were analysed by atomic-absorption-spectrophotometer. Sodium and potassium were determined by flame photometer. The total ash content was determined according to the method of the A.O.A.C. [1]. The results were expressed on a fresh weight basis and statistically analysed.

Results and Discussion

The chemical composition of the twenty three cultivars of carrot is given in Table 1 (a) and 1 (b). The dry matter content varied from 7.92% (Yellow Carrot) to 11.18% (Kurna). This is in accordance with the observations of Kaur et al. [13]. They reported a range of dry matter from 7.57% to 10.05% in a limited study with five cultivars, while Schuphan [17] reported the mean value as 11.63% in a large number of samples. Bajaj et al. [4] reported the variation to be from 8.14 to 12.58%. For canning and freezing purposes, the carrots with high dry matter content are considered desirable (Plucinska & Elkner [16]). Thus the exotic cultivars Kurna, Regol and Duke and local cultivars such as Nantes (IARI), No. 10–75–A, Pusa Kesar and No. 29 are very suitable for this purpose.

β-carotene

The content varied from 0.85 (Yellow Carrot) to 8.50 mg/100 g (No. 10–75A) on a fresh weight basis. Schuphan [17] has reported a range of 0.40

Table 1 (a). Chemical constituents of some cultivars of carrots (*Daucus carota* L.) on fresh wt. basis

Sr. No.	Cultivar	Source	Total soluble solids (%)	Dry matter (%)	β-carotene (mg/100 g)	Phenols (mg/100 g)	Total water soluble sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
1.	Sel. 5B	IARI	7.1	9.70	6.95	83.42	2.84	0.89	1.95
2.	Sel. 5	IARI	6.7	8.91	6.85	60.58	2.88	9.93	1.95
3.	Nantes	IARI	8.0	10.22	6.10	69.49	4.46	1.24	3.22
4.	S-233	PAU	7.5	9.81	4.70	66.70	3.78	0.97	2.81
5.	Sel. 5A	IARI	7.1	8.82	5.85	49.39	3.53	1.09	2.44
6.	Sel. 233-21-75A	PAU	8.2	9.98	5.10	67.86	3.27	0.67	2.60
7.	No. 10-75A	PAU	8.5	10.84	8.50	73.71	5.01	0.87	4.14
8.	No. 29	PAU	8.5	10.27	6.60	80.10	3.15	1.14	2.01
9.	Subagh Sel.	PAU	8.0	9.99	6.60	67.98	3.99	1.03	2.96
10.	Pusa Kesar	IARI	8.3	10.29	5.15	69.97	4.34	1.05	3.29
11.	Yellow Carrot	PAU	7.7	7.92	0.85	69.69	6.25	1.85	4.40
12.	Nantes PBC	PAU	8.5	9.19	6.20	75.35	2.62	0.99	1.63
13.	Waryana Sel.	PAU	8.4	9.38	7.10	76.91	2.94	1.56	1.38
14.	Nabha Sel	PAU	8.5	9.84	5.80	57.07	4.22	1.67	2.55
15.	Nantes Tropical	PAU	8.1	9.60	4.05	86.40	3.18	2.45	0.73
	Mean (1–15)		7.94	9.65	5.76	70.40	3.49	1.16	2.33

16.	Western Red	O.E.	8.5	9.29	5.20	57.60	3.57	1.47	2.10
17.	Chantenay Redico	O.E.	8.6	9.96	6.20	51.79	4.47	1.84	2.63
18.	Banta	O.E.	8.3	8.99	6.30	50.34	3.15	2.24	0.91
19.	Duke	O.E.	8.8	10.59	4.95	48.71	4.69	1.67	3.02
20.	Onward	O.E.	8.9	9.42	4.95	64.05	4.17	1.92	2.25
21.	Regol	O.E.	8.8	10.65	4.80	48.99	4.79	2.15	2.64
22.	Kurna	O.E.	9.2	11.18	6.70	51.43	5.27	0.85	1.42
23.	Royal Chantenay	O.E.	8.2	9.48	5.05	43.61	4.61	2.05	2.56
	Mean (16–23)		8.66	9.94	5.51	52.06	4.34	1.77	2.56
	Overall Mean		8.19	9.75	5.67	63.95	3.78	1.37	2.41
C.D. at 5% level			0.24	0.24	0.45	3.83	0.30	0.15	0.30

IARI – Indian Agricultural Research Institute, New Delhi
PAU – Punjab Agricultural University, Ludhiana
O.E. – Ohlsens Enke, Denmark

N.B. Varieties 1–15 are local and 16–23 are exotic.

