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Studies on Packaging and Storage of Green Capsicum (Cv. Indra) at Different Storage Conditions

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Abstract

The effect of different packaging materials along with two storage conditions i.e. Zero Energy Cool Chamber (ZECC) and Cold Storage (CS) were assessed for maintaining quality attributes and extending shelf life of green capsicum. The qualities of capsicums were assessed by physiological loss in weight, firmness, rotting, ascorbic acid and moisture content. The green capsicum fruits in all the treatments showed increasing trends of physiological loss in weight (%), TSS (°B) and rotting (%) while in moisture content, ascorbic acid (mg 100^{-1} g) and firmness (N) showed decreasing trend during the advancement of storage period in ZECC and CS. The quality of capsicum fruits of green varieties under CS and ZECC were found to be best when packed in cellulose acetate (CA) film followed by breathing bags. The shelf life of green capsicum fruits was extended up to 40 days in CS, 24 days in ZECC when packed in CA film followed by breathing bags and was found to be beneficial in extending the shelf life of capsicum fruits. The green capsicum packed in CA films was found to be best packaging material for extending the shelf life followed by breathing bags and without vent polythene bags of 100 micron, 50 micron and 25 micron, in CS and ZECC storage in respect of quality parameters.

Key words : Capsicum, Cv. indra (green), shelf life, cold storage, zero energy cool chamber, chemical properties.

Capsicum (*Capsicum annum* L.) is one of the important high value vegetable crop in India and successfully grown in the temperate and subtropical regions including North Eastern States. Capsicum is the second important crop among family Solanaceae. It is known by other names such as Shimlamirch, and sweet pepper. The fruit of most species of Capsicum contains capsaicin (methyl vanillylnonenamide), a lipophilic chemical that can produce a strong burning sensation (pungency or spiciness) in the mouth of the unaccustomed eater. Capsicums are used as culinary ingredients for their colour, flavour and pungency. Capsicums are perishable products and are susceptible to chilling injuries. They are not suitable for long term cold storage. Water loss has a great impact on green bell pepper quality and it is a major cause of deterioration. For a maximum shelf life, to reduce water loss and desiccation, it is recommended to keep green bell peppers at 7.5oC and 90-95 per cent relative humidity (RH). Vegetables are highly perishable in nature due to high moisture, action of enzymes, chemicals reactions, structural changes and conditions of storage, most of vegetables are wasted. This is chief hurdle for marketing of fresh produce. Fruits and vegetables are living products undergoing a ripening and at the end ageing process, in which the plant tissue is broken down. One major constraint confronting capsicum production in developing countries is post-harvest losses as a result of unavailability of storage facilities (Anon, 2003).

This necessitates the development of special packaging techniques to extend post-harvest life of capsicum. The main aim of storage is to limit water loss from the crops due to transpiration

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which in turn causes shrivelling, tissue softening, physiological disorders. Controlled atmospheres or modified atmospheres are designed to slow down respiration and thus senescence by reducing oxygen or increasing carbon dioxide concentration (Kader, 1985). To avoid shrivelling and increase shelf-life, proper packaging and storage condition are of paramount importance. Adequate and proper packaging protects the fruit from physical, physiological and pathological deterioration (Zagory and Kader, 1998 and Dhemre *et al*., 2017). Packaging is a very important to glamorize the product in order to attract the consumer's attention.

Materials and methods

Materials and experimental design

Capsicum : Fresh and healthy fruits of capsicums Cv. Indra (green) were procured from a local progressive farmer of Tal- Rahuri, Dist. Ahmednagar for the research work. Freshly harvested fruits were cleaned and sorted manually to remove diseased and unhealthy fruits.

Packaging : The capsicum samples were packed in cellulose acetate (CA) film bags, breathing bags and polythene bags of 25, 50 and 100 micron with 2 and 4 per cent vents and without vents.

Storage : The capsicums of Cv. Indra (green) were stored at two different storage conditions viz., zero energy cool chamber (ZECC) and cold storage (CS) for further storage study.

