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ORIGINAL RESEARCH

Effect of edible chitosan coating on postharvest life of carrot (*Daucus carota* L.)

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ABSTRACT

The carrot is an important vegetable. Carrot is one of the potential sources of natural phyto pigments and antioxidant nutrient such as lycopene and β-carotene. The present research work was conducted on carrot vegetable. Its main purpose is to decrease their losses and preserve for future use by edible coating that helped to reduce rate of respiration and transpiration, growth of microorganism, improve its color and texture quality attributes. Polyethylene bags maintain the high humidity, reduce weight loss and consequently slow down the drying process. It maintained the organoleptic properties of fruits and vegetables. In experiment edible coating such as chitosan (0.5, 1.0, 1.5 and 2.0% concentration) in 0.25 N HCl, 0.50 ml glycerol and packaging material polyethylene was applied on carrot vegetables in order to evaluate their physico-chemical composition i.e weight loss, moisture loss, total soluble solids, pH, ascorbic acid, β-carotene, and also sensory parameters such as color, flavor, texture, taste and overall acceptability at 4th day intervals during 20 days of storage at ambient temperature.

Keywords: Carrot, storage life, physico-chemical composition, sensory evaluation.

Introduction

Carrot (*Daucus carota* L.) a prominent member of the Umbellifereae family, is one of the major vegetable produced and consumed in Pakistan. It occupies a prime position among the winter vegetables. The carrot is believed to have originated in Asia and now under cultivation in all over the world because of its increasing importance as human food (Chen and Tang, 1998). In Pakistan, deficiency of vitamin A was found to be 18.95% among rural adult 20 to 23 years and 24 to 27 years females aged were also found to be deficient. Among the urban adult females aged 28 to 31 years, the deficiency was 24.16%, and females aged 20 to 23 years and 24 to 27 years were also found in the deficient periods (Butt *et al.,* 2007).

Carrots are a cheaper source of essential nutrients in Pakistan, but its use in the daily life of the people is very low because of the limited information on the nutritional importance of this vegetable. The leaves of this crop are also used as fodder for the farm animals. It is used as raw as well as cooked form and also in pickles and sweetmeats (Ahmad *et al.*, 1994; Ahmad *et al.*, 2005; Hassan *et al.*, 2005).

Carrots can be stored for 4 to 6 weeks at 0°C and retain fresh flavor and appearance (Hardenburg *et al*., 1986). The shelf life of carrot at ambient temperature is 4 to 5 days (Carlin *et al*., 1990a). The major postharvest losses of fruits and vegetables are due to fungal infection, physiological disorders, and physical injuries (El-Ghaouth *et al*., 1991, 1992b). The aim of applying postharvest technology to fruits and vegetables is to maintain quality and to reduce losses between harvest and consumption. Most often hi-tech practices are not suitable for small-scale farmers in developing countries for the simple reason of economy scale (Kader, 1997). Limitations faced by small-scale handlers may include labor surpluses, lack of credit for investments in postharvest technology, unreliable electric power supply, lack of transport and storage facilities. There are simple postharvest technologies that may meet the requirements of small scale food handlers. Despite good management practices, some produce require treatment to prevent spoilage especially by pathogenic microorganisms. The senescence responsible for the post-harvest losses can be reduced in order to preservation of fresh produce (Lee *et al*., 1996).

An edible coating with cold storage is one of the latent tactics to prolong the storability of these perishable commodities (Park *et al*., 2005). All biochemical processes such respiration and transpiration rate in fruits and vegetables can be reduced by using edible coatings (Kester and Fennema, 1986). Chitosan is a polysaccharide obtained by deacetylation chitin, originated from crustacean exoskeleton and fungal cell walls. Chitosan has widely been used in antimicrobial films and coatings due to its property of inhibiting the growth of many pathogenic bacteria and fungi (Fang *et al*., 1994).

