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Shelf life enhancement of capsicum (*Capsicum annum* L.) under modified atmosphere packaging

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Abstract
Vegetable crops are maximum perishable crops in which bell pepper is one of them. Capsicum is a highly perishable vegetable and it is to keeping fresh after harvest, quality loss and sped up to ethylene synthesis are the critical factors of short shelf life. In this study, we studied the effectiveness of modified atmospheric packaging on the quality parameters of capsicum fruits. Fruits were picked at the color changing stage and packaged in polyethylene bags with two concentration of o_2 (3 and 5 %) in combination with three co_2 concentrations 5, 10 and 15 (%) and kept at 8 ºC and 12 ºC with 85-90 % RH for 15 days. We measured The flavor analysis, chilling injury, Taste and overall acceptability during storage. Fruit stored in an atmosphere with a environmental gaseous composition served as a control and quickly lost important qualitative characteristics, as seen by faster softening, increased head space ethylene decreased Ethylene evolution rate, respiration rate and firmness during storage. Because of the delay in post- harvest ripening, which could be attributed to the effect of MAP on reducing respiration and ethylene production rates, the efficacy of the fruit was higher in the fruit-filled with MAP (3 % o_2+ 15 co_2+ 8 ºC) compared to the control. Finally, we concluded that the fruit stored with MAP treatments retained maximum quality attributes for 15 days.

Keywords: Capsicum, respiration rate, shelf life, flavor, chilling injury and overall acceptability

Introduction
The bell pepper is important vegetable crop grown all over the globe, which is, when ripe can be green (unripe), red, yellow, orange, or brown. Peppers are low in calories and high in vitamins, particularly A and C (Sakaldas *et al*., 2010) [5]. One of the most often consumed fruits, bell peppers are abundant in bioactive components and possess high antioxidant potential (Devgan *et al*., 2019) [2]. Its consumption is rising in India right now because of rising urban customer needs. Furthermore, exports are in high demand. Chilli pepper (*Capsicum* sp.) is a popular vegetable valued around the world for its colour, flavor, spice, and nutritional value (Berke *et al.,* 2004) [1]. Chilli pepper is also used often in nearly all everyday dishes of the Indian continent. The rich supply of carotenoids contributes to chilli pepper's nutritional value because they serve as pro-vitamin A which after digestion is converted into vitamin 'A' (retinol) and gives the characteristic bright red colour to the ripe fruits (Homero-Mendezet *et al.,* 2002) [3].

Materials and Methods
Flovour (out of 10 marks)
The flavor of capsicum fruit was evaluated by a panel of experts. The panel evaluated the quality of capsicum fruit on the basis of flavor or aroma and the score was expressed on a 0-10 scale after the score offered by experts to each treatment.

Category	Mark/Range
Excellent flavour	7-10
Very good flavour	5-6.9
Good flavour	2-4.9
Poor flavour	0-1.9

Chilling injury index (CII)
The chilling injury index was determined with a five-point hedonic scale based on the surface area of fruit affected by water-soaked lesions, pitting, and skin discoloration. The scale used was; 1, <20% of the affected area in the fruits; 2, 20-40% of the affected area in the fruit.

The chilling injury index was calculated by multiplying the number of fruits scored with the same value of the hedonic scale with the corresponding scale number. Finally, the resultant number was divided by the total number of fruits. The treated fruits were stored at 6 ºC temperature for 35 days in cold storage and sampled periodically to analyzethe chilling injury index. Chilling injury symptoms were evaluated after the fruit had been held for 2 days in the air at 20 °C and ambient RH.

Taste (out of 10 marks)

The taste of capsicum fruit was evaluated by a panel of experts. The panel evaluated the quality of capsicum fruit on the basis of taste and the score was expressed on a 0-10 scale after the score offered by experts to each treatment

Category	Mark/Range
Excellent taste	7-10
Very good taste	5-6.9
Good taste	2-4.9
Poor taste	0-1.9

Overall organoleptic rating (out of 9 marks)

The organoleptic evaluation of capsicum fruits was judged by visual method and on the basis of palatability, scored from 1 to 9 on Hedonic Rating Test Scale. For this purpose, a panel of five judges, examined the skin colour, pulp color, sweetness, and overall acceptance of capsicum fruits. The organoleptic evaluation of capsicum fruits was examined at every 3rdday to 15th day of storage.