Zero energy cool chambers (ZECC) : Based on the principles of direct evaporative cooling, low cost, zero energy input, zero energy cool chamber has been developed. The structure is made out of cheap, locally available raw material such as bricks, sand, bamboo, coconut leaves etc. with a source of water supply. The floor of this storage place is made with a single layer of bricks and the side walls with a double layer of bricks. The space between double walled bricks (3) is filled up with riverbed sieved sand. It is installed under temporary shed (thatch). Once the zero energy cool chamber is saturated with water, sprinkling of water once in the morning and once in the evening is enough to maintain the temperature and relative humidity. The temperature and relative humidity in zero energy cool chamber during research work was varied between 16-22oC and 72-88 per cent, respectively. The packed and unpacked fruits of capsicum were kept in zero energy cool chamber for storage.

Cold storage : The packed and unpacked fruits of capsicums were stored in cold storage. The storage atmosphere in cold storage was maintained at 7 ± 2°C and 85-90 per cent relative humidity.

Experimental details

1. Crop : Capsicum
2. Design : Factorial Completely Randomized Design (FCRD)
3. Treatments details :

   Factor- A : Variety - V_1- Indra (Green)

   Facor - B : Storage conditions. S_1 - Cold storage (CS) (at 7 ± 2°C and 85-90 % RH) and S_2 - Zero Energy Cool Chamber (ZECC)

   Factor - C : Packaging materials

   T_1- Capsicum stored in CA film bags, T_2 - Capsicum stored in Breathing bags, T_3 - Capsicum stored in Polythene bags of 25 micron with 2% vent, T_4 - Capsicum stored in Polythene bags of 25 micron with 4% vent, T_5 - Capsicum stored in Polythene bags of 25 micron without vent, T_6 - Capsicum

stored in Polythene bags of 50 micron with 2 % vent, T_7 - Capsicum stored in Polythene bags of 50 micron with 4% vent, T_8 - Capsicum stored in Polythene bags of 50 micron withoy vent, T_9 - Capsicum stored in Polythene bags of 100 micron with 2% vent, T_{10} - Capsicum stored in Polythene bags of 100 micron with 4% vent, T_{11} - Capsicum stored in Polythene bags of 100 micron without vent, T_{12} - Capsicum stored in open condition (Control).

Details of observations : The observations on physical and chemical parameters were recorded initially and at four days interval for fruits stored at zero energy cool chamber and in cold storage.

Physical parameters (during storage)

Physiological loss in weight (PLW) : The weight of fruits was recorded at four days interval and PLW was calculated by noting the difference between initial and subsequent weights and it was expressed in per cent (Singh *et al*., 2014).

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

Firmness : Firmness is an important factor which affects the quality of fruit and vegetable. It was determined by using Universal Testing Machine (UTM).

Penetration test was carried out at two different positions on the fruit. After running the test, the force required to penetrate into the fruit for given distance was directly obtained from the data recorder (computer). Finally, the averages of fruits from each treatment and replicate and at two different positions were taken as the firmness of capsicum in that treatment.

Rotting : The rotted percentage of stored samples was calculated by using equation,

$$\text{Rotting, \%} = \frac{\text{Wt. of rotted fruit bag}^{-1}\text{ (g)}}{\text{Wt. of total fruit bag}^{-1}\text{ (g)}} \times 100$$

Moisture content : Moisture content of sample was determined by standard oven drying method. The samples were dried in oven at 70°C till constant weight (15 h) (AOAC, 1990). The bone dried samples were removed from oven and cooled in desiccators for 10 min. The per cent moisture content on wet basis was calculated by using following equation (Nambiar and Seshadri, 2001).

$$\text{M.C. \% (w.b.)} = \frac{W_1 - W_2}{W_1} \times 100$$

where, M.C. (w.b.) = Moisture content, % Weight basis W_1= Weight of wet sample, g and W_2 = Weight of dry sample, g

Chemical Parameters : Chemical parameters such as total soluble solids (TSS) (°B), ascorbic acid (mg 100^{-1} g) were determined at 4 days interval as follows.

Total soluble solids (TSS)(°B) : The content of total soluble solids in the fruits was measured by using Erma Hand Refractometer (0–32 °Brix).