Azad Jammu and Kashmir is deficient in vegetable production to meet the requirement of the population. Hence, large quantities of vegetables are marketed from Pakistan. Carrot is not produced in hilly areas of Kashmir but is a beneficial vegetable for women and children as several health benefits are associated with carrots, so we can preserve this vegetable and made it ready for supply to hilly areas. There is no research work carried out on the shelf life of carrot in Azad Jammu and Kashmir. The aim of present research is to preserve the carrots by using edible coating such as chitosan and also polyethylene packaging.

Materials and Methods

Collection of Sample

Fully mature, red, orange and firm carrots devoid of physical damage and fungal infection were collected from the local market. After collection, these were immediately transferred to Food Technology laboratory in Faculty of Agriculture Rawalakot.

Preparatory Operations

Carrots were washed in running tap water, cleaned and dried with a piece of muslin cloth. After drying sorted carrots were divided into nine lots and these lots were treated with different concentrations of chitosan coatings as follow: T_1 Control, T_2 0.5% Chitosan in 0.25N HCl and 0.50mL glycerol, T_3 0.5% Chitosan in 0.25N HCl and 0.50mL glycerol+ Polyethylene, T_4 1% Chitosan in 0.25N HCl and 0.50mL glycerol, T_5 1% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene, T_6 1.5% Chitosan in 0.25N HCl and 0.50mL glycerol, T_7 1.5% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene, T_8 2% Chitosan in 0.25N HCl and 0.50Ll glycerol, T_9 2% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene. These samples were stored at ambient temperature (25^{o}C–30^{o}C and Relative Humidity (60-63 %). The carrots were analyzed for the following parameters during storage at regular intervals of four days.

Physical and Chemical Analysis

Coated carrots were analyzed after an interval of four days for weight loss, ascorbic acid, titratable acidity and sensory parameters such as colour, taste, flavor, texture and overall acceptability after every four days to examine the shelf life stability of coated carrots. The brief description of each method is given below:

Weight Loss %

To determine the effectiveness of chitosan coating the weight of carrots from each treatment were monitored after every four days. Weight loss was determined using the standard method of AOAC (2003).

Titratable Acidity %

The percentage of acidity was determined according to method of AOAC (2003). 15mL of carrot juice was taken in 3 conical flasks and 1 to 2 drops of phenolphthalein was added in each flask. Then 20 ml of distilled water was added for dilution and 0.1 N NAOH solutions were used to titrate against it. The used volume of 0.1 N NAOH was noted.

Ascorbic Acid (mg/ 100mL of vegetable juice)

The ascorbic acid content was estimated using the detective dye, DCPIP (2, 6-dichlorophenolindophenol) according to method of AOAC (2003).

Beta Carotene

Beta carotene was determined according to method of AOAC (2003). Took 0.5-5g of defatted sample and crushed in 10-15mL acetone, A few crystal of anhydrous sodium sulphate, was added with the help of pestle and mortar decant a supernatant into the beaker put into the separating funnel and 10-15mL petroleum ether was added and mix thoroughly. Lower layer was discarded and upper layer was collected into the 100ml volumetric flask make up the volume to 100mL with petroleum ether and optical density was recorded at 452 nm using petroleum ether as blank on spectrophotometer.

Sensory Evaluation

The organoleptic characteristics of carrots samples such as colour, flavour, texture, taste and overall acceptability were evaluated after an interval of four days by a panel of five judges selected from the Department. A nine point hedonic scale was used for sensory evaluation as described by Larmond (1977). Judges were provided with a score card to record their observation.

Statistical Analysis

The data obtained were statistically analyzed using two-factor factorial Completely Randomized Design and comparison of means was done by latent square design as described by Steel *et al*. (1997) using MSTAT-C software (Michigan State University, 1991, United States of America).

