Vegetable Science (2017) 44 (1) : 18-25

Studies on carnauba wax emulsion coating on extension of shelf-life and quality assessment in capsicum (*Capsicum annuum* L.)

Sudhir Singh

Received: January 2017 / Accepted: July 2017

Abstract

Capsicum is an important vegetable crop and rich source of vitamin C. However, it has limited shelf life of 5-7 days at ambient storage temperature. Shelf life and quality attributes in capsicum was studied with different dilutions of carnauba wax emulsion (3.7-4.8 %). Maximum sensory score (7.0-7.5) for flavor and texture sensory score was obtained for 15-20 days at room temperature and 30-35 days of refrigerated storage having dilution of 3.7-4.0% carnauba wax emulsion. Minimum physiological loss in weight of 1.23-1.62% and from 1.39-1.61% was obtained with 3.7 % carnauba wax dilution after 30-35 days of refrigerated and 15-20 days of room temperature, respectively. The hardness value in 3.7 % level of carnauba wax dilution in capsicum decreased to 5.0-12.3% and from 17.25-21.8% after 15-20 days at room temperature and 30-35 days at refrigerated storage temperature, respectively. Similarly ascorbic acid in capsicum also decreased to 6.78-10.22% and from 9.95-12.45% having 3.7% carnauba wax dilution after 15-20 days of room temperature and 30-35 days of refrigerated storage, respectively.

Keywords: Carnauba wax, shelf-life, emulsion coating, capsicum

Introduction

Capsicum or bell pepper (*Capsicum annuum* L.) is an annual herbaceous vegetable crop which belongs to the family Solanaceae. It is one of the most popular and high valued crop worldwide and specially grown in tropical and subtropical parts of the world (Lim et al. 2007) and is commonly known as capsicum (Mahadu and Ranganna 2010). It is produced throughout the world for fresh market consumption. Its consumption is gaining popularity mainly due to its availability in wide variety of colours, shapes and sizes and its characteristic flavour (Frank et al. 2001). Pepper is richest sources of vitamins, especially A and C and is low in calorie (Howard et al. 1994). Bell pepper is a highly perishable vegetable and needs appropriate handling and adequate care to maintain shelf-life and quality. Edible coating, which are defined as thin layers of wax or other material applied to the surface of a food, have been used for over 800 years. Records dated as early as the 12th and 13th centuries showed that wax coatings were applied to citrus fruits in China (Hardenburg 1967). Such coatings decreased the availability of oxygen to the fruit and therefore induced fermentation. In the United State, wax coatings have been used commercially since 1930's when oranges were coated with melted paraffin waxes (Kaplan 1986). These coatings were used to reduce post harvest water loss. Later, coatings were used to create the appearance of a glossy skin. More recently; coatings have been used to preserved attributes associated with fruit and vegetable quality, as well as increased shelf life (Kester and Fennema 1986).

Various waxes and edible coatings made from proteins, polysaccharides and various combinations of these products have been used on many other fruit and vegetable commodities as well as for other food applications including nuts, and meat products (Kester and Fennema 1986). Such coatings have been used to reduce the moisture loss and surface wounding, as well as to reduce a variety of diseases in apple varieties (Hardenburg 1967; Kester and Fennema 1986). Wax coatings retarded respiration, inhibited oxygen supply and increased carbon dioxide content within apple and pear fruit (Smock 1935). Earlier research studies showed that edible coated apples had decreased diffusion of gases across the skin, increased internal carbon dioxide, reduced internal oxygen, reduced the rate of respiration and delayed ripening changes (Trout et al. 1942).

Indian Institute of Vegetable Research, Shahanshahpur, Jakhini, Varanasi, UP

Corresponding author, Email: sudhiriivr@gmail.com

Preservation of fruits and vegetables involves creation of modified atmosphere surrounding the product. Modified atmosphere can serve several purposes, including reducing oxygen availability and increasing the fruit or vegetable's internal carbon dioxide concentration (Smith et al. 1987). Modified atmospheres created by coatings are produced by the physical trapping of carbon dioxide gas within the fruit tissues during respiration. For example, coating bell peppers resulted in increased internal levels of carbon dioxide and decreased concentrations of oxygen (Lerdthanangkul and Krochta 1996). The increased levels of carbon dioxide have been shown to lower respiration rates, and therefore delay senescence. In addition, coating may have different levels of permeability to oxygen. Decreased oxygen permeability can also serve to reduce respiration and increase shelf life.

