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Studies on packaging and storage of red capsicum (cv. BOMBY) 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) on quality attributes and shelf-life of red capsicum were investigated. The quality parameters assessed were physiological loss in weight, firmness, rotting, ascorbic acid and moisture content. The red capsicum fruits in all the treatments showed increasing trends of physiological loss in weight (%), TSS (°B) and rotting (%) while moisture content, ascorbic acid (mg/100g) and firmness (N) showed decreasing trend during storage period in ZECC and CS. The quality of capsicum fruits of red 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 red capsicum fruits was extended upto 40 days in CS, 24 days in ZECC when packed in CA film followed by breathing bags. The CA films was found to be best packaging material for extending the shelf life followed by breathing bags and polythene bags of 100 micron, 50 micron and 25 micron, in CS as well as ZECC storage in respect of quality parameters.

■ **KEY WORDS :** Capsicum, Cv. BOMBY (red), Shelf-life, Cold storage, Zero energy cool chamber, Chemical properties

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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. It is known by other names such as *Shimla mirch* 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. 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 (Anonymous, 2003).

This necessitates the development of special packaging techniques to extend postharvest life of capsicum. The main aim of storage is to limit water loss from the crops due to transpiration 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 shriveling and increasing 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). Packaging is a very important marketing strategy to glamorize the product in order to attract the consumer's attention. The aim of the present work was undertaken with following objectives:

– To study shelf-life of capsicum using different packaging materials at different storage conditions.

– To study the quality parameters of capsicum during storage.

METHODOLOGY

Fresh and healthy fruits of capsicums cv. BOMBY (red) were procured from a local progressive farmer of Brahamni, Tal- Rahuri, dist. Ahmednagar for the research work. Freshly harvested fruits were cleaned and sorted manually to remove diseased and unhealthy fruits. The capsicum samples were packed in CA film bags, breathing bags, polythene bags of 25, 50 and 100 micron with 2 and 4 per cent vents and without vents. Packed samples were stored at two different storage conditions *viz*., zero energy cool chamber (ZECC) and cold storage (CS). The data on temperature (°C) and relative humidity (%) were recorded for the period of experiment for above mentioned storage conditions.

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 temperature and relative humidity in zero energy cool chamber during research work was varied between 16- 22°C 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:

The experimental details are as follows:

Treatments details:

Factor – A : Variety: V_2 – Bomby (Red)
Factor – B : Storage conditions
S_1 : Cold Storage (at 7°C, 90 % RH)
S_2 : Zero Energy Cool chamber (ZECC)
Factor – C : Packaging materials.

T_1	CA film bags	T_7	Polythene bags 50 micron with 4 per cent vent
T_2	Breathing bags	T_8	Polythene bags 50 micron without vent
T_3	Polythene bags 25 micron with 2 per cent vent	T_9	Polythene bags 100 micron with 2 per cent vent
T_4	Polythene bags 25 micron with 4 per cent vent	T_{10}	Polythene bags 100 micron with 4 per cent vent
T_5	Polythene bags 25 micron without vent	T_{11}	Polythene bags 100 micron without vent
T_6	Polythene bags 50 micron with 2 per cent vent	T_{12}	Open condition (Control)

Treatment combinations: Factor A x Factor B x Factor C= 1 x 2 x 12= 24

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).

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

Firmness:

Firmness is an important factor which affects the quality of fruit and vegetable. It was determined by using Universal Testing Machine (UTM), Model – AG-X and Make: Shimadzu Corporation, Japan.

Rotting :

The rotted percentage of stored samples was

calculated by using eq.

$$\text{Rotting (\%)} = \frac{\text{Weight of rotted fruits per bag (g)}}{\text{Weight of total fruits per bag (g)}} \times 100$$

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, 1984).

Chemical parameters:

Chemical parameters such as total soluble solids (TSS) (^oB), ascorbic acid (mg/100g) were determined at 4 days interval as follows.