Results and Discussion

Weight Loss %

The concentration of water in fruits and vegetables is 50-95% (Wills *et al*., 1989a). The water plays fundamental roles as nutrients such as protective and regulator role, essential for temperature and pH regulation in human body. The data depicted in Table 1 shows the effect of different treatments on the weight loss. In Table 1, there was lowest loss of weight mean value observed in T_9 (8.9%) as compared to control (T_1) was 23.7%. The interaction among treatments and storage intervals showed the significant difference were found except T_5, T_3, T_6 (20.58%, 20.34%, 20.26%) followed by T_2 and T_8 (15.18%, 14.96%) respectively. The loss of weight was less in treated carrots this could be due to the coatings (Chitosan) served as a semi permeable around the vegetables and packaging decreased the rate of respiration by degrading ethylene produced by the fruits into carbon dioxide and water. This confirmed the results by Garcia *et al*. (1998b) that the exodus of moisture content in fruit into the environment was delayed due to chitosan film apply on the surface of the fruit responsible to reduce weight loss during storage.

Table 1. Effect of edible coating on quality attributes of carrot during storage.

Treatments	Quality Attributes			
	Weight loss (%)	Titratable Acidity (%)	Ascorbic Acid (mg/100g)	B-carotene (µg/100g)
Control	23.78^{a}	0.33^{b}	5.68^{c}	6972.6^{f}
0.5% Chitosan in 0.25N HCl and 0.50mL glycerol	15.18^{c}	0.39^{ab}	5.77^{c}	7421.2^{de}
0.5% Chitosan in 0.25N HCl and 0.50mL glycerol+ Polyethylene	20.33^{b}	0.38^{ab}	5.74^{c}	7242.2^{ef}
1% Chitosan in 0.25N HCl and 0.50mL glycerol	12.88^{d}	0.43^{ab}	6.12^{b}	7618.2^{cd}
1% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene	20.57^{b}	0.42^{ab}	6.09^{b}	$7734.8^{a\text{-}d}$
1.5% Chitosan in 0.25N HCl and 0.50mL glycerol	20.25^{b}	0.44^{ab}	6.21^{b}	$7731.0^{b\text{-}d}$
1.5% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene	11.07^{e}	0.44^{ab}	6.19^{b}	$7772.7^{a\text{-}c}$
2% Chitosan in 0.25N HCl and 0.50Ll glycerol	14.96^{c}	0.48^{a}	6.55^{a}	7979.7^{ab}
2% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene	8.93^{f}	0.47^{a}	6.57^{a}	8053.2^{a}

Table 2. Effect of edible coating on organoleptic scores of carrot during storage.

Treatments	Organoleptic scores				
	Colour	Flavour	Texture	Taste	Overall Acceptability
Control	6.26^{d}	6.11^{f}	5.78^{d}	6.70^{e}	6.26^{c}
0.5% Chitosan in 0.25N HCl and 0.50mL glycerol	7.41^{a-c}	6.30^{ef}	6.08^{cd}	7.80^{cd}	7.04^{b}
0.5% Chitosan in 0.25N HCl and 0.50mL glycerol+ Polyethylene	6.82^{cd}	6.51^{de}	6.05^{cd}	7.71^{d}	7.00^{b}
1% Chitosan in 0.25N HCl and 0.50mL glycerol	7.15^{bc}	6.83^{cd}	6.18^{b-d}	7.91^{b-d}	7.46^{ab}
1% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene	7.08^{bc}	6.95^{bc}	6.26^{a-c}	7.87^{b-d}	7.45^{ab}
1.5% Chitosan in 0.25N HCl and 0.50mL glycerol	7.26^{bc}	7.11^{a-c}	6.46^{a-c}	7.96^{b-d}	7.43^{ab}
1.5% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene	7.07^{bc}	7.20^{ab}	6.45^{a-c}	8.15^{a-c}	7.53^{a}
2% Chitosan in 0.25N HCl and 0.50Ll glycerol	7.65^{ab}	7.30^{a}	6.56^{ab}	8.23^{ab}	7.75^{a}
2% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene	8.01^{a}	7.38^{a}	6.65^{a}	8.36^{a}	7.68^{a}

The data regard to weight loss showed that there was a general trend of weight loss during storage. The rate of weight loss increased in carrot vegetables with passage of time whether they were coated or not (Fig. 1). But the minimum weight loss has shown in treated carrots. At the first day of storage mean value of weight loss was observed 0.0% as compared to 20th day of storage that was 32.8%, the increasing trend of weight loss might be due to biological changes i.e respiration and transpiration of water occur in the vegetables during storage. These results are correlated with the findings of Ishaq *et al*. (2009) who observed that weight loss increased with the passage of time.