In addition to reducing respiration rates, coating also act as hydrophobic barriers and therefore prevent water loss from transpiration. Such a feature is highly desirable for fruit and vegetable commodities. Water loss can lead to decreased turgor pressure which results in shriveling and wilting, both of which render produce not saleable (Kester and Fennema 1986). Coatings successfully reduce weight loss in green peppers, zucchini and cucumber (Hebeebunnisa et al. 1963). Other quality improvements related to edible coatings include slower softening and texture changes, as well as increased colour retention, all of which have been demonstrated on green bell peppers (Lerdthanangkul and Krochta 1996, Habeebunnisa et al. 1963). Recent studies on eggplant with carnauba wax based edible coating significantly increased the shelf life to 7-8 days during ambient storage in both packaged and unpackaged polypropylene pouches (Singh et al. 2016). In view of greater advantages of carnauba wax based edible coating on fruits and vegetables, the present investigation has been carried out to establish the exact concentration of carnauba wax suitable for extending the shelf life and quality retention in capsicum.

Materials and Methods

The experiment was conducted at the Indian Institute of vegetable Research, Varanasi. The experiment was conducted in CRD with three replications. Fresh capsicum fruits were purchased from the local market of Varanasi. During study, Carnauba wax emulsion was manufactured with the process of making emulsion with varying levels (7.5-10.0%) of oleic acid and addition of hot water (80-100°C). The emulsion contained 7.7% wax level in carnauba wax emulsion is presented in (Fig. 1). Carnauba wax emulsion was diluted with hot water (20-100%) as a result the wax level was reduced from 5.2-3.7%. Different diluted carnauba wax emulsion with water was sprayed evenly with sprayer and wax treated capsicum fruits were kept at room temperature for solidification of wax and fruits were weighed and packaged in polypropylene pouches (15Î13 cm) of thickness 14.5 gauge and sealing with hand sealer. After packing of wax treated capsicum fruits in polyethylene, pouches were stored at room temperature (27-33 °C) and at 10 °C (Refrigerated condition). The observations of storage parameter were recorded 5 days of interval. Physiological loss in weight was calculated after every 2 days of storage using the formula (A-B)/AX100, where A is weight just before storage and B is after specific storage.

Sensory evaluation: A panel of 10 trained judges was set up to evaluate carnauba wax coated capsicum for overall acceptability with regards to flavor, color and appearance and body and texture on 9-point hedonic scale as per the method (Lawless and Haymann 1988).

Physico-chemical analysis: The physico-chemical parameters such as moisture content and ascorbic acid content were analyzed initially and at the interval of 5 days of refrigerated storage and room temperature using standard analytical method (Ranganna 1997).

Texture profile analysis: Texture profile analysis (hardness) of carnauba wax coated samples were studied using TA-XT2i (Stable Micro System, UK) Texture Analyzer fitted with a 50 kg load cell using Needle probe stainless steel P/2N having pre-test speed of 2 mm/sec, test speed of 1 mm/sec and post-test speed of 1 mm/sec.

Statistical analysis: The data generated during the study was analyzed using Design expert version 7.0 which was analyzed using IBM SPSS Statistics Version 20.

Carnauba wax (10g)
↓
Melting (80-90°C)
↓
Addition of oleic acid (7.5-10% of carnauba wax)
↓
Stirring with hand at high speed and addition of 50-100 ml of hot water (75-85°C)
↓
Addition of 20% NaOH (1.5-2.0 ml; pH 8-12)
↓
Addition of 1% acetic acid (10-15 ml; pH 7-8)
↓
Addition of 50 ml of hot water (75-85°C)
↓
Filtration with strainer
↓
Addition of 20-35 ml of hot water (75-85°C)
↓
Wax emulsion (7.7%)

Fig. 1: Process for manufacture of carnauba wax emulsion

Results and Discussion

Changes in mean flavour score of carnauba wax coated capsicum during storage: The flavour score in carnauba wax treated capsicum decreased during storage at room temperature (27-33°C) as well as at low temperature (10°C). The carnauba wax diluted to 4.0 % and 3.7% wax level exhibited maximum (8.5) flavour score at low room temperature which decreased to 6.0 and 6.5 after storage for 40 and 60 days, respectively (Table 1). The carnauba wax treated capsicum fruits with wax level of 4.0% and 3.7% were spoiled after 40 days of storage at room temperature (Table 1). Control capsicum fruits without wax coating had the acceptability for flavor score of 6.0 and 5.0 after 25 days and after 50 days during storage at room temperature and low temperature, respectively. It is evident from Table 1 that maximum flavor score was obtained for wax dilution to 4.0 % and 3.7% while the flavor score was least for carnauba wax treated capsicum with wax dilution of 4.8% as wax level. The analysis of variance studies had shown that storage periods, carnauba wax dilutions, interaction of storage period and dilution and interaction of storage period and replication had significant ($P<0.001$, CD :$I_{0.12}$, $D_{0.16}$, $IxD_{0.08,}$ $IxD_{0.09}$ at room temperature and $P<0.001$, CD:$I_{0.07}$, $D_{0.12}$, $IxD_{0.06,}$ $IxD_{0.06}$ at low temperature) changes in the flavour score of carnauba wax coated capsicum fruits during storage for 60 days (Table 1).

