Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(6): 1577-1581
Received: 18-08-2020
Accepted: 21-09-2020

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Influence of conditions of growing and months of sowing on storability and quality of carrot cv. New Kuroda in cold storage environment

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Abstract
An investigation was carried out at Vegetable Research Station and Floriculture Research Station, Rajendranagar, Sri Konda Laxman Telangana State Horticultural University, Mulugu (V & M), Siddipet Dist., Telangana State during the period of 2017-18 and 2018-19 to determine the influence of conditions of growing and months of sowing on storability and quality of carrot cv. New Kuroda in cold storage environment. The experiment was laid out in CRD with three replications. All the parameters in terms of physiological loss in weight, firmness, decay percentage, β-carotene, ascorbic acid content, TSS, reducing sugars, total sugars were significantly differed among storage and quality of carrot. The minimum per cent of physiological loss in weight (3.13%), firmness (12.81 kg/cm^2) and per cent of decay (1.37%) was recorded in T_2 (October sowing and open field condition). Maximum β-carotene content (3.62 mg/100g), ascorbic acid content (4.41 mg/100g), TSS content (12.08 °Brix) and reducing sugars (1.29 mg/100g) was recorded in T_{10} (December sowing in shade net).

Keywords: Carrot, cold storage, quality, physiological loss in weight, reducing sugars

Introduction
Carrot is very important nutritious vegetable crop cultivated throughout the world as protective food which belongs to the family Umbelliferae. Even though many delicacies are prepared from carrot, it is more acclaimed as salad vegetable due to its characteristic palatability. Carrot comes in different colors whereas orange-yellow color is more predominantly cultivated due to its rich source of carotene. It is a precursor of vitamin A. It consists of nutrients such as proteins, vitamins, carbohydrates, fiber, potassium, sodium, thiamin and riboflavin and also high in sugar. Its use increases resistance against the blood and eye diseases.

The quality of carrot is influenced by both biotic and abiotic parameters, and after harvest, the critical operations like handling, storage and processing (Seljasen *et al.*, 2013) [22]. Unpacked carrots loose water loss and proper packaging will prevent desiccation and hence prolong the shelf life. Low temperatures and absence of ethylene and sufficient oxygen in the packaging headspace atmosphere are important to avoid quality deterioration (Seljasen *et al.*, 2013) [22]. According to Holden *et al.* (1999) [7] raw carrot roots contain, on average, 12% of dry matter, 4.5% of sugars, 2.0% of dietary fibre, 5.7mg/100g of vitamin C. The high biological value of this vegetable relates mainly to carotenoid compounds and dietary fibre, which are components of carrot roots tissue. Carotenoids are red, orange or yellow fat soluble plant pigments. In human organism, some carotenoids are converted into vitamin A (Handelman, 2001) [6]. The main carotenoid compounds found in carrot roots are α-carotene and β-carotene (Simon and Wolff 1987, Mayer-Miebach and Spiess 2003) [23, 15]. Other data show that carotenoid content is highly differentiated among carrot cultivars and ranges from 4 to 25mg/100g or even more (Rubatzky *et al.* 1999) [19]. Skrede *et al.* (1997) [24] found that high carotenoid content in carrot results in a more reddish and darker color of the roots. Carotenoid content increases with the age and size of storage root (Lee, 1986 and Rosenfeld, 1998) [13, 18]. Soluble sugars are the dominant storage compounds in carrot roots. They account for 34-70% of dry weight of the root and are stored in vacuoles of the parenchyma (Daie, 1984 and Nilsson, 1987) [4, 16]. Most of the produced carrots are stored for several months before consumption. Carrot roots can be stored successfully for 6-8 months in cold store conditions, depending upon the cultivar and quality of the roots. Recommended storage conditions are: temperature of 0-1°C and 95-98% RH (Stoll and Weichmann 1987) [26]. Storage conditions are among the main factors influencing changes of carrot roots quality during postharvest period (Seljasen *et al.*, 2001) [21]. However it is believed that carotenoid content in the roots is little affected by postharvest storage (Koca and Karadeniz 2008) [9].

