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Short communication

Quality attributes of novel carrot genotypes

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ABSTRACT

Carrot is rich sources of natural antioxidants. In the present experiments few novel genotype were evaluated for their antioxidant content. Antioxidant activity was measured using four *in vitro* assays viz. ferric reducing antioxidant power (FRAP), cupric reducing antioxidant power (CUPRAC), 2, 2-diphenyl-1-picrylhydrazyl (DPPH) and Trolox equivalent antioxidant capacity assays (TEAC). Additionally five colour attributes were evaluated. Among carrot genotypes, significant difference ($p<0.05$) was observed with respect to antioxidant composition and antioxidant activity. Total phenols and total flavonoids varied from 12.59 to 290.18 mg GAE/100 g fresh weight (fw) and 4.91 to 109.2 mg CE/100 g fw respectively. High positive correlation between phenolics and antioxidant activity suggested that phenolics might be predominant antioxidant in carrot. Although black genotype had highest antioxidant potentiality, it had relatively poor consumer preference. On the other hand dark red and dark orange genotype have high consumer preference despite of its poor antioxidant potentiality.

Key words: *Daucus carota*, novel genotype, antioxidants, colour properties

Routine consumption of fruits and vegetable is associated with reduced risk of various non-communicable diseases like cancer, cardiovascular disease, diabetes, etc. Disease prevention properties of fruits and vegetable are attributed to their inherent nutraceutical, having antioxidant potential. Antioxidant potentiality is highly influenced by its genetic architecture of the crop. Generally, the antioxidant composition is determined by alleles which are specific to the species. However, the antioxidant composition of a novel genotype of that species may be different.

Carrot is an important root vegetable having most of the natural antioxidants (Sun *et al*., 9). Presently carrot cultivar available in the market mostly is orange in colour. However first cultivated carrot exhibited purple or yellow in colour at its center of origin i.e. Afghanistan (Leja *et al*., 8). In Europe, white and orange coloured genotype evolved in early 1600 AD as a result of selection from yellow carrot are/ or hybridization of cultivated carrot with its relative. The Asiatic carrot was developed from the Afghan type and a red type appeared in China and India around the 1700 AD. The orange coloured genotype spread faster to other continents through trade route and become predominant in commercial production (Bransky *et al*., 2). Light red coloured genotype is cultivated mainly in north India to meet the demand for preparation of traditional sweet dessert 'Halwa' (Koley *et al*., 6). Carrots of other colour become obsolete due to less preference among the consumer. However recent time the novelty of these various coloured carrot genotype revealed, which lies in their pigment composition. It has been observed that the carrot of a different colour has different pigment composition. Fortunately, all these pigments have antioxidant potentiality. Although the document on pigment composition is available, scanty information of antioxidant activity has been reported so far. In the present study bioactive compounds, antioxidant potential of novel carrot genotype was evaluated. Additionally, five colour properties of this genotype were also evaluated to understand the possible relationship among colour with antioxidant potentiality.

Seven carrot genotype of various colours (Black: Pusa Asita; Dark Red: Pusa Rudhira, eight Red: VRCAR 109, Dark orange: Kuroda, eight Orange: VRCAR 91-1, Yellow: VRCAR 127 and Cream: VRCAR 160) were collected from the experimental fields of Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh, India. Crops were raised under optimal production practices. Roots were harvested at a fresh harvest maturity stage. Roots were thoroughly washed with ordinary tap water to remove adhering soil and other dirt. After washing, roots were shorted out based on uniform colour and shape of the cultivars. A representative sample was taken for subsequent analysis.

Betacarotene was quantified after chromatographic separation followed by estimation at 452 nm using a spectrophotometer. Total phenolic content was

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estimated using folin ciocalteau reagent (FCR) according to the method followed by Koley *et al.* (6). Results were expressed as mg gallic acid equivalent (GAE/100g). Total flavonoid content was analyzed using aluminium chloride method. The results were expressed as catechin equivalent (mg CE/100 g). Anthocyanin was estimated using pH differential methods followed by Koley *et al.* (6).

Antioxidant activity of the hydrophilic extract was evaluated using four in vitro methods. Reducing power was evaluated using ferric reducing antioxidant power (FRAP) and cupric ion reducing antioxidant capacity (CUPRAC). Free radical scavenging assay was evaluated using DPPH and TEAC methods. These entire assays were carried out accordingly described by Koley *et al.* (6). The core colour of the carrot was determined immediately after harvest. CIELAB parameters were determined using a Colour Tec PCMTM Colourimeter. Additionally, hue and chroma were calculated according to Koley *et al.* (6). Sensory profile of carrot genotype was evaluated by a panel using 5 points hedonic scale.