Total soluble solids (*TSS*) (*^oB*):

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

Ascorbic acid (*mg/100g*):

Ascorbic acid was estimated by 2, 6-dichlorophenol indophenols-dye method given by AOAC (1990). Ascorbic acid is expressed in mg of ascorbic acid per 100 g of sample.

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Chemical composition of fresh capsicum fruits:

Fresh red capsicum had 94.05 per cent (w.b.) moisture content, 5.72 ^oB total soluble solids and 124.58 mg/100g ascorbic acid. Similar results have been

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

Treatment combinations	Days after storage										
	0	4	8	12	16	20	24	28	32	36	40
S_1T_1	124.58	123.33	122.81	120.95	119.85	119.06	118.38	117.79	116.98	115.83	113.36
S_1T_2	124.58	123.02	122.46	120.58	119.42	118.73	118.01	117.40	116.59	115.46	113.10
S_1T_3	124.58	120.60	120.01	118.13	117.00	116.27	115.60	114.94	114.16	112.99	110.80
S_1T_4	124.58	119.54	118.93	117.06	115.94	115.20	114.51	113.88	113.08	111.91	109.73
S_1T_5	124.58	121.76	121.17	119.30	118.17	117.43	116.72	116.12	115.29	114.13	111.93
S_1T_6	124.58	121.13	120.55	118.65	117.52	116.80	116.12	115.48	114.69	113.51	111.33
S_1T_7	124.58	119.90	119.31	117.43	116.30	115.56	114.88	114.26	113.45	112.27	110.10
S_1T_8	124.58	122.37	121.79	119.92	118.77	118.05	117.35	116.73	115.91	114.78	112.54
S_1T_9	124.58	121.43	120.84	118.98	117.84	117.11	116.42	115.79	114.98	113.81	111.62
S_1T_{10}	124.58	120.34	119.76	117.89	116.74	116.01	115.35	114.70	113.90	112.73	110.55
S_1T_{11}	124.58	122.56	121.99	120.13	118.97	118.27	117.56	116.93	116.13	114.99	112.63
S_1T_{12}	124.58	119.03	117.71	115.86	114.72	113.99	112.83	111.72	110.37	109.84	108.54
S_2T_1	124.58	122.46	120.43	118.18	116.10	113.82	111.58	-	-	-	-
S_2T_2	124.58	122.28	120.26	117.98	115.91	113.64	111.40	-	-	-	-
S_2T_3	124.58	120.14	118.14	115.79	113.74	111.46	109.06	-	-	-	-
S_2T_4	124.58	119.11	117.16	114.80	112.71	110.45	107.97	-	-	-	-
S_2T_5	124.58	121.35	119.31	117.03	114.96	112.70	110.38	-	-	-	-
S_2T_6	124.58	120.49	118.45	116.15	114.10	111.82	109.44	-	-	-	-
S_2T_7	124.58	119.30	117.35	114.99	112.89	110.64	108.16	-	-	-	-
S_2T_8	124.58	121.61	119.58	117.29	115.21	112.93	110.64	-	-	-	-
S_2T_9	124.58	121.00	118.98	116.72	114.62	112.37	110.01	-	-	-	-
S_2T_{10}	124.58	119.83	117.85	115.48	113.42	111.14	108.70	-	-	-	-
S_2T_{11}	124.58	122.05	120.03	117.73	115.66	113.38	111.12	-	-	-	-
S_2T_{12}	124.58	117.93	115.98	113.60	111.53	109.28	106.75	-	-	-	-

recorded by Castro *et al.* (2008); Antoniali *et al.* (2007); Rao *et al.* (2011) and Renu and Chidanand (2013) for green and red pepper.

Physico-chemical composition of red 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).

