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Screening for carotenoid content in accessions of tropical carrot (*Daucus carota* L.)

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Abstract
Carotenoids play an important physiological role in human nutrition by acting as pro-vitamin A (vitamin A precursors). Carrots are the abundant source of provitamin A carotene in the human diet. Carrot varieties grown in India are poor in carotenoids, which needs further improvement for nutritional qualities. Forty-eight diverse accessions of tropical carrot (*Daucus carota* L.) were evaluated for carotenoid content at the Vegetable Research Block VIII of Division of Vegetable Crops, ICAR-Indian Institute of Horticultural Research, Hesaraghatta, Bengaluru during season 2018-2019.Carrot varieties grown in India are poor in carotenoids, which needs further improvement for nutritional qualities. The carotenoid content(mg/100g) was estimated using by spectrophotometer method. Acc-156, Acc-196, Acc-196A and Acc-56 (16.93, 16.93, 16.93 and 16.4 mg/100g) recorded highest and significant carotenoid content. Hence these accessions be utilized in quality breeding program as a carotenoid source in carrot under tropical conditions.

Keywords: Carrot, tropical, nutrition, carotenoid content, screening and improvement

Introduction

Carrot (*Daucus carota* L., 2n =2x =18) is a cool weather crop grown in temperate and subtropical regions for its edible storage tap roots both for fresh as well as processed vegetable throughout the world. (Abdelrazek *et al*. 2020; Bennett and Leitch, 1995; Iorizzo *et al*. 2011; Selvakumar *et al*. 2019; Stelmach *et al*. 2021) [1, 4, 17, 28, 32]. The storage root of carrot is a good source of dietary fibers, carotenoids, vitamins, antioxidants, carbohydrates, bioactive micronutrients and minerals (Fe, Ca, Mg and P) (Que *et al*., 2019) [24]. The cultivated carrots are mainly classified based on pigmentation in the carrot roots (Heywood, 1983) [14]. On the basis of root pigmentation, carrot is broadly classified in two groups (A) Carotenoid group (*D. carota* ssp. *sativus* var. *sativus*) and (B) Anthocyanin or purple group (*D. carota* ssp. *sativus* var. *atrorubens*). Eastern carrots are thought to have originated from Afghanistan, while the origin of western carrots is still uncertain (Heywood, 1983; Rong *et al*. 2014) [14, 26]. The roots of the eastern carrots are purple, red, yellow, leaves are slightly dissected and roots are branched. The roots of western carrots are orange, red or white and leaves are highly dissected and the roots are unbranched (Heywood, 1983; Simon, 2008) [14, 29]. Carrot serves as a model plant for biotechnological techniques and is used in experiments analyzing the physiology of plants (Stein and Notahnagel, 1995) [31]. Carrot is among the top ten vegetables in terms of global production (Simon *et al*., 2019) [30]. Around 35 million tonnes of carrots are produced globally each year, which indicates consumer significance (Dhillon *et al*., 2016) [7]. In the past 45 years, the world's carrot production has increased by four times from 5.8 million MT in 1961 to 23.6 MT in 2014 (FAO, 2015) [10]. In India, it occupies an area of 112 thousand hectares and produces 2042 thousand tonnes and productivity of 18.23 t/ha (NHB, 2020). The major growing states are Haryana, Bihar, Punjab, Uttar Pradesh, Madhya Pradesh and Tamil Nadu. (Indian Horticulture Database, NHB, 2020). Carotenoids, anthocyanins, and flavonoids found in carrots may increase health by preventing oxidative stress and reducing cardiovascular risk. (Stintzing and Carle, 2004; Van den berg *et al*., 2000) [33, 34]. For its high concentration of β-carotene and tocopherols, two compounds with health-promoting properties, it has been classified as a vitaminized functional food (Hashimoto and Nagayama, 2004; Hager and Howard, 2006) [13, 12]. About 60 percent of the total carotene content in carrot is β-carotene (Gabelman, 1974) [11]. Carotenoids play an important physiological role in human nutrition by acting as pro-vitamin A (vitamin A precursors). Carrots are the abundant source of provitamin A carotene in the human diet (Simon *et al*., 2019) [30].

Carotenoids from provitamin A help to maintain healthy epithelial cell differentiation, normal reproductive performance and visual functions (Karnjanawipagul *et al*., 2010) [19]. Carrot varieties with high nutritive value are the cheap and inexpensive source of Vitamin A which is essential to combat Xerothpthalmia (night blindness), prevalent among pregnant women and children aged 1-5 years in rural areas of India (Riaz *et al*., 2021) [21]. Carrot varieties grown in India are poor in carotenoids, which needs further improvement for nutritional qualities. Therefore, the present study was undertaken to screen the accessions for carotenoid content in tropical carrot as it can be used for further quality improvement programme in carrot.