Sometimes an increase of carotenoid content is observed (Le Dily et *al*., 1993, Kopas-Lane and Warthesen, 1995, Kidmose *et al*., 2004) [12, 10, 8].

Sugar compounds are the substrates used during storage for the respiration process in the plant tissue. Increasing hexoses and decreasing sucrose content was observed during storage of carrot roots (Suojala, 2000) [27]. Variation in biochemical constituents of carrot was documented by various workers under different storage conditions. In view of this present work to determine the influence of long-term storage of carrot on quality traits, related to their physical and chemical parameters.

Material and Methods

The experiment was carried out during *Rabi* and Summer (2017-18 and 2018-19). The field experiment was carried out at Vegetable Research Station and storage studies was carried out at Laboratory of Floriculture Research Station, Rajendranagar, SKLTSHU, Hyderabad.

Seeds of New Kuroda variety were sown in the plot as per the experimental sowing dates. i.e, September 2nd week, October 2nd week, November 2nd week, December 2nd week, January 2nd week and February 2nd week and two levels of conditions i.e, Open condition and Shade net condition on storage of carrot. Mature carrot roots were harvested and transported on the same day to the Laboratory. The fruits were grouped according to replication and treatment. They were then trimmed and washed with clean tap water to remove any dirt. Each treatment included one kg of roots with three replications and stored at 0^0C and 90% RH conditions. The storage studies were conducted for 90 days and data was collected at 30 days interval. The postharvest experiment was laid out in CRD with three replications and physiological, biochemical observations were recorded.

Physiological Parameters

The Per cent of Physiological loss in weight (PLW) was recorded by the formulae,

$$\% \text{ PLW} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

Percentage of Decay (%)

Carrot cultivars treated with various chemicals were stored at 0^0C and 90% RH monitored daily for signs of decay which included fungal mycelia growth, flaccidity and necrotic spots. The number of decayed roots was expressed as percentage of the total number of roots in the treatment at start of storage.

Biochemical parameters

TSS (^{0}Brix): Total soluble solids content was determined by using ERMA Hand Refract meter,

Ascorbic acid was determined by using the formula given by Ranganna (1986) [17], β-carotene was determined by using the formula given by R.P. Srivastava and Sanjeev Kumar (2002) [25].

Reducing sugar

Reducing sugars content in root was determined at root maturity by using Lane and Eyon method (AOAC, 1965) [11].

Results and discussion

1. Physiological loss in weight (%)

The differences among the different treatments were found to be significant with respect to physiological loss in weight during storage at 0˚C and RH of 90% (Table-1).

At 30, 60 and 90 days of storage study revealed that, the treatment combination T_2 (October sowing and open field condition) recorded minimum per cent of physiological losses in weight (2.00%, 3.00% and 3.13%) respectively, which was on par with T_3 (November sowing in open condition) (2.23%, 3.10% and 3.23%) respectively. At 30 days of storage, the maximum per cent of physiological loss in weight (3.10%) was recorded in T_5 (January sowing in open condition), T_6 (February sowing in open field condition) and T_7 (September sowing in shade net). At 60 and 90 days of storage, maximum per cent of physiological loss in weight (3.73% and 3.77%) was recorded in T_6 (February sowing in open field condition).

Physiological loss in weight was low up to October sown crop thereafter increased gradually up to February sown crop at 30, 60, and 90 days of storage under cold storage condition. Ruhsar *et al.* (1999) [20] reported that, storage temperature will affect the physiological loss in weight of carrot. Further, Correa *et al.* (2012) [3] reported that, the rate of water loss of a carrot is effected by surface area of the root, water vapour pressure deficient and air velocity. Hence the physiological loss in weight was very less in cold storage condition as it is ranged from 3.13 to 3.78 per cent in different treatments.