The interaction effect varieties, storage and packaging material were significantly decreased with advancement of storage period for all the treatment combinations. Red capsicum at CS on 40th day, $V_2S_1T_1$ showed highest ascorbic acid content with 113.36mg/100g followed by $V_2S_1T_2$ (113.10mg/100g) and $V_2S_1T_{11}$ (112.63mg/100g).The lowest ascorbic acid was recorded in $V_2S_1T_{12}$ (108.54mg/100g). At ZECC on 24th day of storage, the highest ascorbic acid recorded in $V_2S_2T_1$ (111.58mg/100g) followed by $V_2S_2T_2$ (111.40mg/100g) and $V_2S_2T_{11}$ (111.12mg/100g).The lowest acid content was recorded in $V_2S_2T_{12}$ (106.75mg/100g).

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.

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

Treatment combinations	Days after storage										
	0	4	8	12	16	20	24	28	32	36	40
S_1T_1	5.72	5.74	5.76	5.79	5.81	5.84	5.87	5.90	5.93	5.95	5.98
S_1T_2	5.72	5.81	5.83	5.86	5.88	5.92	5.94	5.97	6.00	6.03	6.06
S_1T_3	5.72	6.63	6.66	6.69	6.72	6.74	6.77	6.81	6.84	6.87	6.89
S_1T_4	5.72	6.94	6.96	6.98	7.02	7.05	7.08	7.12	7.15	7.17	7.21
S_1T_5	5.72	6.09	6.11	6.13	6.15	6.17	6.20	6.23	6.26	6.30	6.34
S_1T_6	5.72	6.40	6.42	6.44	6.46	6.48	6.50	6.54	6.57	6.60	6.66
S_1T_7	5.72	6.83	6.85	6.88	6.91	6.94	6.97	7.00	7.04	7.07	7.10
S_1T_8	5.72	5.99	6.01	6.03	6.05	6.07	6.11	6.13	6.17	6.20	6.24
S_1T_9	5.72	6.35	6.37	6.39	6.41	6.43	6.45	6.48	6.52	6.56	6.61
S_1T_{10}	5.72	6.78	6.80	6.83	6.86	6.89	6.92	6.95	6.99	7.02	7.04
S_1T_{11}	5.72	5.95	5.97	5.99	6.01	6.04	6.07	6.09	6.13	6.16	6.20
S_1T_{12}	5.72	7.11	7.13	7.15	7.18	7.22	7.24	7.28	7.32	7.35	7.38
S_2T_1	5.72	5.79	5.83	5.89	5.93	5.98	6.02	-	-	-	-
S_2T_2	5.72	5.86	5.91	5.96	6.00	6.06	6.10	-	-	-	-
S_2T_3	5.72	6.63	6.68	6.76	6.79	6.86	6.92	-	-	-	-
S_2T_4	5.72	6.95	7.01	7.11	7.15	7.20	7.25	-	-	-	-
S_2T_5	5.72	6.10	6.16	6.22	6.27	6.32	6.38	-	-	-	-
S_2T_6	5.72	6.45	6.50	6.57	6.61	6.67	6.73	-	-	-	-
S_2T_7	5.72	6.85	6.91	7.00	7.04	7.10	7.15	-	-	-	-
S_2T_8	5.72	6.04	6.09	6.15	6.20	6.25	6.31	-	-	-	-
S_2T_9	5.72	6.36	6.42	6.48	6.52	6.58	6.64	-	-	-	-
S_2T_{10}	5.72	6.78	6.84	6.92	6.96	7.03	7.08	-	-	-	-
S_2T_{11}	5.72	6.00	6.05	6.10	6.15	6.21	6.26	-	-	-	-
S_2T_{12}	5.72	7.13	7.22	7.30	7.35	7.39	7.46	-	-	-	-

Total soluble solids (TSS) (°B):

The effect of packaging material and storage on TSS content of red capsicum is presented in Table 2. The TSS (°B) was increased significantly during storage in all treatment combinations. The increase in the TSS contents was due reduction of moisture content, starch was being converted into sugars, increase of respiration and metabolic activity reported by Ali *et al.* (2011) 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.