Changes in mean body and texture score of carnauba wax coated capsicum during storage: The body and texture score in carnauba wax treated capsicum was decreased during storage at room temperature (27-33°C) and at low temperature (10°C). The carnauba wax diluted to 3.7% wax level exhibited maximum body and texture response at room temperature as well as at low temperature (Table 2). The carnauba wax treated capsicum with wax level of 3.7% had the maximum body and texture score of 6.5 after storage for 60 days at low temperature (10°C) while the carnauba wax treated capsicum with wax level of 3.7% were spoiled after 40 days of storage at room temperature (Table 2). Control capsicum fruits without wax coating had the acceptability for body and texture score of 6.0 and 5.0 after 25 and 50 days during storage at room temperature and at low temperature, respectively. It is evident from Table 2 that maximum body and texture score was obtained for wax dilution of 3.7% while the body and texture score was least for carnauba wax treated capsicum with wax dilution of 4.8% as wax level. The analysis of variance studies had shown that storage periods, carnauba wax dilutions, interaction of storage period and dilution and interaction of storage period and replication had significant ($P<0.001$, CD :$I_{0.10}$, $D_{0.13}$, $IxD_{0.07,}$ $IxD_{0.08}$ at room temperature and $P<0.001$, CD :$I_{0.06}$, $D_{0.10}$, $IxD_{0.05,}$ $IxD_{0.05}$ low temperature) changes of body and texture score of carnauba wax coated capsicum fruits during storage for 60 days (Table 2).

Changes in mean physiological loss in weight of carnauba wax coated capsicum during storage: The mean physiological loss in weight (%) in carnauba wax treated capsicum increased during storage at room temperature (27-33°C) and at low temperature (10°C). The carnauba wax diluted to 3.7% wax level exhibited minimum physiological loss in weight (%) at room temperature as well as at low temperature (Table 3). The carnauba wax treated capsicum with wax level of 3.7 % had the minimum physiological loss in weight (%) of 3.02 after storage for 60 days at low temperature (10°C) while the carnauba wax treated capsicum with wax level of 3.7% were spoiled after 40 days of storage at room temperature (Table 3). Control capsicum fruits without wax coating had the acceptability of

Table 1: Change in mean flavor score of carnauba wax coated capsicum during storage

		Days												
Sample	Temp °C	0	5	10	15	20	25	30	35	40	45	50	55	60
Control	27-33	8.5	8.0	7.0	7.0	6.5	6.0	S	S	S	S	S	S	S
4.8		8.5	8.0	7.5	7.5	7.0	6.5	5.5	5.5	S	S	S	S	S
4.3		8.5	8.0	7.5	7.5	7.0	6.5	6.0	6.0	5.5	S	S	S	S
4.0		8.5	8.0	8.0	7.5	7.0	6.5	6.5	6.5	6.0	S	S	S	S
3.7		8.5	8.5	8.0	7.5	7.0	6.5	6.5	6.5	6.0	S	S	S	S
Control	10	8.5	8.5	8.0	8.0	7.5	7.0	7.0	6.5	6.5	5.0	5.0	S	S
4.8		8.5	8.5	8.5	8.5	8.0	8.0	7.5	7.5	7.0	6.5	6.5	6.0	6.0
4.3		8.5	8.5	8.5	8.5	8.0	8.0	7.5	7.5	7.5	7.5	6.5	6.0	6.0
4.0		8.5	8.5	8.5	8.5	8.0	8.0	7.5	7.5	7.0	7.0	7.0	6.5	6.5
3.7		8.5	8.5	8.5	8.5	8.5	8.0	7.5	7.5	7.5	7.5	6.5	6.5	6.5

$P<0.001$, CD :$I_{0.12}$, $D_{0.16}$, $IxD_{0.08,}$ $IxD_{0.09}$ at room temperature

$P<0.001$, CD :$I_{0.07}$, $D_{0.12}$, $IxD_{0.06,}$ $IxD_{0.06}$ low temperature

Table 2: Change in mean body and texture score of carnauba wax coated carrot during storage