Table 1: Influence of conditions of growing and months of sowing on physiological loss in weight (%), firmness (kg/cm^2) and decay percentage of carrot cv. New Kuroda at 30, 60 and 90 days of storage (0^0C and RH of 90 %)

Treatments	Physiological loss in weight (%)			Firmness (kg/cm^2)			Decay percentage		
	30 days	60 days	90 days	30 days	60 days	90 days	30 days	60 days	90 days
$T_1 – M_1C_1$	2.57	3.37	3.41	13.32	12.93	12.10	0.70	1.50	1.70
$T_2 – M_2C_1$	2.00	3.00	3.13	13.91	13.35	12.81	0.53	0.93	1.37
$T_3 – M_3C_1$	2.23	3.10	3.23	13.65	12.90	12.35	0.63	1.17	1.50
$T_4 – M_4C_1$	2.97	3.40	3.50	12.99	12.60	12.11	1.33	2.13	2.40
$T_5 – M_5C_1$	3.10	3.57	3.67	12.91	12.21	11.62	1.70	2.67	2.77
$T_6 – M_6C_1$	3.10	3.73	3.77	12.53	11.96	11.52	2.40	3.08	3.53
$T_7 – M_1C_2$	3.10	3.20	3.48	13.23	12.68	12.11	0.73	1.47	1.60
$T_8 – M_2C_2$	2.57	3.33	3.40	13.05	12.63	11.84	0.97	1.57	1.70
$T_9 – M_3C_2$	2.53	3.23	3.57	13.52	13.04	12.33	0.72	1.13	1.57
$T_{10} – M_4C_2$	2.33	3.13	3.26	13.36	12.83	12.30	0.70	1.33	1.52
$T_{11} – M_5C_2$	3.00	3.47	3.48	12.85	12.30	11.89	1.23	2.13	2.4
$T_{12} – M_6C_2$	3.07	3.30	3.57	12.65	12.14	11.59	1.67	2.50	2.67
SE(m)±	0.15	0.04	0.05	0.73	0.15	0.14	0.02	0.1	0.11
C.D. at 5%	0.43	0.12	0.14	NS	0.44	0.42	0.05	0.3	0.32

M_1C_1- September sowing in open condition, M_2C_1-October sowing in open condition, M_3C_1-November sowing in open condition
M_4C_1 December sowing in open condition, M_5C_1-January sowing in open condition, M_6C_1-February sowing in open condition

M_1C_2-September sowing in shade net condition, M_2C_2-October sowing in shade net condition, M_3C_2-November sowing in shade net condition M_4C_2-December sowing in shade net condition, M_5C_2-January sowing in shade net condition, M_6C_2-February sowing in shade net condition

2. Firmness (kg/cm^2)

At 30, 60 and 90 days of storage the treatment combination T_2 (October sowing and open field condition) recorded maximum firmness (13.91 kg/cm^2,13.35 kg/cm^2 and 12.81 kg/cm^2) respectively (Table 1). At 30 days of storage, the minimum firmness (12.53 kg/cm^2) was recorded in T_6 (February sowing in open field condition). At 60 and 90 days of storage, the minimum firmness (11.96 kg/cm^{2}and 11.52 kg/cm^2) was recorded in T_6 (February sowing in open field condition) which was on par with T_5 (January sowing in open condition) (12.21 kg/cm^2 and 1.62 kg/cm^2) and T_{12} (February sowing in shade net) (12.14 kg/cm^2 and 1.59 kg/cm^2)

Results revealed that, the firmness of the carrot roots stored at 0°C and 90% RH during the year 2017-18 and 2018-19 ranged between 11.14 to 12.51 (kg/cm^2) and 11.52 to 12.81 (kg/cm^2) respectively. The crop sown during October under open field condition recorded more firmness compared to crop sown in February month. The carrot roots harvested from open condition showed good firmness than from shade net condition. These results are in conformity with the findings of Ruhsar *et al*. (1999) [20] and Majid Rashidi *et al.* (2009) [14].