Titratable Acidity (%)

The results related to titratable acidity of carrots during its storage are shown in Table 1. The titratable acidity was higher in fresh vegetable 0.62 % which was reduce to 0.47% showing a decreasing trend with the passage of storage time (Fig. 2). During storage decreasing trend of acidity might be due to the metabolic changes in fruits or was due to use of organic acid in respiratory process that is in line with those of Echerverria and Valich (1989) The data depicted in Table 5 shows the effect of different treatments on the titratable acidity. In Table 1, there was highest value of titratable acidity was observed in T_9 and T_8 (0.47 %, 0.48 %) as compared to control T_1 was 0.33%. The interaction among treatments and storage intervals showed the significant difference except T_7, T_6, T_5, T_4 T_3 and T_2 (0.44% 0.44% 0.42% 0.43% 0.38% 0.39%) respectively. It is clear from above mentioned data acidity of vegetable reduced with the passage of time. These results are in agreement with (Yagi, 1980) and (Sakiyama, 1970). The maximum mean value for TA was observed in 1st storage period and minimum mean value for TA was observed in 20th day of each coating. These results are in agreement with those of Smith and Stow (1984) who concluded that coatings and/or films significantly affected TA.

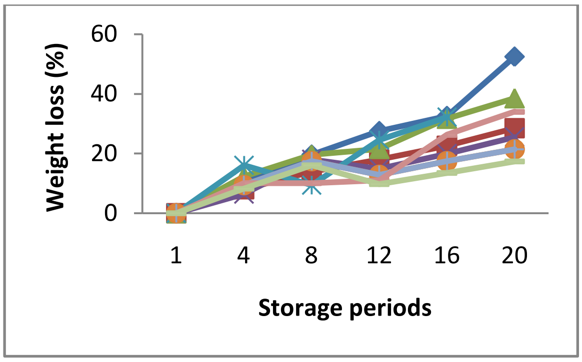

Fig. 1. Effect of edible coating on storage intervals of on weight loss (%) of carrot.

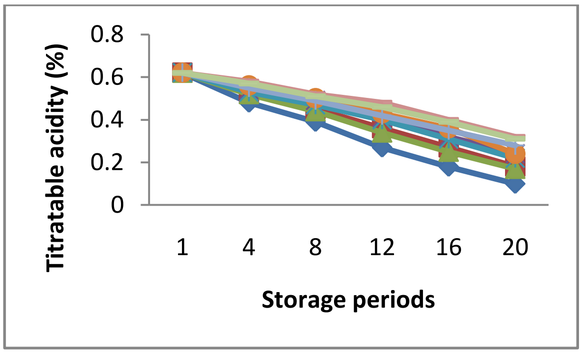

Fig. 2. Effect of edible coating on storage intervals of on Titratable acidity (%) of carrot.

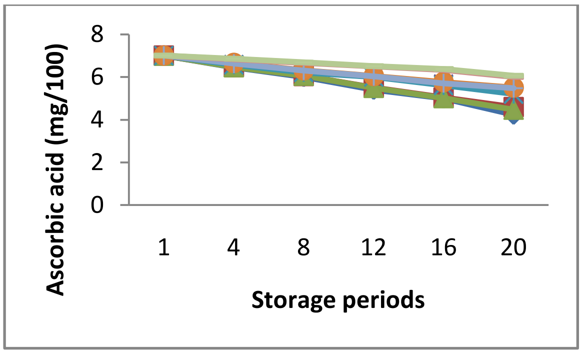

Fig. 3. Effect of edible coating on storage intervals of on ascorbic acid (mg/100g) of carrot.