		Days												
Sample	**Temp (^oC)**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Control	27-33	8.5	8.0	7.0	7.0	6.5	6.0	S	S	S	S	S	S	S
4.8		8.5	8.0	7.0	7.0	6.5	6.5	5.0	5.0	S	S	S	S	S
4.3		8.5	8.0	7.5	7.5	7.0	6.5	5.5	5.5	5.0	S	S	S	S
4.0		8.5	8.0	7.5	7.5	7.0	6.5	6.0	6.0	5.5	S	S	S	S
3.7		8.5	8.5	8.0	7.0	7.0	6.5	6.5	6.5	6.0	S	S	S	S
Control	10	8.5	8.5	8.0	8.0	7.5	7.0	7.0	6.5	6.5	5.5	5.0	S	S
4.8		8.5	8.5	8.5	8.5	8.0	8.0	7.5	7.5	7.0	7.0	6.5	6.0	6.0
4.3		8.5	8.5	8.5	8.5	8.0	8.0	7.5	7.5	7.0	7.0	6.5	6.0	6.0
4.0		8.5	8.5	8.5	8.5	8.0	8.0	7.5	7.5	7.5	7.0	6.5	6.5	6.5
3.7		8.5	8.5	8.5	8.5	8.5	8.0	7.5	7.5	7.5	7.5	7.0	6.5	6.5

$P<0.001$, CD :$I_{0.10}$, $D_{0.13}$, $IxD_{0.07,}$ $IxD_{0.08}$ at room temperature
$P<0.001$, CD :$I_{0.06}$, $D_{0.10}$, $IxD_{0.05,}$ $IxD_{0.05}$ low temperature

Table 3: Change in mean physiological loss in weight (%) score of carnauba wax coated capsicum during storage

		Days												
Sample	**Temp (^oC)**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Control		0.00	1.84	2.24	2.52	2.95	3.86	S	S	S	S	S	S	S
4.8		0.00	0.81	1.81	2.42	2.82	3.56	3.78	4.51	S	S	S	S	S
4.3	27-33	0.00	0.74	1.44	1.48	2.16	3.01	3.35	3.63	3.85	S	S	S	S
4.0		0.00	0.71	1.31	1.43	1.79	2.91	3.13	3.36	4.48	S	S	S	S
3.7		0.00	0.69	1.02	1.39	1.61	2.38	3.18	3.21	3.99	S	S	S	S
Control		0.00	1.32	1.70	2.27	2.38	2.62	2.82	3.65	4.28	6.18	6.78	S	S
4.8		0.00	0.80	1.25	1.27	1.61	1.90	2.47	2.89	3.85	4.35	4.95	5.55	6.15
4.3	10	0.00	0.73	0.78	0.93	1.12	1.43	1.59	2.20	3.32	3.52	3.82	4.07	4.37
4.0		0.00	0.64	0.72	0.82	0.89	1.23	1.48	1.81	3.02	3.32	3.57	3.97	4.22
3.7		0.00	0.63	0.70	0.78	0.79	1.12	1.23	1.62	1.92	2.17	2.42	2.72	3.02

$P<0.001$, CD :$I_{0.03}$, $D_{0.03}$, $IxD_{0.02,}$ $IxD_{0.02}$ at room temperature
$P<0.001$, CD :$I_{0.03}$, $D_{0.04}$, $IxD_{0.02,}$ $IxD_{0.02}$ low temperature

physiological loss in weight (%) score of 3.86 and 6.78 after 25 days and after 50 days during storage at room temperature and low temperature, respectively. It is evident from (Table 3) that minimum physiological loss in weight (%) score was obtained for wax dilution of 3.7 % while the physiological loss in weight (%) score was maximum for carnauba wax treated capsicum with wax dilution of 4.8% as wax level. Afolabi and Sunmola (2009) studied the effects of jojoba wax, soy bean gum, Arabic gum, glycerol as edible coatings on apple fruits and water loss percentage during storage at 0^{o}C and 90% RH upto 60 days of storage was studied and similar to our observations, maximum (5.82%) water loss percentage was obtained in control apple fruits while soybean oil and jojoba wax coated apple fruits contained minimum 3.0 and 3.11% water loss percentage during storage for 60 days.

The analysis of variance studies had shown that storage periods, carnauba wax dilutions, interaction of storage period and dilution and interaction of storage period and replication had significant ($P<0.001$, CD :$I_{0.03}$, $D_{0.03}$, $IxD_{0.02,}$ $IxD_{0.02}$ at room temperature and $P<0.001$, CD :$I_{0.03}$, $D_{0.04}$, $IxD_{0.02,}$ $IxD_{0.02}$ low temperature) changes of physiological loss in weight (%) of carnauba wax coated capsicum fruits during storage for 60 days (Table 3).

Changes in mean green colour (a-value) of carnauba wax coated capsicum during storage: The mean green colour (a-value) in carnauba wax treated capsicum increased during storage at room temperature (27-33^{o}C) and at low temperature (10^{o}C). The carnauba wax diluted to 3.7% wax level exhibited maximum green colour (a-value) response at room temperature as well as low temperature (Table 4). The carnauba wax treated capsicum with wax level of 3.7% had the maximum green colour (a-value) of -0.18 after storage for 60 days at low temperature (10^{o}C) while the carnauba wax treated capsicum with wax level of 3.7% were spoiled after 40 days of storage at room temperature. Control capsicum fruits without wax coating had the acceptability for green colour (a-value) of 1.22 and -0.24 after 25 days and after 50 days during storage at room temperature and at low temperature, respectively.