Ascorbic acid (mg 100^{-1} g) : Ascorbic acid was estimated by 2, 6-dichlorophenol indophenols-dye method given by AOAC (1990) and Ranganna (2005). Ascorbic acid is expressed in mg of ascorbic acid per 100 g of sample. The equation is,

$$\text{Ascorbic acid, mg } 100^{-1}\text{ g} = \frac{\text{Titre value (burette vale) x dye factor}}{\text{Volume of extract taken for titration}} \times \frac{\text{Volume of extract (ml)}}{\text{Weight of sample}} \times 100$$

Results and discussion

Chemical composition of fresh capsicum fruits : Fresh green capsicum had 92.61 per cent moisture content on wet basis, 4.52°B total soluble solids and 86.68 mg 100^{-1} g ascorbic acid. The results obtained in the present investigation are similar to earlier values recorded by Castro *et al*. (2008) and Antoniali *et al*. (2007) for yellow bell pepper; Manolopoulou *et al*. (2010) for green bell pepper; Rao *et al*. (2011) for sweet pepper; Renu and Chidanand (2013) for bell pepper and Singh *et al*. (2014) for green bell pepper .

Physico-chemical composition of green capsicums during storage

Ascorbic acid : The data regarding changes in ascorbic acid content of capsicum is presented in Table 1. The ascorbic acid was decreased significantly during the storage period in all the treatment combinations. The decline in ascorbic acid might be due to oxidation during storage since the oxygen present in the air. Less weight loss was observed due to less respiration rate, had more retention of ascorbic acid which is concluded by Manolopoulou *et al*. (2010).

Effect of varieties, storage and packaging material : The interaction effect of varieties, storage and packaging materials were significantly decreased with advancement of storage period for all the treatment

Table 1. Effect of varieties, storage conditions and packaging materials on ascorbic acid content of green capsicum along with their treatment combinations

Treatment combinations	Days after storage										
	0	4	8	12	16	20	24	28	32	36	40
V1S1T1	86.68	85.50	84.35	83.15	82.03	81.36	80.63	79.88	78.99	77.97	76.03
V1S1T2	86.68	85.29	84.14	82.93	81.80	81.19	80.41	79.68	78.76	77.79	75.86
V1S1T3	86.68	83.09	81.92	80.69	79.63	78.96	78.21	77.45	76.56	75.51	73.66
V1S1T4	86.68	82.05	80.86	79.65	78.63	77.90	77.21	76.40	75.51	74.49	72.63
V1S1T5	86.68	84.34	83.15	81.95	80.86	80.23	79.45	78.71	77.80	76.78	74.90
V1S1T6	86.68	83.44	82.26	81.05	79.97	79.32	78.56	77.81	76.90	75.87	74.01
V1S1T7	86.68	82.22	81.04	79.84	78.89	78.09	77.38	76.58	75.70	74.65	72.80
V1S1T8	86.68	84.59	83.41	82.20	81.10	80.47	79.70	78.95	78.06	77.05	75.14
V1S1T9	86.68	84.00	82.80	81.59	80.52	79.88	79.10	78.36	77.44	76.43	74.56
V1S1T10	86.68	82.73	81.57	80.37	79.30	78.61	77.89	77.11	76.22	75.18	73.32
V1S1T11	86.68	85.04	83.87	82.67	81.55	80.93	80.15	79.41	78.51	77.52	75.60
V1S1T12	86.68	81.70	80.67	79.53	78.49	77.82	76.38	75.22	74.35	73.30	71.46
V1S2T1	86.68	84.62	82.65	80.43	78.44	76.28	74.18	-	-	-	-
V1S2T2	86.68	84.42	82.50	80.24	78.25	76.10	74.01	-	-	-	-
V1S2T3	86.68	82.29	80.40	78.09	76.05	73.96	71.83	-	-	-	-
V1S2T4	86.68	81.28	79.42	77.01	75.03	72.92	70.81	-	-	-	-
V1S2T5	86.68	83.48	81.56	79.32	77.26	75.17	73.06	-	-	-	-
V1S2T6	86.68	82.60	80.72	78.43	76.41	74.30	72.17	-	-	-	-
V1S2T7	86.68	81.46	79.58	77.20	75.21	73.10	70.99	-	-	-	-
V1S2T8	86.68	83.71	81.79	79.55	77.51	75.40	73.31	-	-	-	-
V1S2T9	86.68	83.16	81.23	78.97	76.94	74.84	72.73	-	-	-	-
V1S2T10	86.68	81.99	80.08	77.73	75.75	73.61	71.50	-	-	-	-
V1S2T11	86.68	84.14	82.23	80.00	77.98	75.85	73.76	-	-	-	-
V1S2T12	86.68	80.10	78.26	75.83	73.85	72.76	69.65	-	-	-	-