Material and Methods

Forty-eight accessions of carrot were screened along with Arka Suraj (check) at experimental farm, Division of Vegetable Crops, ICAR-IIHR, Hesaraghatta, Bengaluru, Karnataka, India, during winter season December, 2018 to April, 2019. The carrot accessions were included in the experiment are germplasm accessions maintained at the Division of Vegetable Crops, ICAR- IIHR, Bengaluru. The details of the accessions are listed in Table1. The carotenoid content was estimated using by method of AOAC, 2000 [3] (Fig.1).

Total carotenoids

Homogenized sample (5g) was taken in a mortar and pestle and ground with 100 Percent acetone. Supernatant was transferred to a 50 ml volumetric flask. Extraction was repeated until the residue becomes colorless. All the extractions were carried out under low light or red light. All the extracts were transferred in to volumetric flask and volume was made up with acetone and kept overnight in the dark place and absorbance was read at 450 nm for carotenoids. The carotenoid content was calculated using standard β-carotene using standard curve (AOAC, 2000) [3].

$$C = \frac{D \times V \times f \times 100}{2500}$$

Where,

C = Total amount of carotenoids (mg).

D = Absorbance at 450 nm in a 1.0 cm cell.

V = Volume of the original extract in ml.

f = Dilution factor.

2500 = Average extinction coefficient of the pigments.

Results and Discussion

Carrots are ranked seventh in terms of nutrition contribution among fruits and vegetables. (Simon, 2000; Alasalvar *et al*., 2001) [2]. There are positive associations between high intakes of nutrients like β-carotene and β-cryptoxanthin and the outcomes related to asthma and allergies (Devereux, 2006) [6]. Recent research has found that carotenoids can help prevent bladder cancer when consumed in a certain way (Hung *et al*., 2006) [16]. Carrots are one of the most important sources for dietary intake of vitamin A. The main carotenoids of common carrots are α and β-carotene. (Nagata *et al*., 2008; Dunemann *et al*., 2022) [22, 8]. Because it contains a wealth of β-carotene, it has been classified as a functional vitamin food (Hashimoto and Nagayama, 2004; Hager and Howard, 2006) [13, 12]. Orange carrots contain high amount of α and β-carotene which account for about half of the provitamin A (Sun *et al*., 2009). Kalloo *et al*. (1993) [18] reported that the total carotenoid content on fresh weight basis was 9.62 mg/100g in Hisar Gairic compared with 4.70 mg/100g in Pusa Kesar. Fresh purple and orange cultivars contain 102 and 35 mg of polyphenols per 100 grams of material, respectively. (Alasavar *et al*., 2005). Carrots contain 160 to 380 μg−1 fresh biomass carotenes, with β-carotene accounting for about 80 percent of total carotenoids (Koudela *et al*., 2021) [20]. The food industry needs to know the composition and content of biologically active substances in both fresh and processed carrots. Such information is also necessary for consumers who are becoming more aware of their nutritional needs (Purkiewicz *et al*., 2020) [23]. The significant differences have been observed between accessions for carotenoid content (Table, 2). Significantly higher carotenoid content was observed in Acc-156 and Acc-96A (16.94 mg/100g), whereas, the lowest value was observed in Acc-261 (7.08 mg/100g). The accessions (Acc-88) and (Acc-113B) had 13.44 mg /100 g and 9.00 mg carotenoid content, respectively. The check variety Arka Suraj had higher value (11.27 mg/100g) than accession (Acc-113B, Acc-261) and lower content than accession (Acc-88). Carotenoid content was highest in Acc-154 and Acc-96A (16.93 mg/100g) Whereas in Acc-113B and check variety (Arka Suraj) the carotenoid content were 9 mg/100g and 11.27mg/100g. However, Choudhary *et al*. 2013 reported that carotenoid content had positively correlated. Miglio *et al*. (2008) [21] estimated high concentrations of two vitamin precursors, the carotenoids α and β-carotene (4.6 and 6.4 mg/100g) in raw carrots. Booth and Dark (2009) [5] found that fresh carrots contained an average of 13.8 mg of carotene per 100 grams. Fikselova *et al*. (2010) investigated the effects of cultivation and storage on carotene content in carrot roots (*Daucus carota* L.), finding that carrot varieties (Nevis F1, Idaho F1, Florida F1, Kathmandu F1) had the highest mean content of β-carotene (23.25 mg100 g-1). Sahabi *et al*. (2012) [27] selected ten different locally grown and widely consumed vegetables for the screening of total carotenoids and β-carotene contents. Among ten different vegetables, carrot (*Daucus carota*) has the highest values of both the total carotenoids (397.8 ± 2.0 μg/g) and β-carotene (203.0 μg/g). Acc-156, Acc-196, Acc-196A and Acc-56 (16.93, 16.93, 16.93 and 16.4 mg/100g) recorded highest and significant carotenoid content respectively. Hence these accessions be utilized in quality breeding program as a carotenoid source in carrot under tropical conditions.