3. Decay percentage

The differences among the different treatments were found to be significant with respect to decay percentage during storage at 0˚C and RH of 90 % (Table-1).

At 30, 60 and 90 days of storage, the treatment combination T_2 (October sowing and open field condition) recorded minimum decay percentage (0.53%, 0.93% and 1.37%) respectively followed by T_3 (November sowing in open condition) (0.63%, 1.13% and 1.50%) respectively. The maximum decay percentage (0.40%, 3.08% and 3.53%) was recorded in T_5 (January sowing in open condition).

After 90 days of storage, carrot roots under cold storage condition showed slight decrease in decay which ranged from 1.3 to 3.57 per cent during 2017-18 and 1.37 to 3.53 per cent during 2018-19. The roots harvested from early sown crop recorded lowest decay per cent compare to late sown crop due to unfavorable conditions experienced during that season.

4. β-carotene (mg/100g)

The differences among the different treatments were found to be significant with respect to decay percentage during storage at 0˚C and RH of 90 % (Table-2).

The study revealed that, at 30, 60 and 90 days of storage, the treatment T_{10} (December sowing in shade net) (3.98 mg/100g, 3.74 mg/100g and 3.62 mg/100g) respectively recorded maximum β-carotene which was on par with T_2 (October sowing and open condition) (3.91 mg/100g, 3.71 mg/100g and 3.55 mg/100g) respectively followed by T_3 (November sowing in open condition) (3.84 mg/100g, 3.69 mg/100g and 3.51 mg/100g) respectively. The minimum β-carotene (3.29 mg/100g, 3.09 mg/100g and 3.12 mg/100g respectively was recorded in T_6 (February sowing in open condition).

Table 2: Influence of conditions of growing and months of sowing on β-carotene (mg/100 g), ascorbic acid (mg/100 g) and TSS (^{0}Brix) of carrot cv. New Kuroda at 30, 60 and 90 days of storage (0^{0}C and RH of 90 %)

Treatments	β-carotene (mg/100 g)			Ascorbic acid (mg/100 g)			TSS (^{0}Brix)		
	30 days	60 days	90 days	30 days	60 days	90 days	30 days	60 days	90 days
T_1 – M_1C_1	3.75	3.49	3.34	4.46	4.36	4.29	9.74	9.91	10.10
T_2 – M_2C_1	3.91	3.72	3.55	4.65	4.43	4.38	11.64	11.89	12.08
T_3 – M_3C_1	3.84	3.69	3.51	4.56	4.42	4.36	11.57	11.76	11.95
T_4 –M_4C_1	3.32	3.42	3.21	4.35	4.21	4.15	11.37	11.61	11.13
T_5 – M_5C_1	3.31	3.15	3.19	3.68	3.59	3.53	10.45	10.62	11.19
T_6 – M_6C_1	3.29	3.09	3.12	3.57	3.35	3.29	9.42	9.66	9.88
T_7 – M_1C_2	3.56	3.47	3.4	4.48	4.32	4.26	9.04	9.13	9.68
T_8 –M_2C_2	3.45	3.39	3.23	4.47	4.29	4.26	8.69	9.50	9.95
T_9 – M_3C_2	3.81	3.57	3.43	4.51	4.38	4.32	11.27	10.14	11.68
T_{10}– M_4C_2	3.98	3.74	3.62	4.66	4.49	4.41	11.80	11.90	12.08
T_{11}– M_5C_2	3.41	3.29	3.21	3.75	4.00	3.59	11.17	11.37	11.58
T_{12} – M_6C_2	3.32	3.16	3.15	3.62	3.47	3.36	10.54	10.71	10.95
SE(m)±	0.04	0.05	0.04	0.05	0.22	0.05	0.14	0.13	0.13
C.D. at 5%	0.13	0.15	0.12	0.15	0.18	0.15	0.42	0.39	0.39