Red capsicum at CS on 40thday, $V_2S_1T_{12}$ recorded highest TSS as 7.38°B and lowest in $V_2S_1T_1$ (5.98°B). At ZECC on 24th day, $V_2S_2T_{12}$ recorded highest TSS as 7.46°B and lowest in $V_2S_2T_1$ (6.02°B).

The results obtained in the present study are in conformity with the observations recorded by Kadam and Singh (2006) for bell peppers, Getenit *et al.* (2008); Ali *et al*. (2011); Rao *et al*. (2011) and Samira *et al.* (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 significantly with advancement of storage in all the treatment combinations. The per cent decrease in moisture content might be due to the ripening process that undergoes 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

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

Treatment combinations	Days after storage										
	0	4	8	12	16	20	24	28	32	36	40
S_1T_1	94.05	93.68	93.07	92.75	92.16	91.33	90.82	90.13	89.25	88.39	87.82
S_1T_2	94.05	93.40	92.84	92.41	91.53	90.91	90.24	89.54	88.86	87.97	87.12
S_1T_3	94.05	91.29	90.41	90.10	89.49	87.90	86.77	86.03	85.39	84.58	84.04
S_1T_4	94.05	88.73	87.14	85.48	84.49	83.57	82.12	81.12	80.23	79.39	78.17
S_1T_5	94.05	92.21	91.75	91.10	90.28	88.57	88.24	86.96	86.44	85.28	84.74
S_1T_6	94.05	91.46	90.64	90.23	89.62	88.04	87.03	86.24	85.51	84.69	84.16
S_1T_7	94.05	89.25	88.26	87.37	86.72	85.31	84.94	84.07	82.98	81.58	80.65
S_1T_8	94.05	92.64	92.07	91.51	90.75	89.09	88.66	87.57	86.81	85.75	85.16
S_1T_9	94.05	91.67	91.13	90.54	90.03	88.37	87.11	86.39	85.96	85.13	84.61
S_1T_{10}	94.05	89.95	88.59	87.68	87.08	86.03	85.24	84.58	83.14	82.04	81.11
S_1T_{11}	94.05	92.96	92.26	91.70	90.94	89.22	88.92	87.69	86.80	86.02	85.53
S_1T_{12}	94.05	88.65	86.81	84.62	82.88	81.31	79.74	78.09	76.21	74.25	73.42
S_2T_1	94.05	92.64	91.75	90.93	90.04	88.73	87.18	-	-	-	-
S_2T_2	94.05	92.12	91.29	90.42	89.51	88.20	87.02	-	-	-	-
S_2T_3	94.05	89.18	87.64	86.53	84.59	83.53	82.84	-	-	-	-
S_2T_4	94.05	87.75	85.64	83.78	82.96	81.90	80.99	-	-	-	-
S_2T_5	94.05	90.99	89.20	87.91	87.03	85.22	84.13	-	-	-	-
S_2T_6	94.05	89.54	88.01	86.94	84.93	83.98	83.20	-	-	-	-
S_2T_7	94.05	88.13	86.24	84.09	83.30	82.15	81.44	-	-	-	-
S_2T_8	94.05	91.31	89.49	88.22	87.60	85.59	84.54	-	-	-	-
S_2T_9	94.05	89.85	88.29	87.24	85.11	84.32	83.50	-	-	-	-
S_2T_{10}	94.05	88.37	86.65	84.48	83.60	82.49	81.74	-	-	-	-
S_2T_{11}	94.05	91.67	89.80	88.41	87.93	85.92	84.85	-	-	-	-
S_2T_{12}	94.05	87.06	83.31	80.54	78.32	75.43	70.45	-	-	-	-

content was decreased with increase in storage period in all treatment combinations.