Table 1: List of carrot accessions used in the study

Sl. No.	Accessions	Root color	Special Characters	Source
1.	Acc-21C	Orange	Big cylindrical root,	Tropical type
2.	Acc-22A	Deep orange	Excellent	Tropical type
3.	Acc-29	Orange	Root	Tropical type
4.	Acc-50	Orange	Orange, smooth and tender	Tropical type
5.	Acc-51	Orange	Big root, orange, thick and vigorous	Tropical type
6.	Acc-52C	Dark orange	Big	Tropical type
7.	Acc-54	Dark orange	Big and thick	Tropical type
8.	Acc-56B	Dark orange	Medium and good	Tropical type
9.	Acc-60	Dark orange	Good	Tropical type
10.	Acc-64	Dark orange	Small root	Tropical type
11.	Acc-72	Dark orange	Small root, and conical	Tropical type
12.	Acc-76	Very dark orange	Medium size and cylindrical	Tropical type
13.	Acc-77	Orange	Very big root	Tropical type
14.	Acc-77B	Dark orange	Very big root	Tropical type
15.	Acc-84	Dark orange	Big root	Tropical type
16.	Acc-85	Very dark orange	Big root	Tropical type
17.	Acc-87	Orange	Self-core	Tropical type
18.	Acc-88	Dark orange	Small root to medium	Tropical type
19.	Acc-91	Orange	Big and cylindrical root	Tropical type
20.	Acc-92	Orange	Medium and cylindrical	Tropical type
21.	Acc-96A	Dark orange	Self-core	Tropical type
22.	Acc-105	Very dark orange	Tender	Tropical type
23.	Acc-113B	Orange	Medium size and cylindrical	Tropical type
24.	Acc-135	Orange	Very big root and uniform	Tropical type
25.	Acc-135B	Orange	Big root and uniform	Tropical type
26.	Acc-144	Orange	Very dark orange and cylindrical	Tropical type
27.	Acc-144B	Orange	Medium size and cylindrical,	Tropical type
28.	Acc-145	Dark orange	Long tender, big and smooth	Tropical type
29.	Acc-146	Very dark orange	Big	Tropical type
30.	Acc-147	Orange	Big root and smooth,	Tropical type
31.	KSP181	Orange	Self-core	Tropical type
32.	Acc-149	Orange	Tender, long and medium root,	Tropical type
33.	Acc-152B	Purple	Big root	Tropical type
34.	Acc-152	Orange	Big root, smooth and long	Tropical type
35.	Acc-154	Very dark orange	Big	Tropical type
36.	Acc-156	Very dark orange	Big thick root	Tropical type
37.	Acc-159	Orange	Self-core	Tropical type
38.	Acc-163B	Very dark orange	Self-core and big	Tropical type
39.	Acc-164	Orange	Tender and big root,	Tropical type
40.	Acc-167B	Orange	Big	Tropical type
41.	Acc-261	Dark orange	Very big and short	Tropical type
42.	Acc-278	Dark purple	Big root	Tropical type
43.	KSP123	Red color	Long root	Tropical type
44.	Bermuda	Orange color	Very smooth and cylindrical,	Tropical type
45.	Nevis	Dark orange	Root narrow cylindrical shape,	Tropical type
46.	KSP 134	Red	Long root	Tropical type
47.	KSP135	Orange	Roots long	Tropical type
48.	Arka Suraj	Deep orange	Roots with self-core. Smooth root surface. Conical shape. Root length 15-18 cm, root diameter 3-4 cm. TSS 8-10°Brix. Carotene content 11.27 mg/100g.	Tropical type