Table 1 (b). Mineral contents of some cultivars of carrot (*Daucus carota* L.) on fresh wt. basis

Sr. No.	Cultivar	Iron (mg/100 g)	Copper (mg/100 g)	Zinc (mg/100 g)	Manganese (mg/100 g)	Sodium (mg/100 g)	Potassium (mg/100 g)	Phosphorus (mg/100 g)	Ash (%)
1.	Sel-5B	4.85	0.097	0.388	0.174	65.95	288.57	29.10	0.63
2.	Sel-5	5.52	0.267	0.445	0.369	30.29	269.76	53.46	0.56
3.	Nantes	3.16	0.245	0.515	0.137	48.03	304.04	16.35	0.38
4.	Sel. 233	2.84	0.147	0.765	0.220	50.03	304.11	29.43	0.78
5.	Sel. 5A	2.02	0.158	0.485	0.185	70.56	273.42	21.15	0.22
6.	Sel. 233-21-75B	4.99	0.279	0.399	0.523	63.87	414.17	59.88	0.71
7.	No. 10-75A	3.57	0.162	1.788	0.265	63.95	319.78	26.01	0.81
8.	No. 29	4.51	0.195	0.872	0.267	55.45	279.85	30.81	0.77
9.	Subagh Sel.	3.89	0.149	1.198	0.369	50.24	305.69	29.97	0.70
10.	Pusa Kesar	3.18	0.128	0.617	0.308	68.94	281.43	24.69	0.67
11.	Yellow Carrot	2.61	0.150	0.736	0.209	40.78	199.98	23.76	0.63
12.	Nantes PBC	2.48	0.174	0.781	0.110	60.65	197.58	18.38	0.53
13.	Waryana Sel.	2.72	0.234	2.110	0.314	55.34	253.26	18.76	0.51
14.	Nabha Sel.	3.44	0.236	1.712	0.241	51.16	255.84	15.74	0.43
15.	Nantes Tropical	2.59	0.120	0.480	0.187	70.08	230.40	28.80	0.53
Mean (1-15)		3.49	0.182	0.886	0.285	56.35	285.19	28.42	0.59
16.	Western Red	2.13	0.139	0.418	0.125	50.16	246.18	22.29	0.32
17.	Chantenay Redico	2.29	0.099	0.597	0.179	50.29	236.55	21.91	0.49
18.	Banta	5.21	0.089	0.404	0.188	66.52	267.45	26.97	0.61
19.	Duke	2.64	0.105	1.779	0.158	69.98	275.34	16.94	0.49
20.	Onward	2.16	0.117	1.507	0.273	50.86	254.34	18.84	0.55
21.	Regol	1.81	0.133	0.319	0.143	48.99	290.21	21.30	0.54
22.	Kurna	3.68	0.20	0.670	0.218	54.78	324.22	33.54	0.63
23.	Royal Chantenay	1.23	0.213	1.308	0.213	57.82	312.84	18.96	0.45
Mean (16-23)		2.64	0.137	0.875	0.187	56.16	263.39	20.96	0.51
Overall mean		3.19	0.166	0.882	0.207	56.28	277.60	25.82	0.56
C.D. at 5% level		0.36	0.03	0.18	0.03	3.21	15.48	3.39	0.03

to 4.30 mg/100 g. Axelsson [3] has reported a range of 2.8 to 12.4 mg/100 g. It has been reported that preservation either by canning or by freezing does not reduce the pro-vitamin A (β-carotene) contents of carrots so that preserved carrots too are valuable in this respect (Booth [5]). Carrots with a high carotene content and TSS are preferred for dehydration purposes (Pantastico [15]).

Total soluble solids

The cultivar Kurna had the highest TSS content (9.2%) which was supported by the fact that it also had the highest content of total water soluble carbohydrates (5.27%). This was followed by the cultivars Duke, Onward and Regol. Exotic cultivars were generally found to have higher TSS content than the local cultivars.