It is evident from (Table 4) that maximum green colour (a-value) was obtained for wax dilution of 3.7% while the green colour (a-value) was minimum for carnauba wax treated capsicum with wax dilution of 4.8% as wax level. The analysis of variance studies had shown that storage periods, carnauba wax dilutions, interaction of storage period and dilution and interaction of storage period and replication had significant ($P<0.001$, CD :$I_{0.12}$, $D_{0.15}$, $IxD_{0.08,}$ $IxR_{0.09}$ at room temperature and $P<0.001$, CD :$I_{0.05}$, $D_{0.09}$, $D_{0.09,}$ $IxD_{0.04}$ low temperature) changes in green colour (a-value) of carnauba wax coated capsicum fruits during storage for 60 days (Table 4).

Changes in mean hardness of carnauba wax coated capsicum during storage: Fresh firmness is one of the most important parameters as regards to consumer acceptance and acceptability of fruits and vegetables. The mean hardness (g) in carnauba wax treated capsicum was decreased during storage at room temperature (27-33°C) and at low temperature (10°C). The carnauba wax diluted 3.7% wax level exhibited maximum hardness (g) at room temperature as well as at low temperature (Table 5). The carnauba wax treated capsicum with wax level of 3.7 % had the maximum hardness of 280.70 g after storage of 60 days at low temperature (10°C) while the carnauba wax treated capsicum with wax level of 3.7% were spoiled after 40 days of storage at room temperature (Table 5). Control capsicum fruits without wax coating had shown minimum hardness (212.11 and 160 g) after 25 days and after 50 days during storage at room temperature and at low temperature, respectively. It is evident from Table 5 that maximum hardness in carnauba wax capsicum samples coated with wax dilution of 3.7% while the minimum force was reflected in carnauba wax treated capsicum with wax dilution of 4%. El-Anany et al (2009) supported our findings and reported that firmness level was significantly ($P<0.05$) decreased with storage time in both edible coated and uncoated apple samples. Control apple fruits had the lowest ($P<0.05$) firmness (3.95 kg cm^{-2}) while apple coated with jojoba wax, paraffin oil, soygum and glycerol retained the highest ($P<0.05$) firmness (4.94, 4.96, 4.95, 4.94, kg cm^{-2}, respectively). The analysis of variance studies had shown that storage periods, carnauba wax dilutions, interaction of storage period and dilution and interaction of storage period and replication had significant ($P<0.001$, CD :$I_{3.27}$, $D_{4.18}$, $IxD_{2.30,}$ $IxR_{2.51}$ at room temperature and $P<0.001$, CD :$I_{1.01}$, $D_{1.62}$, $IxD_{0.77,}$ $IxR_{0.82}$ atlow temperature) changes in hardness of carnauba wax coated capsicum fruits during storage for 60 days (Table5).

Changes in mean moisture content of carnauba wax coated capsicum during storage: The mean moisture content (%) score in carnauba wax treated capsicum decreased during storage at room temperature (27-33°C) and at low temperature (10°C). The carnauba wax diluted to 3.7% wax level exhibited maximum moisture content at room temperature as well as at low temperature (Table 6). The carnauba wax treated capsicum with wax level of 3.7% had the maximum (89.53%) moisture content after 60 days of storage at low temperature (10°C) while the carnauba wax treated capsicum with wax level 3.7% were spoiled after 40 days of storage at room temperature (Table 6). Control capsicum fruits without wax coating had the moisture content (%) of 92.96 and 87.28 after 25 and 50 days of storage at room temperature and at low temperature, respectively. It is evident from Table 6 that maximum moisture content (%) was obtained for wax dilution of 3.7% while the moisture content (%) was minimum for carnauba wax treated capsicum after 4.8% wax dilution. Chien et al. (2005) also reported that higher loss in uncoated fruits

Table 4: Change in mean green colour (a-value) score of carnauba wax coated capsicum during storage