Red capsicum at CS on 40th day, $V_2S_1T_1$ showed highest moisture content as 87.82 per cent followed by $V_2S_1T_2$ as 87.12 per cent, $V_2S_1T_{11}$ as 85.53 per cent and lowest in $V_2S_1T_{12}$ as 73.42 per cent. At ZECC on 24th day of storage, the highest moisture content was recorded in $V_2S_2T_1$ as 87.18per cent followed by $V_2S_2T_2$ as 87.02 per cent, $V_2S_2T_{11}$ as 84.85 per cent and lowest in $V_2S_2T_{12}$ as 70.45 per cent.

The results obtained in this study are in agreement with Kadam and Singh (2006) for bell pepper and Samira *et al.* (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 *et al*. (2004a) reported that firmness is directly related to water loss.

The interaction effect of varieties, storage conditions and packaging materials on firmness of capsicum was significantly decreased during storage period. Red capsicum at the end of 40th day storage in CS, the highest firmness was recorded in $V_2S_1T_1$ (5.80N) followed by $V_2S_1T_2$ (5.78N), $V_2S_1T_{11}$ (5.76N) and lowest in $V_2S_1T_{12}$ (5.40N). In ZECC on 24th day of storage, $V_2S_2T_1$ recorded highest firmness as5.54N followed by $V_2S_2T_2$ (5.53N) which is at par, $V_2S_2T_{11}$ (5.52N) and lowest in $V_2S_2T_{12}$ (5.02N).

Singh *et al*. (2014) reported continuous decline in fruit firmness in all packaging material by the passage

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

Treatment combinations	Days after storage										
	0	4	8	12	16	20	24	28	32	36	40
S_1T_1	7.09	6.97	6.83	6.69	6.60	6.50	6.39	6.27	6.09	5.97	5.80
S_1T_2	7.09	6.95	6.81	6.68	6.59	6.48	6.37	6.25	6.08	5.95	5.78
S_1T_3	7.09	6.84	6.70	6.57	6.49	6.37	6.27	6.15	5.97	5.84	5.68
S_1T_4	7.09	6.79	6.65	6.52	6.43	6.32	6.21	6.10	5.91	5.79	5.62
S_1T_5	7.09	6.90	6.76	6.63	6.54	6.43	6.33	6.20	6.03	5.90	5.74
S_1T_6	7.09	6.85	6.71	6.58	6.49	6.39	6.28	6.16	5.98	5.85	5.69
S_1T_7	7.09	6.80	6.66	6.53	6.44	6.33	6.22	6.11	5.92	5.80	5.64
S_1T_8	7.09	6.91	6.77	6.64	6.55	6.44	6.33	6.21	6.04	5.91	5.74
S_1T_9	7.09	6.87	6.73	6.60	6.51	6.41	6.30	6.18	6.00	5.87	5.71
S_1T_{10}	7.09	6.81	6.68	6.55	6.46	6.35	6.24	6.12	5.94	5.82	5.66
S_1T_{11}	7.09	6.92	6.79	6.65	6.56	6.46	6.35	6.23	6.05	5.93	5.76
S_1T_{12}	7.09	6.88	6.70	6.49	6.33	6.21	6.11	5.96	5.79	5.59	5.40
S_2T_1	7.09	6.82	6.56	6.31	6.05	5.80	5.54	-	-	-	-
S_2T_2	7.09	6.81	6.55	6.31	6.04	5.79	5.53	-	-	-	-
S_2T_3	7.09	6.70	6.44	6.19	5.93	5.68	5.42	-	-	-	-
S_2T_4	7.09	6.64	6.38	6.14	5.86	5.61	5.36	-	-	-	-
S_2T_5	7.09	6.76	6.50	6.25	5.99	5.74	5.48	-	-	-	-
S_2T_6	7.09	6.71	6.45	6.20	5.94	5.69	5.43	-	-	-	-
S_2T_7	7.09	6.65	6.39	6.15	5.88	5.63	5.37	-	-	-	-
S_2T_8	7.09	6.77	6.51	6.26	6.00	5.75	5.49	-	-	-	-
S_2T_9	7.09	6.73	6.47	6.22	5.96	5.71	5.45	-	-	-	-
S_2T_{10}	7.09	6.67	6.41	6.16	5.90	5.65	5.39	-	-	-	-
S_2T_{11}	7.09	6.79	6.54	6.29	6.02	5.78	5.52	-	-	-	-
S_2T_{12}	7.09	6.71	6.39	6.13	5.73	5.41	5.02	-	-	-	-