combinations. The green capsicum on 40th day at CS, the highest retention of ascorbic acid was found in treatment V1S1T1 as 76.03 mg 100^{-1} g followed by V1S1T2 (75.86 mg 100^{-1} g) and V1S1T11 (75.60 mg 100^{-1} g), V1S1T12 showed the lowest value of ascorbic acid content (71.46 mg 100^{-1} g). At ZECC on 24th day of storage, V1S2T1 showed highest ascorbic acid content (74.18 mg 100^{-1} g) followed by V1S2T2 (74.01 mg 100^{-1} g) and V1S2T11 (73.76 mg 100^{-1} g). Lowest ascorbic acid was recorded in V1S2T12 (69.65 mg 100^{-1} g).

The results obtained in case of ascorbic acid content are similarly reported by Kadam and Singh (2006) for studying the effect of packaging materials and ethylene absorbent on shelf life of bell pepper; Manolopoulou *et al*. (2010) and Singh *et al*. (2014) for green bell pepper.

Total soluble solids (TSS) (°B) : The data regarding changes in TSS content of green capsicum is presented in Table 2. The TSS (°B) was increased significantly during storage in all treatment combinations. The increase in the TSS contents might be due reduction of moisture content, starch was being converted into sugars, increase of respiration and metabolic activity reported by Kad and Dhemre (2017) that the higher respiration rate increases the synthesis and use of metabolites result in higher TSS due to the higher change from carbohydrates to sugars.

Table 2. Effect of varieties, storage conditions and packaging materials on TSS (°B) of green capsicum along with their treatment combinations

Treatment combinations	Days after storage										
	0	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**40**
V1S1T1	4.52	4.54	4.57	4.60	4.62	4.65	4.68	4.70	4.73	4.75	4.78
V1S1T2	4.52	4.61	4.64	4.66	4.69	4.71	4.75	4.76	4.80	4.81	4.85
V1S1T3	4.52	5.36	5.40	5.42	5.46	5.50	5.53	5.55	5.58	5.62	5.65
V1S1T4	4.52	5.67	5.69	5.73	5.77	5.80	5.82	5.84	5.89	5.93	5.96
V1S1T5	4.52	4.85	4.88	4.90	4.94	4.97	5.01	5.03	5.06	5.10	5.12
V1S1T6	4.52	5.14	5.17	5.20	5.23	5.26	5.30	5.32	5.34	5.39	5.42
V1S1T7	4.52	5.56	5.58	5.62	5.66	5.69	5.72	5.74	5.78	5.82	5.85
V1S1T8	4.52	4.76	4.79	4.82	4.85	4.87	4.91	4.93	4.95	4.99	5.02
V1S1T9	4.52	5.10	5.14	5.16	5.19	5.23	5.26	5.29	5.31	5.35	5.38
V1S1T10	4.52	5.51	5.54	5.57	5.61	5.65	5.67	5.70	5.73	5.77	5.80
V1S1T11	4.52	4.73	4.76	4.78	4.82	4.84	4.87	4.90	4.92	4.96	4.98
V1S1T12	4.52	5.83	5.86	5.89	5.94	5.96	5.98	6.01	6.05	6.09	6.12
V1S2T1	4.52	4.58	4.62	4.67	4.73	4.77	4.82	-	-	-	-
V1S2T2	4.52	4.66	4.69	4.75	4.81	4.85	4.90	-	-	-	-
V1S2T3	4.52	5.45	5.47	5.53	5.59	5.63	5.69	-	-	-	-
V1S2T4	4.52	5.78	5.80	5.86	5.92	5.67	6.02	-	-	-	-
V1S2T5	4.52	4.91	4.94	5.01	5.05	5.10	5.15	-	-	-	-
V1S2T6	4.52	5.26	5.28	5.34	5.40	5.45	5.50	-	-	-	-
V1S2T7	4.52	5.68	5.70	5.76	5.82	5.56	5.92	-	-	-	-
V1S2T8	4.52	4.85	4.88	4.94	5.00	5.04	5.09	-	-	-	-
V1S2T9	4.52	5.17	5.19	5.26	5.31	5.36	5.41	-	-	-	-
V1S2T10	4.52	5.61	5.63	5.69	5.75	5.48	5.85	-	-	-	-
V1S2T11	4.52	4.81	4.84	4.89	4.96	5.00	5.05	-	-	-	-
V1S2T12	4.52	5.97	6.00	6.05	6.12	5.87	6.22	-	-	-	-

Effect of varieties, storage and packaging material : For green capsicum at CS on 40th day of storage, V1S1T12 showed highest TSS (6.12°B) and lowest TSS was found in V1S1T1 as 4.78°B. At ZECC on 24th day, V1S2T12 recorded highest TSS (6.22°B) and lowest TSS was found in V1S2T1 (4.82°B).