M_1C_1- September sowing in open condition, M_2C_1-October sowing in open condition, M_3C_1-November sowing in open condition
M_4C_1 December sowing in open condition, M_5C_1-January sowing in open condition, M_6C_1-February sowing in open condition
M_1C_2-September sowing in shade net condition, M_2C_2-October sowing in shade net condition, M_3C_2-November sowing in shade net condition
M_4C_2-December sowing in shade net condition, M_5C_2-January sowing in shade net condition, M_6C_2-February sowing in shade net condition

5. Ascorbic acid (mg/100 g)

The differences among the different treatments were found to be significant with respect to decay percentage during storage at 0˚C and RH of 90 % (Table-2).

At 30, 60 and 90 days of storage, treatment T_{10} (December sowing in shade net) (4.66 mg/100g, 4.49 mg/100g and 4.41 mg/100g) respectively recorded maximum ascorbic acid which was on par with T_2 (October sowing and open condition) (4.65 mg/100g, 4.43 mg/100g and 4.38 mg/100g) respectively, T_3 (November sowing in open condition) (4.56 mg/100g, 4.42 mg/100g and 4.36 mg/100g) respectively and T_9 (November sowing in shade net condition) (4.51 mg/100g, 4.38 mg/100g and 4.32 mg/100g) respectively. The minimum ascorbic acid (3.57 mg/100g, 3.35 mg/100g and 3.29 mg/100g) respectively was recorded in T_6 (February sowing in open condition) which was on par with T_5 (January sowing in open field condition) (3.62 mg/100g, 3.47 mg/100g and 3.36 mg/100g) respectively.

Decreasing tendency of β-carotene and ascorbic acid was recorded from October sown crop to February sown crop in both conditions. The extent of loss of β-carotene and ascorbic acid during the storage of 90 days is comparatively very less, hence storage of carrots under cold storage condition will help in slow deterioration of these quality parameters where carrot is very important source of ascorbic acid in human diet. Tang (2010) and Fikselova Martina *et al.,* (2010) [28, 5] also reported loss of quality traits in carrot over a period of storage condition.

6. TSS (°Brix)

The differences among the different treatments were found to be significant with respect to TSS during storage at 0°C and RH of 90 % (Table-2).

At 30, 60 and 90 days of storage, treatment T_{10} (December sowing in shade net) (11.80 °Brix, 11.90 °Brix and 12.08°Brix) respectively recorded maximum TSS which was on par with T_2 (October sowing and open condition) (11.64 °Brix, 11.89 °Brix and 12.08 °Brix) respectively and T_3 (November sowing in open condition) (11.57 °Brix, 11.76 °Brix and 11.95 °Brix) respectively.

At 30 days of storage the minimum TSS (8.69 °Brix,) was recorded in T_8 (October sowing in shade net condition). At 60 and 90 days of storage the minimum TSS (9.13 °Brix and 9.68 °Brix) was recorded in T_7 (September sowing in shade net) which was on par with T_8 (October sowing in shade net condition) (9.50 °Brix and 9.95 °Brix)

Results revealed that, there was a slight increase tendency in TSS content during storage period. However, the rate of increase in TSS under cold storage condition was not dramatic. Similar results were also reported by Ruhsar *et al.*, (1999) [20], Majid Rashidi *et al.,* (2009) [14] and Anthony Opoku *et al.*, (2009) [2] in carrot.

7. Reducing sugars (mg/100g)

The differences among the different treatments were found to be significant with respect to reducing sugars during storage at 0°C and RH of 90 % (Table-3).