		Days												
Sample	Temp (°C)	0	5	10	15	20	25	30	35	40	45	50	55	60
Control	27-33	-1.42	-1.30	-0.95	-0.65	0.35	1.22	S	S	S	S	S	S	S
4.8		-0.9	-0.72	-0.38	-0.13	0.45	0.66	0.89	1.38	S	S	S	S	S
4.3		-1.18	-0.91	-0.50	-0.28	0.12	0.31	0.44	0.89	1.25	S	S	S	S
4.0		-1.25	-1.07	-0.61	-0.36	-0.11	0.19	0.26	0.62	0.93	S	S	S	S
3.7		-1.32	-1.20	-0.73	-0.52	-0.32	-0.12	0.13	0.40	0.84	S	S	S	S
Control	10	-1.42	-1.30	-1.21	-1.09	-0.95	-0.82	-0.70	-0.61	-0.50	-0.28	-0.24	S	S
4.8		-1.02	-0.99	-0.95	-0.87	-0.75	-0.6	-0.48	-0.39	-0.28	-0.2	-0.11	-0.06	-0.02
4.3		-1.18	-1.14	-1.05	-0.93	-0.79	-0.66	-0.54	-0.45	-0.34	-0.26	-0.17	-0.12	-0.08
4.0		-1.25	-1.18	-1.09	-0.97	-0.83	-0.7	-0.58	-0.49	-0.38	-0.30	-0.21	-0.16	-0.12
3.7		-1.32	-1.24	-1.15	-1.03	-0.89	-0.76	-0.64	-0.55	-0.44	-0.36	-0.27	-0.22	-0.18

$P<0.001$, CD :$I_{0.12}$, $D_{0.15}$, $IxD_{0.08,}$ $IxR_{0.09}$at room temperature
$P<0.001$, CD :$I_{0.05}$, $D_{0.09}$, $D_{0.09,}$ $IxD_{0.04}$low temperature

Table 5: Change in mean hardness (g) of carnauba wax coated capsicum during storage

		Days												
Sample	**Temp (°C)**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Control	27-33	460.70	329.94	309.50	293.72	254.41	212.11	S	S	S	S	S	S	S
4.8		460.70	384.18	353.34	320.32	300.39	289.46	258.53	219.60	S	S	S	S	S
4.3		460.70	419.06	390.68	375.86	326.26	313.66	287.06	228.46	204.86	S	S	S	S
4.0		460.70	441.9	425.13	409.34	390.16	372.90	333.64	301.38	275.12	S	S	S	S
3.7		460.70	445.65	440.90	437.67	403.98	393.5	375.22	355.45	310.35	S	S	S	S
Control	10	460.70	389.30	363.00	313.70	264.40	225.10	212.80	201.50	190.20	182.30	160.00	S	S
4.8		460.70	403.18	378.22	366.26	320.30	294.34	278.38	248.40	236.46	207.50	194.54	190.58	152.62
4.3		460.70	437.94	416.45	370.84	356.23	333.62	303.01	275.05	262.05	248.18	220.57	210.94	195.35
4.0		460.70	449.06	437.67	417.40	392.86	392.86	375.59	353.35	335.78	316.78	304.51	298.58	275.97
3.7		460.70	455.32	449.90	440.98	427.06	400.14	381.22	360.38	340.46	322.38	308.54	300.62	280.70

$P<0.001$, CD :$I_{3.27}$, $D_{4.18}$, $IxD_{2.30}$, $IxR_{2.51}$ at room temperature

$P<0.001$, CD :$I_{1.01}$, $D_{1.62}$, $IxD_{0.77}$, $IxR_{0.82}$ at low temperature

can be attributed due to higher respiration and transpiration rate during storage.

The analysis of variance studies had shown that storage periods, carnauba wax dilutions and interaction of storage period and replication had significant ($P<0.001$, CD :$IxR_{0.82}$ at room temperature and $P<0.001$, CD :$I_{0.53}$, $D_{0.84}$, $IxR_{0.43}$ at low temperature) changes in the moisture content of carnauba wax coated capsicum fruits during storage for 60 days (Table 6).

Changes in mean ascorbic acid of carnauba wax coated capsicum during storage: The mean ascorbic acid (mg/100g) in carnauba wax treated capsicum decreased during storage at room temperature (27-33°C) and at low temperature (10°C). The carnauba wax diluted to 3.7% wax level exhibited maximum ascorbic acid (mg/100g) at room temperature as well as at low temperature (Table 7). The carnauba wax treated capsicum with wax level of 3.7% had the maximum ascorbic acid of 94.62 mg/100g after 60 days of storage at low temperature (10°C) while the carnauba wax treated capsicum with wax level of 3.7% spoiled after 40 days of storage at room temperature (Table 7). Capsicum fruits without wax coating had the ascorbic acid of 70.24 and 80.69 mg/100 g after 25 days and 50 days of storage at room temperature and at low temperature, respectively. It is evident from Table 7 that maximum ascorbic acid was obtained in wax dilution of 3.7% while minimum ascorbic acid was reported in carnauba wax treated capsicum with 4.8% wax level dilution. Abbasi et al. (2009) also supported our findings and reported that the rate of the decrease level of ascorbic acid was of higher level in untreated mango fruits as compared to chitosan coated mango fruits. The analysis of variance studies had shown that storage periods, carnauba wax dilution and interaction of storage period and dilution had significant ($P<0.001$, CD:$I_{0.03}$, $D_{0.04}$, $IxD_{0.02}$ at room temperature and $P<0.001$, CD :$I_{0.09}$, $D_{0.15}$, $IxD_{0.07}$, $IxR_{0.82}$ at low temperature) changes of ascorbic acid content of carnauba wax coated capsicum fruits during storage for 60 days (Table 7).