Values are presented as a mean of three replicates. The results were statistically analyzed by ANOVA. Statistical significance was accepted at a level of 5% level. Due presence of an extreme value, spearman rank correlation was performed among the attributes using SPSS 16 software.

In the present study three major groups of hydrophilic antioxidant and one lipophilic antioxidant was evaluated (Table 1). Phenolics were predominant antioxidant in all genotype. The total phenol content found to vary significantly ($p<0.05$) among all genotype, ranging from 12.59 to 290.18 mg/100g fwb. Compare to other colour, black carrot genotype has very high phenolic content, which is also reported by Koley *et al.* (6) and Leja *et al.* (8). Among other colour groups, yellow colour genotype has higher total phenol content compare to red, orange and cream coloured genotype. Like phenolics, a similar trend was observed for total flavonoids content. Black carrot genotype showed very high flavonoids content, whereas carrots of other colour have relative much lower flavonoids content. The information on the total flavonoids content of carrot is scanty. Anthocyanin was only detected in black carrot genotype. The total monomeric anthocyanins content of black carrot genotype was 86.5 mg C3G/100g FW. The level of anthocyanins in the present study was within the range as reported various researcher which varied from 1.50 to 350.00 mg C3G/ 100 g fw (Kammerer *et al*., 4; Sun *et al*., 9). Among four major carotenoids, β-carotene is the predominant carotenoid in carrot genotype (Sun *et al*., 9). The β-carotene content in various genotypes ranged between 0 and 4.62 mg/100 g. High β-carotene content was observed for orange coloured genotype, whereas moderate quantity was observed in red coloured genotype. Relatively lower quantity beta carotene was observed in yellow and cream coloured genotype. No β-carotene was detected black coloured genotype. The present result is comparable with earlier published literature (Sun *et al.*, 9).

Table 1. Antioxidants, antioxidant activity and colour properties of various coloured genotype of carrot.

Parameter	Black	Dark red	Light red	Dark orange	Light orange	Yellow	Cream
Phenolics (mg GAE/100g)	290.18^{a}	20.42^{c}	15.93^{d}	12.59^{e}	14.14^{d}	30.8^{b}	21.94^{c}
Flavonoids (mg CE/100g)	109.2^{a}	6.82^{c}	4.87^{d}	5.49^{d}	5.32^{d}	9.45^{b}	4.91^{d}
TMA (mg C3G/100g)	86.5	nd	nd	nd	nd	nd	nd
β-carotene (mg/100 g)	Nd	3.31^{b}	2.94^{b}	4.62^{a}	4.23^{a}	0.32^{c}	0.09^{c}
TEAC (µmol TE/g)	54.31^{a}	3.13^{c}	2.43^{c}	2.15^{d}	1.72^{d}	5.00^{b}	3.97^{bc}
DPPH (µmol TE/g)	29.72^{a}	1.42^{c}	0.79^{d}	0.58^{d}	0.62^{d}	2.81^{b}	3.45^{b}
FRAP (µmol TE/g)	50.51^{a}	1.62^{b}	1.04^{c}	0.81^{c}	0.89^{c}	1.75^{b}	1.90^{b}
CUPRAC (µmol TE/g)	75.47^{a}	4.11^{c}	3.13^{d}	2.75^{d}	2.71^{d}	5.55^{b}	5.42^{b}
Lightness (L)	15.95^{e}	53.14^{d}	60.67^{c}	57.82^{c}	70.33^{ab}	75.89^{a}	67.04^{b}
Redness (a*)	3.61^{c}	13.68^{a}	10.19^{a}	12.75^{a}	5.83^{b}	-9.10^{d}	-8.09^{d}
Yellowness (b*)	-4.58^{d}	25.65^{c}	29.34^{c}	44.72^{b}	51.94^{a}	43.85^{b}	28.87^{c}
Hue (°)	308.25^{a}	61.93^{e}	70.85^{d}	74.08^{cd}	83.60^{c}	281.74^{b}	285.65^{b}
Chroma	5.83^{d}	29.07^{c}	31.06^{c}	46.51^{b}	52.27^{a}	44.79^{b}	29.99^{c}

Notes: Values are mean of three replicates; TMA: total monomeric anthocyanins; nd: not detected; L*: approximate measure of lightness; a*: positive values for reddish colours and negative values for greenish ones; b*: positive for yellowish colour and negative for the bluish; different letters in the same row represent statistically different results ($p < 0.05$).