The results obtained in the present study are in conformity with the observations recorded by Kadam and Singh (2006) for bell peppers; Rao *et al*. (2011) and Samira (2013) for capsicum ; Renu and Chidanand (2013) for bell peppers.

Moisture content : The data on effect of various factors like varieties, storage conditions and packaging materials on changes in moisture content of capsicum are presented in Table 3. The moisture content was found to be decreased statistically significantly during advancement of storage in all the treatment combinations. The per cent decrease in moisture content was pronounced in fruits might be due to the ripening process that undergo throughout the storage period of pepper fruit causes changes in the permeability of cell membranes, making them more sensitive to loss of water (Suslow, 2000 and Antoniali *et al*., 2007).

The moisture content was decreased with increase in storage period in all treatment combinations. The Green capsicum on 40th day of storage in CS, V1S1T1 showed the highest moisture content as 86.46 per cent followed by

Table 3. Effect of varieties, storage conditions and packaging materials on moisture content (%) of green capsicums along with their treatment combinations

Treatment combinations	Days after storage										
	0	4	8	12	16	20	24	28	32	36	40
V1S1T1	92.61	92.29	91.69	91.35	90.76	89.91	89.43	88.77	87.91	87.05	86.46
V1S1T2	92.61	92.02	91.47	91.00	90.15	89.51	88.85	88.16	87.50	86.63	85.79
V1S1T3	92.61	89.87	88.97	88.70	88.09	86.49	85.39	84.66	84.01	83.20	82.69
V1S1T4	92.61	87.85	86.88	85.97	85.31	84.20	83.52	82.69	81.58	80.17	79.29
V1S1T5	92.61	90.78	90.33	89.70	88.89	87.15	86.82	85.60	85.09	83.89	83.29
V1S1T6	92.61	90.08	89.23	88.82	88.21	86.65	85.61	84.82	84.12	83.33	82.81
V1S1T7	92.61	88.55	87.17	86.29	85.68	84.61	83.86	83.20	81.78	80.64	79.74
V1S1T8	92.61	91.24	90.69	90.11	89.34	87.69	87.27	86.18	85.22	84.40	83.77
V1S1T9	92.61	90.27	89.74	89.13	88.57	86.99	85.70	84.99	84.60	83.75	83.21
V1S1T10	92.61	89.28	87.79	86.76	85.94	84.90	84.43	83.51	82.17	81.11	80.22
V1S1T11	92.61	91.56	90.87	90.31	89.58	87.87	87.53	86.32	85.41	84.65	84.16
V1S1T12	92.61	87.25	85.70	84.07	83.05	82.13	80.69	79.73	78.84	78.01	76.80
V1S2T1	92.61	91.24	90.33	89.52	88.71	87.34	85.79	-	-	-	-
V1S2T2	92.61	90.71	89.84	89.02	88.10	86.78	85.60	-	-	-	-
V1S2T3	92.61	87.77	86.22	85.13	83.15	82.10	81.44	-	-	-	-
V1S2T4	92.61	86.29	84.23	82.36	81.54	80.49	79.61	-	-	-	-
V1S2T5	92.61	89.58	87.76	86.50	85.60	83.81	82.70	-	-	-	-
V1S2T6	92.61	88.10	86.58	85.53	83.51	82.56	81.78	-	-	-	-
V1S2T7	92.61	86.71	84.83	82.65	81.87	80.75	80.01	-	-	-	-
V1S2T8	92.61	89.88	88.08	86.77	86.18	84.19	83.11	-	-	-	-
V1S2T9	92.61	88.41	86.89	85.80	83.68	82.89	82.10	-	-	-	-
V1S2T10	92.61	86.94	85.24	83.06	82.19	81.08	80.31	-	-	-	-
V1S2T11	92.61	90.23	88.39	86.99	86.51	84.52	83.45	-	-	-	-
V1S2T12	92.61	86.18	83.84	81.08	79.93	76.80	72.10	-	-	-	-

V1S1T2 85.79 per cent, V1S1T11 as 84.16 per cent and V1S1T12 showed the lowest 76.80 per cent. At ZECC on 24th day of storage, V1S2T1 showed highest moisture content 85.79 per cent followed by V1S2T2 85.60 per cent, V1S2T11 83.45 per cent and lowest was recorded in V1S2T12 72.10 per cent.