of storage period and also reported that fruit stored in refrigerated MAP has more firmness than other storage conditions. The results obtained in this study are similar with Cantwell *et al.* (2009) for sweet pepper; Manolopoulou *et al.* (2010) and Lahay *et al.* (2013) for capsicum.

Physiological loss in weight (PLW)

The data on changes in physiological loss in weight of capsicum is 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 chambers 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. Red capsicum at CS on 40th day of storage, $V_2S_1T_1$ showed the lowest PLW as 6.24 per cent followed by $V_2S_1T_2$ as 6.92 per cent, $V_2S_1T_{11}$ as 8.51 per cent and highest in $V_2S_1T_{12}$ as 20.62 per cent. In ZECC on 24th day of storage, lowest PLW was recorded in $V_2S_2T_1$ as 6.89 per cent followed by $V_2S_2T_2$ as 7.08 per cent, $V_2S_2T_{11}$ as 9.24 per cent and highest in $V_2S_2T_{12}$ as 23.60 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.

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.

The interaction effect of varieties, different storage

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

Treatment combinations	Days after storage										
	0	4	8	12	16	20	24	28	32	36	40
S_1T_1	-	0.39	1.01	1.33	1.92	2.77	3.26	3.93	4.79	5.65	6.24
S_1T_2	-	0.67	1.23	1.69	2.56	3.17	3.84	4.52	5.18	6.07	6.92
S_1T_3	-	2.80	3.69	3.97	4.59	6.18	7.30	8.01	8.65	9.46	10.00
S_1T_4	-	5.36	6.94	8.60	9.59	10.50	11.95	12.91	13.80	14.65	15.86
S_1T_5	-	1.87	2.35	2.98	3.79	5.51	5.84	7.10	7.60	8.76	9.29
S_1T_6	-	2.61	3.44	3.85	4.45	6.02	7.05	7.82	8.53	9.34	9.87
S_1T_7	-	4.83	5.81	6.70	7.36	8.47	9.15	10.00	11.06	12.45	13.38
S_1T_8	-	1.43	2.01	2.57	3.34	5.00	5.42	6.50	7.23	8.31	8.87
S_1T_9	-	2.43	2.96	3.55	4.07	5.70	6.98	7.67	8.07	8.91	9.43
S_1T_{10}	-	4.13	5.50	6.39	7.01	8.05	8.84	9.49	10.90	12.00	12.93
S_1T_{11}	-	1.11	1.80	2.36	3.12	4.83	5.14	6.35	7.26	8.02	8.51
S_1T_{12}	-	5.39	7.23	9.42	11.15	12.76	14.32	15.97	17.83	19.81	20.62
S_2T_1	-	1.43	2.35	3.16	4.05	5.32	6.89	-	-	-	-
S_2T_2	-	1.95	2.80	3.65	4.56	5.88	7.08	-	-	-	-
S_2T_3	-	4.90	6.45	7.54	9.50	10.56	11.24	-	-	-	-
S_2T_4	-	6.36	8.45	10.30	11.11	12.17	13.08	-	-	-	-
S_2T_5	-	3.10	4.90	6.17	7.06	8.85	9.96	-	-	-	-
S_2T_6	-	4.55	6.09	7.13	9.15	10.09	10.89	-	-	-	-
S_2T_7	-	5.95	7.84	10.00	10.80	11.92	12.65	-	-	-	-
S_2T_8	-	2.77	4.59	5.88	6.48	8.50	9.55	-	-	-	-
S_2T_9	-	4.24	5.79	6.85	8.99	9.79	10.58	-	-	-	-
S_2T_{10}	-	5.71	7.43	9.60	10.48	11.59	12.35	-	-	-	-
S_2T_{11}	-	2.41	4.27	5.67	6.16	8.15	9.24	-	-	-	-
S_2T_{12}	-	6.98	10.75	13.52	15.73	18.64	23.60	-	-	-	-