Carbohydrates

The carbohydrate content (mono- and disaccharides) in carrots is of importance for the choice of cultivars (Schuphan [17]). The total water soluble carbohydrates ranged from 2.62% (Nantes PBC) to 6.25% (Yellow Carrot). Reducing and non-reducing sugars varied from 0.67% (Sel 233–21–75B) to 2.45% (Nantes Tropical) and from 0.73% (Nantes Tropical) to 4.42% (Kurna), respectively. Schuphan [17] reported a range of total sugars from 1.87 per cent to 5.17 per cent. Kaur et al. [13] reported the mean values of total water soluble sugars, reducing sugars and non-reducing sugars as 3.39%, 2.31% and 1.08%, respectively, in a limited study with five cultivars of carrots. Bajaj et al. [4] reported a variation of total water soluble sugars from 3.51% to 6.82%.

Phenols

The phenolic content varied from 43.61 mg/100 g (Royal Chantenay) to 86.40 mg/100 g (Nantes Tropical). Phenolic compounds have been shown to be regulatory factors during the dormant stage and to effect the natural immunity of root vegetables such as carrots, beets and horse-radish. They also play an important role during the storage of vegetables (Feldman et al. [9]). Phenolic compounds in plants in addition to imparting disease resistance (Farkas & Kiraly [8]), act as antioxidants (Hermann [11]).

Minerals

The mineral composition data are given in Table 1 (b). Little information is available about the mineral constituents present in different carrot cultivars. Phosphorus content varied from 15.34 mg/100 g (Nabha Sel) to 59.88 mg/100 g (Sel 233–21–75B). Kaur et al. [13] have reported a range of phosphorus content of 47.31 to 61.55 mg/100 g while Schuphan [17] has reported a range of 23 mg to 45 mg/100 g. Iron content, expressed as mg/100 g, varied from 1.23 (Royal Chantenay) to 5.52 (Sel-5). Copper, zinc

and manganese content (mg/100 g) varied from 0.089 (Banta) to 0.279 (Sel 233–21–75b), 0.319 (Regol) to 2.110 (Waryana Sel), and 0.11 (Nantes PBC) to 0.523 (Sel 233–21–75B), respectively. Ash content varied from 0.22% (Sel-5A) to 0.81% (No. 10–75A). Kaur et al. [13] have reported a mean value of iron, copper, zinc, manganese and total ash as 2.61 mg/100 g, 0.10 mg/100 g, 0.27 mg/100 g, 0.30 mg/100 g and 0.70%, respectively, in a few cultivars of carrots. Interestingly, copper, manganese, phosphorus and potassium were found to be highest in the variety Sel. 233–21–75B. Sodium and potassium content (mg/100 g) varied from 30.29 (Sel-5) to 70.56 (Sel-5A) and from 197.58 (Nantes PBC) to 414.17 (Sel 233–21–75B), respectively. Schuphan [17] reported ranges of K, Na, Fe and phosphorus in mg/100 g of 166 to 330, 46 to 107, 2 to 5, and 23 to 45, respectively.

Data in Table 2 give information about root weight and length, flesh thickness, core diameter, number of forked and cracked roots and the days to maturity. A considerable range of variation existed for all the characters indicating high genetic variability in the material under study. Days to maturity for various cultivars varied from 90 to 95 days.

For dehydration purposes large carrots are preferred. The Western Red cultivar was found to have maximum root weight (183.0 g) followed by the cultivars Yellow Carrot, Nantes (PBC), Waryana Sel, S-233 and Subagh Sel (all from the Punjab Agricultural University, Ludhiana); the other cultivars had comparatively low average root weights. The root length of different cultivars varied from 12.1 cm (Nantes) to 19.4 (Yellow Carrot). Flesh thickness varied from 1.4 cm (Regol) to 2.3 cm (Sel. 5A) and the range of core diameter was from 1.0 cm (Nantes) to 2.1 cm (Western Red). Carrots canned whole should have a shoulder diameter between 1.27 cm to 2.54 cm. The cultivars Western Red and Chantenay Redico with maximum core-diameter are recommended varieties for canning and preparation of slices and dices (Pantastico [15]). Carrots to be used for canning should not be forked or cracked. The maximum number of cracked roots were observed in the cultivar No. 29, followed by No. 10–75 A, Waryana Sel., Nabha Sel and Subagh Sel. Other cultivars Banta, Western Red Kurna, Regol, Onward, Duke, Chantenay-Redico, Nantes Tropical, Nantes (PBC), Pusa Kesar and Sel 5A had small numbers of cracked roots. The maximum number of forked roots was observed in the cultivar Nabha followed by Waryana Sel., S–233, No. 29 and Subagh Sel.