At 30, 60 and 90 days of storage, treatment T_{10} (December sowing in shade net) (1.47 mg/100g, 1.38 mg/100g and 1.29 mg/100g resp.) recorded maximum reducing sugars which was on par with T_2 (October sowing and open condition) (1.43 mg/100g, 1.36 mg/100g and 1.28 mg/100g) respectively and T_3 (November sowing in open condition) (1.42 mg/100g, 1.36 mg/100g and 1.26 mg/100g) respectively. The minimum reducing sugars (1.29 mg/100g, 1.26 mg/100g and 1.20 mg/100g) respectively was recorded in T_6 (February sowing in open condition) which was on par with T_{12} (February sowing in shade net) (1.34 mg/100g, 1.27 mg/100g and 1.22 mg/100g) respectively.

After 90 days of storage reducing sugars content of carrot roots decreased from initial levels. Carrot roots harvested from October sowing under open condition in both the years maintained good levels of reducing sugars during cold storage. Shahram also expressed similar results in carrot.

Table 3: Influence of conditions of growing and months of sowing on reducing sugars (mg/100g) and total sugars (mg/100g) of carrot cv. New Kuroda at 30, 60 and 90 days of storage (0^0C and RH of 90 %)

Treatments	Reducing sugars (mg/100g)			Total sugars (mg/100g)		
	30 days	60 days	90 days	30 days	60 days	90 days
$T_1 – M_1C_1$	1.35	1.35	1.24	4.44	4.54	4.59
$T_2 – M_2C_1$	1.43	1.43	1.28	4.50	4.57	4.60
$T_3 – M_3C_1$	1.42	1.42	1.26	4.49	4.56	4.61
$T_4 – M_4C_1$	1.38	1.38	1.25	4.50	4.57	4.59
$T_5 – M_5C_1$	1.35	1.35	1.23	4.41	4.45	4.49
$T_6 – M_6C_1$	1.29	1.29	1.20	4.02	4.06	4.09
$T_7 – M_1C_2$	1.40	1.40	1.24	4.37	4.41	4.46
$T_8 – M_2C_2$	1.41	1.41	1.25	4.45	4.49	4.52
$T_9 – M_3C_2$	1.41	1.41	1.26	4.50	4.48	4.51
$T_{10} – M_4C_2$	1.47	1.47	1.29	4.55	4.59	4.64
$T_{11} – M_5C_2$	1.35	1.35	1.22	4.51	4.55	4.59
$T_{12} – M_6C_2$	1.34	1.34	1.22	4.44	4.48	4.51
SE(m)±	0.02	0.02	0.02	0.24	0.06	0.06
C.D. at 5%	0.06	0.06	0.05	NS	0.18	0.18

M_1C_1- September sowing in open condition, M_2C_1-October sowing in open condition, M_3C_1-November sowing in open condition
M_4C_1 December sowing in open condition, M_5C_1-January sowing in open condition, M_6C_1-February sowing in open condition
M_1C_2-September sowing in shade net condition, M_2C_2-October sowing in shade net condition, M_3C_2-November sowing in shade net condition
M_4C_2-December sowing in shade net condition, M_5C_2-January sowing in shade net condition, M_6C_2-February sowing in shade net condition

8. Total sugars (mg/100g)

The study revealed that, at 30 days of storage, the differences among the different treatments were found to be non-significant with respect to total sugars during storage at 0°C and RH of 90% (Table-3). At 60 and 90 days of storage, total sugars content was found significant due to growing conditions and sowing months. The treatment T_{10} (December sowing in shade net) (4.59 mg/100g and 4.64 mg/100g) recorded significantly maximum total sugars. The minimum total sugars (4.06 mg/100g and 4.09 mg/100g) was recorded in T_6 (February sowing in open condition).

Total sugars content of stored carrot roots increased slightly. Carrots harvested from October sown crop retained good levels of total sugars even after 90 days of storage.

Conclusion

From this investigation, it can be concluded that the minimum per cent of physiological loss in weight, firmness and per cent of decay was recorded in T_2 (October sowing and open field condition). Maximum β-carotene content, ascorbic acid content, TSS content and reducing sugars was recorded in T_{10} (December sowing in shade net).

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