Category	Marks
Extremely acceptable	9
Very much acceptable	8
Moderately acceptable	7
Slightly acceptable	6
Neither acceptable nor unacceptable	5
Slightly unacceptable	4
Moderately unacceptable	3
Very much unacceptable	2
Extremely unacceptable	1

$$\text{Acceptance (\%)} = \frac{\text{Number of fruits per each degree of liking}}{\text{Total number of fruit in each treatment}} \times 100$$

Treatment combinations

Treatment	Details	Notation
T_1	Control (at Ambient temperature)	$O_0C_0T_0$
T_2	3% O_2 & 5% CO_2+ 8 ºC storage temperature	O_1C_1 T_1
T_3	3% O_2 & 10% CO_2 + 8 ºC storage temperature	O_1C_2 T_1
T_4	3% O_2 & 15% CO_2 + 8 ºC storage temperature	O_1C_3 T_1
T_5	5% O_2 & 5% CO_2 + 8 ºC storage temperature	O_2C_1 T_1
T_6	5% O_2 & 10% CO_2 + 8 ºC storage temperature	O_2C_2 T_1
T_7	5% O_2 & 15% CO_2 + 8 ºC storage temperature	O_2C_3 T_1
T_8	3% O_2 & 5% CO_2 + 12 ºC storage temperature	O_1C_1 T_2
T_9	3 % O_2 & 10% CO_2 + 12 ºC storage temperature	O_1C_2 T_2
T_{10}	3% O_2 & 15% CO_2+ 12 ºC storage temperature	O_1C_3 T_2
T_{11}	5% O_2 & 5% CO_2 + 12 ºC storage temperature	O_2C_1 T_2
T_{12}	5% O_2 & 10% CO_2 + 12 ºC storage temperature	O_2C_2 T_2
T_{13}	5% O_2 & 15% CO_2 + 12 ºC storage temperature	O_2C_3 T_2

Discussion

Flavour (out of 10 marks)

The flavour of the samples in table no 1 was conducted from the 3rd day to the 15th day. The flavour decreased irrespective of gaseous composition treatments in the storage duration.This could be due to the breakdown of complex micro-nutrients by the passage of the storage period. The difference could be due to the effect of lower relative humidity in MAP samples as compared to the later treatments.

Chilling injury (out of 10 marks)

Initially chilling injury was not found but on the 9th day, the highest Chilling injury was found in treatment control on all the storage days while it was lowest in fruits under O_1, C_3 treatment in table no 2. Further, the Chilling injury increased irrespective of gaseous composition treatments in the storage duration. All the samples were not in acceptable condition on the 15th day of storage as they registered sensory quality scores of less than 5. due to severe yellowing, shrivelling, decay and off-flavour in the case of samples stored at ambient conditions whereas moderate off-flavour and severe chilling injury were observed in the case of samples stored at 8 ºC. The results agreed with the results reported by (Fasake *et al.*, 2021) [4].

Taste (out of 10 marks)

The Taste decreased irrespective of gaseous composition treatments in the storage duration. The lowest Taste was found in the treatment combination T_1 on all the storage days while it was maximum in fruits under T_4 ($O_1C_3T_1$) in table no 3. This could be due to the breakdown of complex micro-nutrients by the passage of the storage period. The difference could be due to the effect of lower relative humidity in MAP samples as compared to the later treatments.

Overall Acceptability (out of 10 marks)

In table no 4 overall acceptability decreased irrespective of gaseous composition treatments in the storage duration. It was observed that the samples treated with 3% O_2 and 15% CO_2 with 8 ºC packs received the highest score. The minimum scores were obtained by the control samples. Tirkey *et al.* (2014) also reported similar results with fresh-cut unripe papaya in MAP storage. Fasake *et al.*, 2021 [4] reported the minimally processed cauliflower stored by such means can be stored for about 4 weeks to acceptable consumer preference. (Fasake *et al.*, 2021) [4].

Table 1: Effect of MAP and storage temperature on flavour (out of 10 marks) during storage

Treatment	Storage days				
	3rd day	6th day	9th day	12th day	15th day
	Pooled	Pooled	Pooled	Pooled	Pooled
T_1	6.32	5.60	5.20	4.26	3.17
T_2	7.14	6.60	5.68	5.39	5.14
T_3	7.20	6.80	5.84	5.48	5.22
T_4	7.23	6.90	6.11	5.63	5.38
T_5	6.84	5.80	5.52	4.86	4.83
T_6	6.88	6.06	5.61	4.87	4.88
T_7	6.99	6.32	5.67	5.19	5.11
T_8	6.89	5.75	5.27	4.69	4.39
T_9	7.01	5.77	5.35	4.81	4.46
T_{10}	7.07	5.79	5.48	4.83	4.69
T_{11}	6.67	5.63	5.14	4.29	3.69
T_{12}	6.73	5.70	5.19	4.49	3.88
T_{13}	6.88	5.74	5.21	4.53	4.10
SEm±	0.03	0.04	0.02	0.02	0.02
CD(P=0.05)	NS	0.11	0.08	0.07	0.07