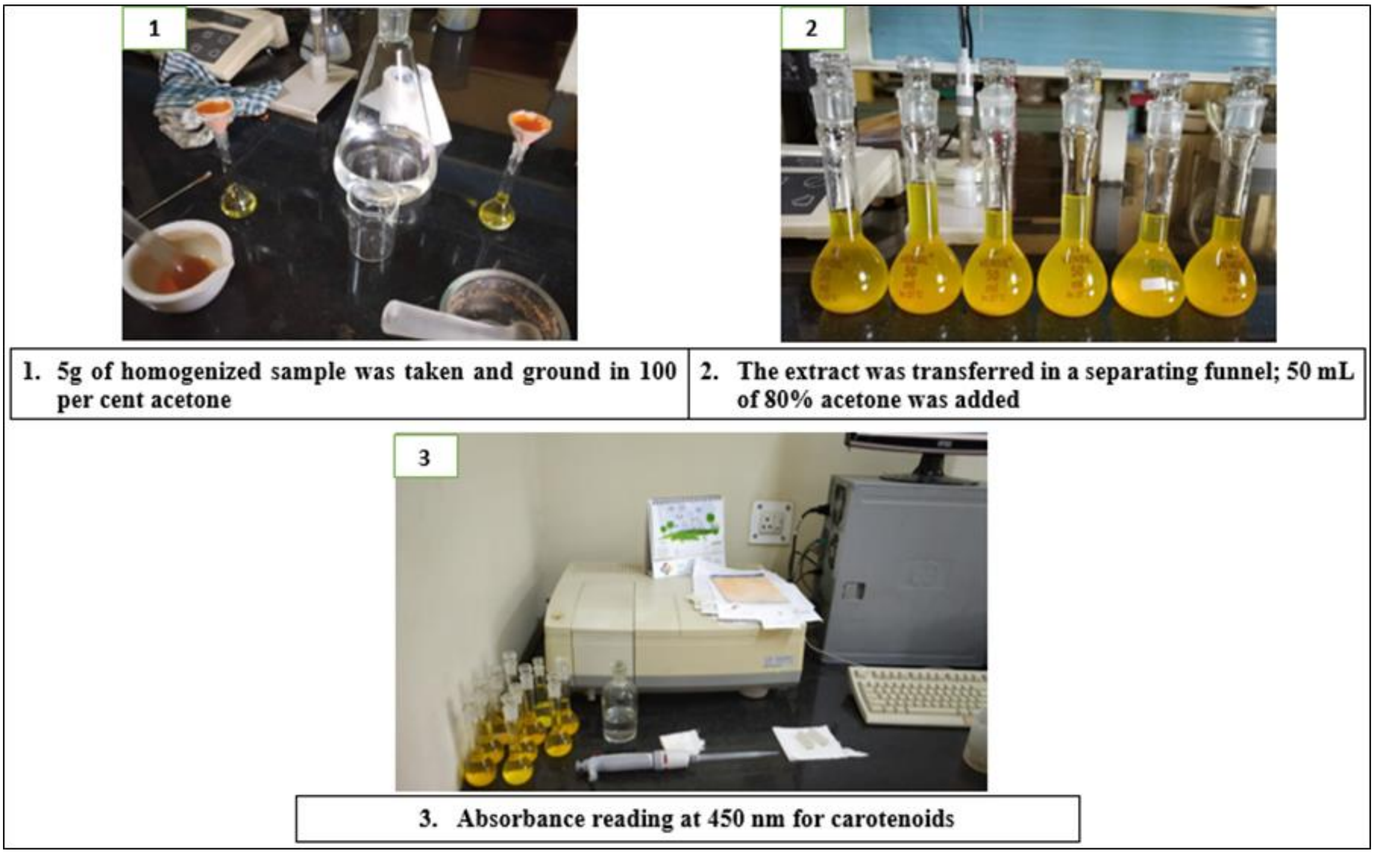

Fig 1: Estimation of carotenoid content of carrot accessions by spectrophotometer method

Table 2: Evaluation of carotenoid content of carrot accessions

S. No.	Accession No.	Average Carotenoid content (mg/100g)
1.	Acc-21C	05.97
2.	Acc-22A	05.41
3.	Acc-29	12.04
4.	Acc-50	10.08
5.	Acc-51	11.01
6.	Acc-52C	11.79
7.	Acc-54A	10.57
8.	Acc-56B	09.74
9.	Acc-60	11.74
10.	Acc-64	11.15
11.	Acc-72	12.82
12.	Acc-76	13.59
13.	Acc-77	09.32
14.	Acc-77B	09.40
15.	Acc-84	08.72
16.	Acc-85	16.03
17.	Acc-87	NA
18.	Acc-88	13.44
19.	Acc-91	12.63
20.	Acc-92	15.39
21.	Acc-96A	16.94
22.	Acc-105	11.13
23.	Acc-113B	09.01
24.	Acc-135	12.69
25.	Acc-135B	12.69
26.	Acc-144	11.57
27.	Acc-144B	11.57
28.	Acc-145	11.45
29.	Acc-146	09.81
30.	Acc-147	10.63
31.	KSP181	0.00
32.	Acc-148	11.57
33.	Acc-149	09.01

34.	Acc-152	13.32
35.	Acc-152B	12.69
36.	Acc-154	15.49
37.	Acc-156	16.94
38.	Acc-159	12.01
39.	Acc-163B	07.79
40.	Acc-164	11.65
41.	Acc-167B	09.77
42.	Acc-261	07.09
43.	Acc-278	09.61
44.	Bermuda	11.57
45.	Nevis	12.41
46.	KSP 134	NA
47.	KSP135	NA
48.	Arka Suraj	11.27
CD(0.01)		2.72

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