Table 6: Change in mean moisture content (%) score of carnauba wax coated capsicum during storage

		Days												
Sample	**Temp (°C)**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Control		96	93.68	93.24	93.13	93.09	92.96	S	S	S	S	S	S	S
4.8		96	93.79	93.64	93.47	93.24	93.17	92.89	92.63	S	S	S	S	S
4.3	27-33	96	93.80	93.78	93.72	93.58	93.43	92.92	92.72	92.77	S	S	S	S
4.0		96	93.93	93.84	93.79	93.66	93.56	93.12	92.83	92.95	S	S	S	S
3.7		96	94.18	94.02	93.86	93.79	93.68	93.42	93.24	93.09	S	S	S	S
Control		96	93.31	92.65	92.58	91.98	91.05	91.03	90.03	90.00	87.51	87.28	S	S
4.8		96	93.87	93.68	93.06	92.08	92.06	91.15	91.12	90.10	89.55	89.32	88.84	88.67
4.3	10	96	93.92	93.82	93.20	92.15	92.26	91.38	91.28	90.18	89.62	89.52	89.43	88.82
4.0		96	94.77	94.23	93.24	93.18	92.84	91.87	91.75	90.35	89.80	89.73	89.61	89.24
3.7		96	94.84	94.48	93.96	93.62	93.09	92.01	91.97	91.17	90.52	90.28	89.90	89.53

$P<0.001$, CD :$IxR_{0.82}$at room temperature

$P<0.001$, CD :$I_{0.53}$, $D_{0.84}$, $IxR_{0.43}$ at low temperature

Table7: Change in mean ascorbic acid (mg/100g) score of carnauba wax coated capsicum during storage

		Days												
Sample	**Temp (°C)**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Control		134	120.11	117.91	110.71	100.01	70.24	S	S	S	S	S	S	S
4.8		134	122.52	120.47	112.42	102.37	75.31	61.11	45.42	S	S	S	S	S
4.3	27-33	134	125.89	121.99	115.09	109.19	81.27	66.23	48.11	30.24	S	S	S	S
4.0		134	129.19	123.37	118.55	117.79	84.72	70.54	54.35	42.12	S	S	S	S
3.7		134	132.11	126.71	124.91	120.31	94.32	76.31	61.32	47.34	S	S	S	S
Control		134	125.30	120.01	108.72	101.43	98.14	90.85	87.56	84.56	82.86	80.69	S	S
4.8		134	127.98	122.67	119.01	112.05	100.74	98.43	95.12	92.12	90.98	87.19	85.88	80.57
4.3	10	134	128.25	125.93	120.61	113.29	103.97	100.65	97.33	92.33	90.69	89.37	87.05	83.57
4.0		134	132.81	131.48	124.15	122.82	121.49	119.16	102.83	98.50	97.17	96.84	93.51	87.73
3.7		134	133.78	132.02	130.68	127.34	124.00	120.66	117.32	114.98	108.64	105.30	100.96	94.62

$P<0.001$, CD :$I_{0.03}$, $D_{0.04}$, $IxD_{0.02}$ at room temperature
$P<0.001$, CD :$I_{0.09}$, $D_{0.15}$, $IxD_{0.07}$, $IxR_{0.82}$ atlow temperature

सारांश

शिमला मिर्च सबसे महत्वपूर्ण सब्जी फसल है जिनमें विटामिन सी की मात्रा सबसे अधिक होती है। सामान्य तापमान पर इसका स्वजीवन मात्र 5–7 दिनों का होता है। शिमला मिर्च में विविध सान्द्रता के कार्नोबावैक्स पायसन (3.7–4.8 प्रतिशत) का तनूकरण कर स्वजीवन व गुणवत्ता घटक का अध्ययन किया गया। अधिकतम संवेदी अंक (7.0–7.5) सुगन्ध तथा दैहिकी व संरचनात्मक संवेदी अंक सामान्य कमरे के तापमान पर 15–20 दिनों के लिए पाया गया तथा शीत भण्डारण में 30–35 दिनों तक कार्नोबा बैक्स के 3.7–4.0 प्रतिशत तनूकरण पर पाया गया। अधिकतम दैहिकी नुकसान 1.23–1.62 प्रतिशत भार एवं कार्नोबा बैक्स के 3.7 प्रतिशत तनूकरण पर 30–35 दिनों तक शीत भण्डारण के 15–20 दिनों की तुलना पर मात्र 1.39–1.61 प्रतिशत ही पाया गया । शिमला मिर्च में कार्नोबा बैक्स तनूकरण 3.7 प्रतिशत स्तर पर 5.0–12.3 प्रतिशत गिरावट पर रहा और 17. 25–21.80 प्रतिशत सामान्य तापक्रम पर 15–20 दिन उपरान्त व शीत भण्डारित भण्डारण तापक्रम का 30–35 तक क्रमशः पाया गया। इसी प्रकार शिमला मिर्च में एस्कार्बिक एसीड में गिरावट 6.78–10.22 प्रतिशत एवं 3.7 प्रतिशत कार्नोबा बैक्स के 3.7 प्रतिशत तनूकरण 15–20 दिन सामान्य तापक्रम व 30–35 दिन शीत भण्डारित में केवल 9.95–12.5 प्रतिशत ही पाया गया।