Table 2: Effect of MAP and storage temperature on chilling injury (out of 10 marks) during storage

Treatment	Storage days				
	3rd day	6th day	9th day	12th day	15th day
	Pooled	Pooled	Pooled	Pooled	Pooled
T_1	0.00	0.00	0.29	1.00	1.29
T_2	0.00	0.00	0.37	0.50	0.51
T_3	0.00	0.00	0.26	0.38	0.46
T_4	0.00	0.00	0.00	0.30	0.40
T_5	0.00	0.00	0.10	0.65	0.75
T_6	0.00	0.00	0.08	0.60	0.65
T_7	0.00	0.00	0.06	0.54	0.53
T_8	0.00	0.00	0.21	0.86	1.04
T_9	0.00	0.00	0.15	0.80	0.99
T_{10}	0.00	0.00	0.13	0.74	0.91
T_{11}	0.00	0.00	0.26	0.93	1.20
T_{12}	0.00	0.00	0.24	0.91	1.14
T_{13}	0.00	0.00	0.21	0.87	1.09
SEm±	0.00	0.00	0.001	0.005	0.006
CD(P=0.05)	0.00	0.00	0.003	0.013	0.016

Table 3: Effect of MAP and storage temperature taste (out of 10 marks) during storage

Treatment	Storage days				
	3rd day	6th day	9th day	12th day	15th day
	Pooled	Pooled	Pooled	Pooled	Pooled
T_1	6.18	5.38	4.27	3.74	2.78
T_2	6.90	6.39	5.79	5.43	4.98
T_3	7.11	6.50	5.90	5.54	5.16
T_4	7.23	6.62	6.21	5.64	5.33
T_5	6.54	5.75	5.12	4.91	4.25
T_6	6.63	6.88	5.32	5.05	4.58
T_7	6.77	6.05	5.66	5.24	4.80
T_8	6.90	5.56	4.74	4.57	3.69
T_9	6.45	5.60	4.80	4.65	3.82
T_{10}	6.49	5.71	4.86	4.78	4.01
T_{11}	6.26	5.42	4.34	3.89	2.98
T_{12}	6.27	5.45	4.62	3.92	3.24
T_{13}	6.31	5.54	4.68	4.40	3.57
SEm±	0.035	0.039	0.026	0.024	0.023
CD (P=0.05)	0.099	0.109	0.074	0.116	0.065

Table 4: Effect of MAP and storage temperature on overall acceptability (out of 10 marks) during storage

Treatment	Storage days				
	3rd day	6th day	9th day	12th day	15th day
	Pooled	Pooled	Pooled	Pooled	Pooled
T_1	5.30	5.87	6.450	6.300	6.00
T_2	7.20	7.20	7.750	8.055	4.50
T_3	7.24	7.43	7.80	8.20	4.23
T_4	7.40	7.66	7.98	8.31	4.15
T_5	6.67	6.75	7.49	7.53	4.86
T_6	6.84	6.89	7.56	7.59	4.79
T_7	6.92	6.98	7.70	7.80	4.53
T_8	6.12	6.37	6.98	7.13	5.32
T_9	6.26	6.51	7.14	7.20	5.13
T_{10}	6.45	6.66	7.27	7.37	4.95
T_{11}	5.36	5.89	6.53	6.64	5.71
T_{12}	5.51	6.13	6.63	6.64	5.67
T_{13}	5.80	6.26	6.75	6.74	5.42
SEm±	0.033	0.440	0.038	0.038	0.033
CD (P=0.05)	0.093	NS	0.107	NS	NS

Conclusion

Finally we are concluded that MAP and storage temperature technique effectively flavour decreased irrespective of gaseous composition treatments in the storage duration. Chilling injury increased irrespective of gaseous composition treatments in the storage duration. All the samples were not in acceptable condition on the 15th day of storage as they registered sensory quality scores of less than 5 due to severe yellowing, shrivelling, decay and off-flavour in the case of samples stored at ambient conditions whereas moderate off-flavour and severe chilling injury were observed in the case of samples stored at 8 ºC. The highest Taste and overall acceptability of bell pepper fruit was found in on all the storage days in fruits under T_4 ($O_1C_3T_1$).

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