In a nutshell, the present study suggests that black coloured genotype have very high hydrophilic antioxidant content. A recent study suggests that black carrot have antidiabetic potential (Karkute *et al*., 5). Studies on experimental animal also suggest that black carrot can be used as a safe antihyperglycemic nutraceutical as an alternative to synthetic drugs (Koley *et al*., 7). In addition to this black carrot anthocyanins are acylated with various hydroxycinnamic acid and hydroxybenzoic acid and thus they are stable to various processing and storage condition such as temperature, light and pH changes compare to non-acylated anthocyanins. Thus black carrot can be used as a functional food.

In the present experiment, four in vitro methods of the antioxidant potentiality of carrot were investigated (Table 1). Free radical scavenging assay was evaluated using two methods viz. TEAC and DPPH. In DPPH assay antioxidant activity varies from 0.58 to 29.72, higher value comes from black carrot genotype. A similar trend was observed in case of TEAC assay. It is interesting to observe that the values of TEAC were slightly higher than the DPPH assay. This can be explained by the kinetic nature of the experiment in both assays. Huang *et al.* (3) reported that many antioxidants in particular phenolics that react quickly with peroxyl radicals may react slowly or may even be inert to DPPH. Thus there are chances of presences of antioxidants which react with TEAC but remain inert to DPPH. In addition to this, in the case of TEAC, redox reaction proceeds so rapidly that all reactions are complete within six minutes. However, many phenolics react slowly to DPPH and reaction continued for several hours. Thus fixed end point determination may lead to underestimation of antioxidant potentiality measured through DPPH assay. A similar trend earlier also reported carrot (Sun *et al*., 9). Reducing the capacity of carrot genotype was evaluated using FRAP and CUPRAC assays. In FRAP assay the value of antioxidant activity varies 0.81 to 50.51 µmolTE/g, wither values come from black coloured genotype. Similarly, in CUPRAC assay the value of antioxidant activity varies from 2.75 to 75.47 µmol TE/g. The antioxidant activities of these novel genotypes were similar to the earlier report (Sun *et al*., 9; Koley *et al*., 6). Overall values of in the CUPRAC assay were significantly ($p<0.05$) higher than FRAP values. High antioxidant activity in CUPRAC may be attributed due to the presence of flavonoids in carrot extract. The antioxidant potency of flavonoids is roughly proportional to the total number of -OH groups and is positively affected by the presence of an o-dihydroxy moiety in the B-ring (Apak *et al*., 1). Moreover, FRAP is electron transfer (ET) based methods. In ET methods the reactivity depends on the deprotonation and ionization potential of the reactive functional group. In general, ionization potential values decrease with increasing pH, reflecting electron donating capacity with deprotonation. FRAP assay works on a low pH range. Therefore at the acidic condition, the reducing capacity might be restrained due to protonation of antioxidant compounds (Huang *et al*., 3). Thus low antioxidant activity is observed when it measured through FRAP when compared with CUPRAC. Among all the genotype assessed, black coloured genotype has very high antioxidant potentiality. Similar to the present study, many researchers also affirmed the high antioxidant potential of black carrot (Koley *et al*., 6). Very high antioxidant activity of black carrot could due to presence high amount of phenolic compounds and anthocyanins.

Colour is the most important quality parameter both for fresh produce and processed products. It determines the acceptability of produce by the consumer. Among the different existing colour spaces, CIELAB is commonly used and recommended for most industrial applications, particularly for foods, because it uniformly covers the full visible spectrum of the human eye. Although the antioxidant composition of various coloured carrot reported by the various researcher, limited information is available on colour properties. Lightness is varied from 15.95 to 75.89. Lower values are coming from black carrot genotype due to the presence of intense anthocyanin pigments (Table 1). Redness (a*) varies from -9.10 to 13.68, with higher values coming from red and orange genotype representing the presence of red pigments lycopene and β-carotene in higher quantity. Yellowness (b*) varies from -4.35 to 51.94, with higher values coming from yellow and orange genotype representing the presence of lutein and alpha-carotene, respectively in higher quantity (Sun *et al*., 9). Both the coordinates a* and b* give access to new indices, the hue angle which represent the basic colour of carrot (Koley *et al*., 6). Positive a* and b*coordinates of red and orange coloured genotype keeping them in the first quadrant of CIELAB space with hue angle 61.93° to 70.85° and 74.08° to 83.60° for red and orange coloured cultivars, respectively. Positive a* and negative b* coordinates keeping black coloured genotype in the fourth quadrant of colour space with a hue angle of 308.25°. Similarly, negative a* and positive b* coordinate keeping yellow and cream coloured genotype in the fourth quadrant of colour space with a hue angle 281.74° to 285.65°.