References

Abbasi NA, Zafar I, Maqbool M and Hafiz IA (2009) Post harvest quality of mango (*Mangifera indica* L.) fruits as affected by chitosan coating. Pakistan J Bot 41 (1): 343-347.

Afolabi and Sunmola I (2009) The preservative efficacies of bemul wax coating in combination with $CaCl_2$ dip on low temperature stored *Citrus sinesis*. Bio Chem 21(1): 1-8.

Mahadu BJ and Ranganna S (2010). Modified atmosphere packaging to enhance the shelf-life of capsicum bell peppers. Mysore J Agri Sci 44(2): 417-420.

Chien PJ, Shen F and Yang FH (2005). Effect of edible chitosan on quality and shelf life of sliced mango fruit. J Food Engg 29(3): 23-29.

El-Anany AM, Hassan GFA and Ali FMR (2009) Effect of edible coatings on the shelf life and quality of Annaaple (*Malus domestica* Borkh) during cold storage. J Food Technol 7(1): 5-11.

Frank CA, Nelson RG, Simonne EH, Behe BK and Simonne AH (2001) Consumer preferences for color, price, and vitamin C content of bell peppers. Hort Sci 36: 801-804.

Habeebunnisa M, Pushpa C and Srivastava HC (1963) Studies on the effect of the protective coating on the refrigerated and common storage of bell peppers. Food Sci 12: 192-196.

Hardenburg RE (1967) Wax and related coatings for horticulture products. A bibliography, Agricultural Research Service Bulletin 51-15. USDA, Washington, DC.

Howard LR, Smith RT, Wangner AB, Villalion B and Burns E (1994) Provitamin A and ascorbic acid content of fresh pepper cultivars (*Capsicum annuum*) and processed jalapenos. J Food Sci 59: 362–365

Kaplan HJ (1986). Washing, waxing and color adding. Pages 379-395. In: Fresh Citrus Fruits. W.F. Wardowski, S. Nagy and W. Grierson (Eds.). Avi Publishing Company, Inc., Connecticut.

Kester JJ and Fennema OR (1986) Edible films and coatings: a review. Food Tech 12: 47-59.

Lawless HT and Heymann H (1988) Acceptance and preference testing.p.430-470. In: HT Lawless and H Heymann (eds.), Sensory Evaluation of Food, Principles and Practices. Chapman and Hall, New York.

Lerdthanangkul S and Kroctha JM (1996) Edible coating effects on post harvest quality of green bell peppers. J Food Sci 61(1): 176-179.

Lim CS, Kang GSM, Cho JL, Gross KC and Woolf AB (2007) Bell pepper (*Capsicum annuum* L.) fruits are susceptible to chilling injury at the breaker stage of ripening. Hort Sci 42: 1659–1664.

Ranganna S (1997) Handbook of analysis and quality control for fruits and vegetable products. Tata McGraw Hill Publishing Company Limited, New Delhi, pp 169-185.

Singh Sudhir, Khemariya Priti, Rai A, Rai AC, Koley TK and Singh B (2016) Carnauba wax based edible coating enhances shelf life and retain quality in eggplant (Solanum melongena) fruits. LWT-Food Sci Technol 74: 420-426.

Smith S, Geeson J and Stow J (1987) Production of modified atmospheres in deciduous fruits by the use of films and coatings. Hort Sci 22(5): 772-776.

Smock RM (1935) Certain effects of wax treatment on various varieties of apples and pears. Proc Amer Soc Hort Sci 33: 284-289.

Trout SA, Hall EG, Robertson RN, Hackney FMV and Sykes SM (1942) Studies on the metabolism of apples. I. Preliminary investigations on internal gas composition and its relation to changes in stored granny smith apples. Aust J Exp Biol Med Sci 20: 219-231.