The results obtained in this study are in agreement with Kadam and Singh (2006) for bell pepper and Samira (2013) for capsicum.

Firmness : The data on changes in firmness of capsicum are presented in Table 4. The firmness of capsicum was significantly decreased in all treatment combinations by increasing storage period. Cantwell (2004) reported that firmness is directly related to water loss.

At the end of 40th day storage in CS for green capsicum, V1S1T1 recorded highest firmness as 9.84N followed by V1S1T2 as 9.83N, V1S1T11 as 9.80N and lowest in V1S1T12 (9.55N). At the end of 24th day storage in ZECC, V1S2T1 recorded highest firmness as 9.50N followed by V1S2T2 as 9.49N which is at par, V1S2T11 as 9.48N and lowest in V1S2T12 (9.01N).

Singh *et al*. (2014) reported continuous decline in fruit firmness in all packaging material by the passage of storage period and also reported that fruit stored in refrigerated MAP

Table 4. Effect of varieties, storage conditions and packaging materials on firmness (N) of green capsicums along with their treatment combinations

Treatment combinations	Days after storage										
	0	4	8	12	16	20	24	28	32	36	40
V1S1T1	11.80	11.59	11.38	11.19	10.97	10.79	10.59	10.40	10.19	9.97	9.84
V1S1T2	11.80	11.59	11.37	11.18	10.96	10.78	10.58	10.39	10.18	9.96	9.83
V1S1T3	11.80	11.47	11.26	11.07	11.86	10.68	10.47	10.28	9.90	9.87	9.73
V1S1T4	11.80	11.36	11.16	10.96	11.46	10.57	10.39	10.18	9.80	9.76	9.62
V1S1T5	11.80	11.52	11.31	11.12	11.91	10.73	10.52	10.33	10.13	9.91	9.77
V1S1T6	11.80	11.48	11.27	11.07	11.87	10.69	10.48	10.29	9.91	9.87	9.73
V1S1T7	11.80	11.38	11.17	10.98	11.48	10.59	10.40	10.20	9.82	9.78	9.64
V1S1T8	11.80	11.53	11.32	11.13	11.92	10.74	10.54	10.35	10.14	9.92	9.78
V1S1T9	11.80	11.50	11.29	11.09	11.89	10.70	10.50	10.31	10.11	9.89	9.75
V1S1T10	11.80	11.41	11.20	11.02	11.51	10.62	10.43	10.23	9.85	9.81	9.67
V1S1T11	11.80	11.55	11.34	11.16	10.94	10.76	10.55	10.36	10.15	9.93	9.80
V1S1T12	11.80	11.59	11.32	11.17	10.95	10.75	10.53	10.28	10.05	9.79	9.55
V1S2T1	11.80	11.50	11.14	10.78	10.39	10.00	9.50	-	-	-	-
V1S2T2	11.80	11.50	11.13	10.77	10.39	9.99	9.49	-	-	-	-
V1S2T3	11.80	11.39	11.03	10.67	10.28	9.88	9.39	-	-	-	-
V1S2T4	11.80	11.33	10.97	10.61	10.22	9.83	9.33	-	-	-	-
V1S2T5	11.80	11.45	11.08	10.73	10.34	9.94	9.44	-	-	-	-
V1S2T6	11.80	11.40	11.04	10.68	10.29	9.89	9.40	-	-	-	-
V1S2T7	11.80	11.34	10.98	10.62	10.23	9.84	9.34	-	-	-	-
V1S2T8	11.80	11.46	11.10	10.74	10.35	9.95	9.46	-	-	-	-
V1S2T9	11.80	11.42	11.06	10.70	10.31	9.91	9.42	-	-	-	-
V1S2T10	11.80	11.36	11.00	10.64	10.25	9.86	9.36	-	-	-	-
V1S2T11	11.80	11.48	11.12	10.76	10.37	9.97	9.48	-	-	-	-
V1S2T12	11.80	11.22	10.68	10.19	9.85	9.44	9.01	-	-	-	-

has more firmness than other storage conditions. The results obtained in this study are similar with Cantwell *et al*. (2009) for sweet pepper.