Correlation between chemical constituents and plant characters

Correlations between the biochemical and plant characteristics given in Table 3. A knowledge of inter-relationship of these characteristics is highly useful for objective selections since the selection for one trait invariably effects a number of other associated characters. A significant positive correlation between β-carotene content and days to maturity was found. Booth & Dark [6] have reported an increase in the β-carotene concentration with age

Table 2. Plant characters of some cultivars of carrot (*Daucus carota* L.)

Sr. No.	Cultivar	Root weight (g)	Root length (cm)	Flesh thickness (cm)	Core diameter (cm)	No. of forked roots	No. of cracked roots	Days to maturity
1.	Sel. 5B	94.4	15.6	1.7	1.3	15.7	1.5	90.0
2.	Sel. 5	87.9	14.6	1.9	1.2	14.2	2.0	90.0
3.	Nantes	64.0	12.1	1.8	1.0	6.2	1.7	90.0
4.	S-233	136.8	16.1	2.2	1.9	31.0	1.2	91.0
5.	Sel. 5A	100.9	13.2	2.3	1.4	16.7	2.0	91.0
6.	Sel. 233-21-75A	137.1	16.3	2.1	1.9	16.0	3.5	93.0
7.	No. 10-75A	121.0	16.4	2.2	1.7	15.2	15.7	94.0
8.	No. 29	127.2	18.4	1.9	1.6	25.2	17.0	94.0
9.	Subagh Sel.	138.5	17.3	1.8	1.6	21.0	9.0	94.0
10.	Pusa Kesar	129.8	16.0	2.0	1.3	13.0	6.0	94.0
11.	Yellow Carrot	153.5	19.4	1.7	2.0	22.2	1.5	90.0
12.	Nantes PBC	146.0	13.7	2.2	1.5	12.0	1.5	94.0
13.	Waryana Sel.	148.0	17.0	2.1	1.5	32.0	10.5	95.0
14.	Nabha Sel.	122.3	17.4	1.9	1.5	54.0	10.5	90.0
15.	Nantes Tropical	89.2	13.5	1.7	1.2	9.0	1.5	90.0
16.	Western Red	183.0	17.7	1.7	2.1	19.4	0	91.0
17.	Chantenay Redico	131.1	12.7	2.9	2.0	6.0	0	92.0
18.	Banta	98.5	15.6	1.7	1.5	19.5	0	91.0
19.	Duke	122.1	15.3	2.1	1.3	10.0	0	90.0
20.	Onward	105.3	14.5	1.8	1.3	7.5	3	90.0
21.	Regol	107.8	15.3	1.4	2.0	9.0	0	90.0
22.	Kurna	91.0	14.2	2.1	1.1	6.5	3	90.0
23.	Royal Chantenay	121.9	13.1	2.0	1.6	12.0	0	90.0
C.D. at 5% level		13.30	2.15	0.19	0.21	12.75	4.82	N.S.

Table 3. Association between quality characters and other plant characters of carrot roots

Characters	Dry matter	β-carotene	Total soluble sugars	Phenols	Ash (%)	Phosphorus
Root weight (g)	−0.2135	−0.2444	+0.0303	+0.0451	+0.0965	−0.0895
Root length (cm)	−0.1142	−0.2042	+0.1047	+0.2756	+0.3419	+0.1288
Flesh thickness (cm)	+0.0666	+0.3268	−0.0944	−0.0417	+0.0535	+0.0716
Core diameter (cm)	−0.1479	−0.3112	+0.1876	−0.1513	+0.1465	+0.0404
Days to maturity	+0.1501	+0.4219*	−0.0415	−0.0181	+0.4077*	+0.2037

* Significant at 5% level

which varied little at maturity. On the basis of the fact that β-carotene is highest at maturity, Fritz & Habbin [10] have determined the optimum harvest time for carrots. A positive correlation of β-carotene content with flesh thickness and a negative correlation with core diameter, though not significant was also observed. Total percentage ash, which represents the total mineral content, had a positive correlation with days to maturity; this is in agreement with the observation of Carvalho Avelae et al. [7] who have reported an increased uptake of minerals by carrot roots from soil with an increased number of days to maturity.