conditions and packaging materials on rotting of capsicum was significantly increased during storage period in all treatment combinations. Red capsicum at CS on 40th day of storage, $V_2S_1T_1$ showed the lowest rotting as (9.42%) followed by $V_2S_1T_2$ (9.51%) and the highest in $V_2S_1T_{11}$ as 10.61 per cent. In ZECC on 24th day of storage, lowest rotting was recorded in $V_2S_2T_1$ (11.89 %) followed by $V_2S_2T_2$ (11.98%) and highest in $V_2S_2T_{11}$ (13.06%).

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 red 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/100g) and firmness (N) showed decreasing trend during the advancement of storage period in ZECC and CS. The quality of capsicum fruits of red varieties under CS and ZECC were found to be best when packed in CA film followed by breathing bags. The shelf-life of red capsicum fruits was extended upto 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 red 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

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

Treatment combinations	Days after storage									
	4	8	12	16	20	24	28	32	36	40
S_1T_1	-	-	0.31	0.75	1.86	2.73	3.89	5.16	7.18	9.42
S_1T_2	-	-	0.40	0.84	1.94	2.81	3.96	5.22	7.25	9.51
S_1T_3	-	-	1.01	1.43	2.49	3.39	4.56	5.79	7.83	10.11
S_1T_4	-	-	0.71	1.12	2.17	3.08	4.25	5.49	7.52	9.79
S_1T_5	-	-	1.26	1.66	2.71	3.63	4.81	6.01	8.05	10.33
S_1T_6	-	-	1.08	1.50	2.58	3.48	4.66	5.85	7.90	10.17
S_1T_7	-	-	0.76	1.22	2.26	3.20	4.36	5.56	7.60	9.87
S_1T_8	-	-	1.38	1.82	2.91	3.81	4.98	6.17	8.22	10.48
S_1T_9	-	-	1.17	1.60	2.67	3.60	4.78	5.98	8.02	10.28
S_1T_{10}	-	-	0.95	1.41	2.45	3.37	4.54	5.76	7.79	10.09
S_1T_{11}	-	-	1.50	1.93	2.96	3.89	5.06	6.29	8.31	10.61
S_1T_{12}	-	-	0.58	1.09	2.13	3.05	4.21	5.46	7.49	9.75
S_2T_1	0.38	1.65	3.70	6.76	8.47	11.89	-	-	-	-
S_2T_2	0.47	1.71	3.79	6.85	8.52	11.98	-	-	-	-
S_2T_3	1.09	2.35	4.41	7.46	9.15	12.60	-	-	-	-
S_2T_4	0.76	2.01	4.07	7.14	8.81	12.25	-	-	-	-
S_2T_5	1.30	2.57	4.65	7.70	9.36	12.81	-	-	-	-
S_2T_6	1.12	2.39	4.46	7.51	9.19	12.64	-	-	-	-
S_2T_7	0.80	2.07	4.15	7.20	8.87	12.31	-	-	-	-
S_2T_8	1.41	2.69	4.76	7.83	9.50	12.96	-	-	-	-
S_2T_9	1.19	2.48	4.55	7.62	9.28	12.74	-	-	-	-
S_2T_{10}	0.96	2.25	4.31	7.38	9.04	12.51	-	-	-	-
S_2T_{11}	1.52	2.82	4.87	7.94	9.61	13.06	-	-	-	-
S_2T_{12}	0.65	1.96	4.02	7.08	8.75	12.20	-	-	-	-

storage in respect of quality parameters.

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