Physiological loss in weight (PLW) : The data on changes in physiological loss in weight of capsicum are presented in Table 5. The physiological loss in weight was found to be increased during storage period and the rate was more under zero energy cool chamber as compared to cold storage.

The interaction effect of varieties, different storage conditions and packaging materials on PLW of capsicum was significantly increased during storage period in all treatment combinations. At the end of 40th day storage of green capsicum in CS, V1S1T1 recorded the lowest PLW as 6.18per cent followed by V1S1T2 as 6.86 per cent, V1S1T11 as 8.48 per cent and highest in V1S1T12 15.83 per cent. In ZECC on 24th day of storage, the lowest PLW was observed in V1S2T1 6.86 per cent followed by V1S2T2 7.05 per cent, V1S2T11 as 9.20 per cent and highest in V1S2T12 20.52 per cent.

The results obtained in present study are in agreement with Nyanjage *et al*. (2005) for sweet pepper; Kadam and Singh (2006) for bell pepper; Kablan *et al*. (2008) for bell pepper; Nath *et al*. (2010) for capsicum and Singh *et al*. (2014) for shelf life enhancement under active modified atmosphere storage of capsicum.

Table 5. Effect of varieties, storage conditions and packaging materials on physiological loss in weight (PLW %) of green capsicums along with their treatment combinations

Treatment combinations	Days after storage										
	0	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**40**
V1S1T1	-	0.35	0.96	1.29	1.88	2.72	3.20	3.87	4.73	5.59	6.18
V1S1T2	-	0.62	1.17	1.64	2.50	3.12	3.79	4.48	5.13	6.01	6.86
V1S1T3	-	2.76	3.67	3.94	4.56	6.15	7.27	7.98	8.62	9.43	9.97
V1S1T4	-	4.80	5.79	6.66	7.32	8.44	9.12	9.96	11.02	12.43	13.35
V1S1T5	-	1.85	2.32	2.95	3.77	5.49	5.81	7.06	7.58	8.74	9.26
V1S1T6	-	2.57	3.41	3.82	4.43	5.99	7.02	7.78	8.50	9.30	9.84
V1S1T7	-	4.10	5.47	6.35	6.98	8.02	8.80	9.45	10.87	11.96	12.89
V1S1T8	-	1.39	1.96	2.53	3.30	4.96	5.37	6.46	7.38	8.27	8.83
V1S1T9	-	2.41	2.92	3.50	4.04	5.67	6.95	7.64	8.05	8.89	9.40
V1S1T10	-	3.40	4.87	5.90	6.70	7.73	8.20	9.13	10.46	11.55	12.40
V1S1T11	-	1.08	1.77	2.32	3.07	4.80	5.10	6.30	7.22	7.98	8.48
V1S1T12	-	5.33	6.90	8.56	9.57	10.47	11.90	12.87	13.76	14.60	15.83
V1S2T1	-	1.40	2.32	3.13	4.02	5.30	6.86	-	-	-	-
V1S2T2	-	1.92	2.78	3.62	4.53	5.85	7.05	-	-	-	-
V1S2T3	-	4.86	6.42	7.51	9.48	10.53	11.20	-	-	-	-
V1S2T4	-	6.34	8.41	10.28	11.09	12.15	13.04	-	-	-	-
V1S2T5	-	3.07	4.88	6.13	7.04	8.82	9.93	-	-	-	-
V1S2T6	-	4.53	6.07	7.10	9.12	10.07	10.86	-	-	-	-
V1S2T7	-	5.93	7.82	9.98	10.77	11.89	12.63	-	-	-	-
V1S2T8	-	2.75	4.57	5.86	6.45	8.46	9.52	-	-	-	-
V1S2T9	-	4.21	5.77	6.83	8.97	9.76	10.55	-	-	-	-
V1S2T10	-	5.69	7.40	9.57	10.46	11.57	12.33	-	-	-	-
V1S2T11	-	2.39	4.24	5.65	6.14	8.12	9.20	-	-	-	-
V1S2T12	-	6.42	8.76	11.52	12.67	15.83	20.52	-	-	-	-

Rotting : The data regarding changes in rotting of capsicums are presented in Table 6. The rotting was found to be increased during storage period and the rate was more under zero energy cool chamber as compared to cold storage.