Acknowledgement

This work was done as a part of the vegetable improvement project financed by I.C.A.R. Thanks are due to Dr. K.S. Nandpuri, Professor & Head, Department of Vegetable Crops, Landscaping and Floriculture, Punjab Argicultural University, Ludhiana, for providing facilities.

References

1. A.O.A.C. (1975) Official methods of analysis, 12th edn. Washington DC: Association of Official Analytical Chemists, pp 130 and 529
2. A.O.V.C. (1966) Methods of vitamin assay, 3rd edn. New York: Interscience, p 97
3. Axelsson F (1976) Experiments of the development of F_1 hybrid varieties of carrot. Agric Hortic Genet 34: 42–58
4. Bajaj KL, Kaur G, Brar JS, Sukhija BS (1978) Chemical composition and keeping quality of carrot (*Daucus carota* L.) varieties. Plants Foods Man 2: 159–165
5. Booth VH (1958) The stability of carotene in vegetable foods and forages. Qual Plant Mater Veg 3(14): 317–326
6. Booth VH, Dark SOS (1949) The influence of environment and maturity on total carotenoids in carrots. J Agric Sci 39(2): 226–230
7. Carvalho Avelae B de, Aguiar Sans LM, Ferreira Mendes J (1973) Uptake of nitrogen, phosphorus, potassium, calcium and magnesium in carrot. Pesq Agropecu Bras [Agron] 8(8): 209–212
8. Farkas GL, Kiraly Z (1962) Role of phenolic compounds in the physiology of plant diseases and disease resistance. Phytopathol Z 44: 105–150
9. Feldman AL, Gusar ZD, Girkhovskya EB, Poznyakova GP (1977) Changes in physiologically active substance of vegetable during storage in refrigerated chamber. Izv Vyssh Uchebn Zaved Pishch Tekhnol 4: 96–99 [Food Sci Technol Abstr 10, 6J 789]
10. Fritz D, Habbin J (1975) Determination of ripeness of carrot (*Daucus carota* L.). Acta Hortic 52: 231–238
11. Hermann K (1973) Phenolische Pflanzenin-haltsstoffe als natürliche Antioxydantien. Fette Seifen Anstrichm 75: 499–504
12. Jackson ML (1958) Soil chemical analysis. Englewood Cliffs NJ: Prentice-Hall, p 151
13. Kaur G, Jaiswal SP, Brar JS, Nandpuri KS, Kumar JC (1976) Physicochemical characteristics of some important varieties of carrot (*Daucus carota* L.). Indian Food Packer 30(2): 5–8
14. Noelting G, Bernfield P (1948) Helv Chim Acta 31:286. Cited from Bernfield P (1955) Amylases, alpha and beta assay methods. In: Colowick SP, Kaplan NO (eds) Methods in enzymology, vol 1. New York: Academic Press, pp 149–150
15. Pantastico ErB (1975) Post-harvest physiology. Handling and utilization of tropical and subtropical fruits and vegetables. Westport CN: AVI, pp 494–495
16. Plucinska M, Elkner K (1974) The suitability of carrot varieties for the canning

industry and freezing. Biul Warzywniczy 16: 367–387 [Plant Breed Abstr 46(4): 3837]
17. Schuphan W (1965) Nutritional values in crops and plants. London: Faber and Faber, p 68
18. Swain T, Hillis WE (1959) The phenolic constituents of *Prunus domestica.* I. The quantitative analysis of phenolic constituents. J Sci Food Agric 10: 63–68
19. Yemm EW, Willis AJ (1954) The estimation of carbohydrates in plant extract by anthrone. Biochem J 57: 508–514