People of Indian subcontinent preferred freshly harvested carrot as salad vegetables. Thus sensory evaluation of fresh carrot is more important. In the

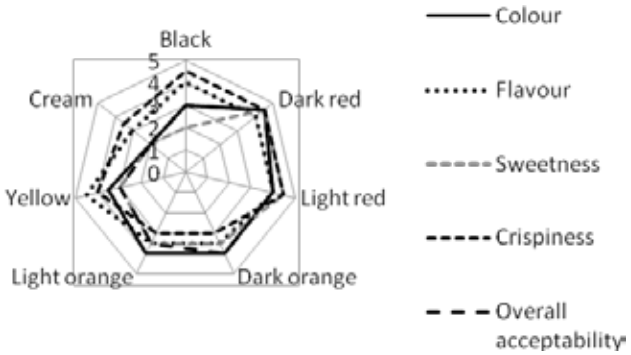

Fig. 1. Sensory profile of fresh carrot of different colour.

present study dark red coloured genotype was most preferred for colour (Fig. 1). The order of genotype for colour attributes are as follows: dark red> light red, dark orange, light orange>yellow> black>cream. Likewise, for flavor attribute, the orders of genotype are as follows: yellow>black, dark red, light red>dark orange, light orange> cream. For sweetness, a different trend was observed. The order of the genotypes is as follows: dark red, light red>dark orange, light orange>yellow>black, cream. For crispiness the order of genotype are as follows: black, dark red, light red> yellow>dark orange, light orange>cream. The overall acceptability was highest for the dark red and dark orange genotype. Although both of this genotype has low antioxidant potentiality compare to black coloured genotype, they are still preferred by the consumer. One of the reasons might be due to the market prevalence of these two genotypes. Carrot of other colour rarely observed in the market. Thus consumers are most aware of these two genotypes. Low preference of black carrot might be due to high phenolic content which gives astringent taste to the genotype. Unlike our observation, Surles *et al.* (10) have observed a different trend for the sensory character of carrot genotype. This may be due to the difference in genotype, prevalent climatic condition, soil condition, and consumer preference.

Correlation analysis was performed to understand the possible relationship among antioxidant content, antioxidant activity, colour parameter and sensory profile of carrot genotype (Table 2). Due presence of extreme value, most of the variables not followed normality at a 5% level of significance. Thus Spearman rank correlation was performed. Pair-wise correlations between the antioxidant contents (except β-carotene) and antioxidant activity were positive among all the genotype. The total phenolics contents were highly positively (p-value < 0.0001) correlated with FRAP (rs = 0.964), CUPRAC (rs = 0.964), TEAC (rs = 0.964) and DPPH (rs = 0.964).

Table 2. Correlation coefficient of antioxidant contents and antioxidant activity.

Spearman correlation coefficients, N = 7 Prob N |r| under H0: Rho = 0				
	TEAC	DPPH	FRAP	CUPRAC
Total phenolics	0.964**	0.964**	0.964**	0.964**
	<0.0001	<0.0001	<0.0001	<0.0001
Total flavonoids	0.607	0.429	0.429	0.607
	0.148	0.337	0.337	0.148
Total anthocyanin	0.612	0.612	0.612	0.612
	0.144	0.144	0.144	0.144
β-carotene	-0.893**	-0.964**	-0.964**	-0.893**
	0.007	<0.0001	<0.0001	0.007

The correlation with total flavonoids and anthocyanin were little lower in comparison to total phenolics. The present study suggested that the phenolic is the predominant antioxidant in carrot. A similar trend was observed in Indian carrot (Koley *et al*., 6). The correlation between colour/sensory attribute and antioxidant were not statistically significant (data not presented).

The present study demonstrates the antioxidant potentiality of various colour carrot genotype. A high positive correlation between phenolics and antioxidant activity suggested that phenolics might be predominant antioxidant in carrot. Black coloured genotype had the highest content of hydrophilic antioxidant with highest antioxidant potentiality. However, it had a low preference among the consumer. On the other hand, dark red and dark orange coloured genotypes had low hydrophilic antioxidant, with low antioxidant potentiality.

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