At the end of 40th day of storage of green capsicums in CS, V1S1T1 recorded the lowest rotting as (9.38 %) followed by V1S1T2 as 9.47 per cent and highest in V1S1T11 (10.57 %). In ZECC on 24th day of storage, the lowest rotting was observed in V1S2T1 (11.86 %) followed by V1S2T2 (11.94 %) and the highest rotting was recorded in V1S2T11 (13.02 %).

The results obtained are similar with Nyanjage *et al*. (2005) for sweet pepper; Kablan *et al*. (2008) for bell pepper and Nath *et al*. (2010) for capsicum.

Summary and conclusion

The green capsicum fruits in all the treatments showed increasing trends of physiological loss in weight (%), TSS (°B) and rotting (%) while in moisture content, ascorbic acid (mg 100^{-1} g), and firmness (N) showed decreasing trend during the advancement of storage period in ZECC and CS. The quality of capsicum fruits of green and varieties under CS and ZECC were found to be best when packed in CA film followed by breathing bags. The shelf life of green capsicum fruits was extended up to

Table 6. Effect of varieties, storage conditions and packaging materials on rotting (%) of green capsicums along with their treatment combinations

Treatment combinations	Days after storage									
	4	8	12	16	20	24	28	32	36	40
V1S1T1	-	-	0.25	0.70	1.80	2.68	3.86	5.10	7.12	9.38
V1S1T2	-	-	0.32	0.79	1.86	2.76	3.93	5.16	7.19	9.47
V1S1T3	-	-	0.95	1.38	2.43	3.34	4.53	5.73	7.77	10.07
V1S1T4	-	-	0.65	1.07	2.13	3.04	4.22	5.43	7.46	9.76
V1S1T5	-	-	1.20	1.60	2.65	3.58	4.78	5.95	7.99	10.29
V1S1T6	-	-	1.02	1.45	2.49	3.43	4.63	5.79	7.84	10.13
V1S1T7	-	-	0.72	1.17	2.19	3.15	4.33	5.50	7.54	9.83
V1S1T8	-	-	1.34	1.78	2.80	3.76	4.95	6.11	8.16	10.44
V1S1T9	-	-	1.13	1.56	2.60	3.55	4.75	5.92	7.96	10.24
V1S1T10	-	-	0.89	1.35	2.41	3.32	4.51	5.70	7.73	10.05
V1S1T11	-	-	1.44	1.88	2.93	3.84	5.03	6.23	8.25	10.57
V1S1T12	-	-	0.53	1.05	2.10	3.01	4.18	5.40	7.43	9.72
V1S2T1	0.34	1.60	3.67	6.73	8.40	11.86	-	-	- -	
V1S2T2	0.43	1.68	3.75	6.81	8.48	11.94	-	-	- -	
V1S2T3	1.03	2.30	4.37	7.43	9.10	12.55	-	-	- -	
V1S2T4	0.70	1.97	4.04	7.10	8.77	12.21	-	-	- -	
V1S2T5	1.27	2.53	4.60	7.66	9.33	12.78	-	-	- -	
V1S2T6	1.08	2.36	4.43	7.49	9.16	12.60	-	-	- -	
V1S2T7	0.76	2.04	4.11	7.17	8.84	12.28	-	-	- -	
V1S2T8	1.38	2.66	4.73	7.79	9.46	12.91	-	-	- -	
V1S2T9	1.16	2.45	4.52	7.58	9.25	12.70	-	-	- -	
V1S2T10	0.93	2.21	4.28	7.34	9.01	12.47	-	-	- -	
V1S2T11	1.48	2.77	4.84	7.90	9.57	13.02	-	-	- -	
V1S2T12	0.61	1.92	3.99	7.05	8.72	12.16	-	-	- -	

40 days in CS, 24 days in ZECC when packed in CA film followed by breathing bags and was found to be beneficial in extending the shelf life of capsicum fruits.

The green capsicum packed in CA films was found to be best packaging material for extending the shelf life followed by breathing bags, 100 micron, 50 micron and 25 micron without vent polythene bags, in CS and ZECC storage in respect of quality parameters.

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