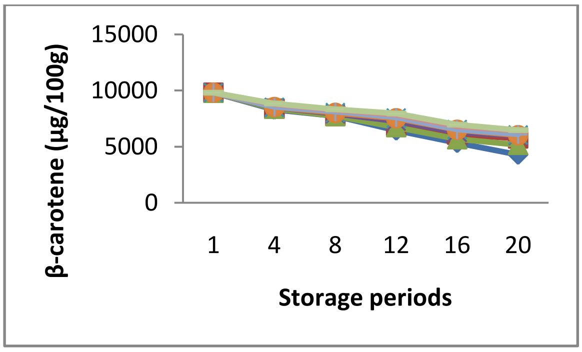

Fig. 4. Effect of edible coating on storage intervals of on beta-carotene (µg/100g) of carrot.

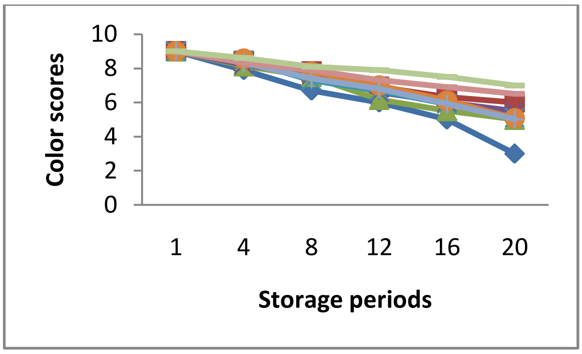

Fig. 5. Effect of edible coating on storage intervals of on colour (scores) of carrot.

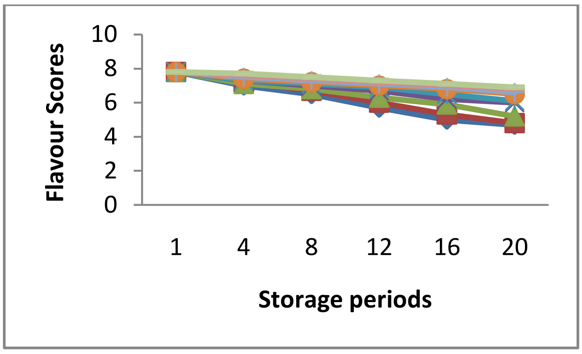

Fig. 6. Effect of edible coating on storage intervals of on flavour (scores) of carrot.

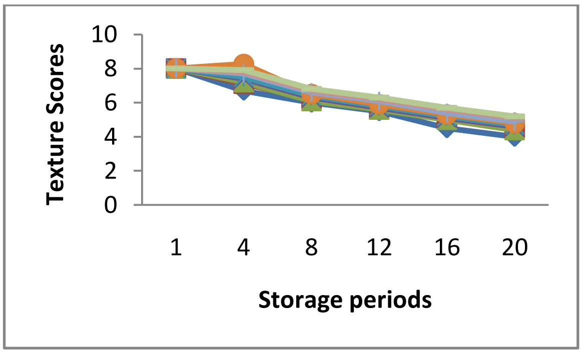

Fig. 7. Effect of edible coating on storage intervals of on texture (scores) of carrot.

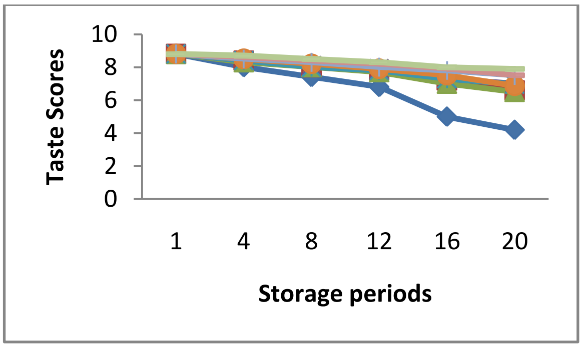

Fig. 8. Effect of edible coating on storage intervals of on taste (scores) of carrot.

Ascorbic Acid (mg/100g)

In plant tissue various forms of the same vitamin may exist. Ascorbic acid is an example of such a vitamin. The data depicted in Table 6 shows the effect of different treatments on the Ascorbic acid. In Table 1, there was highest value of ascorbic acid was observed in T_9 and T_8 (6.57 mg, 6.55 mg) as compared to control T_1 was 5.68 mg. The interaction among treatments and storage intervals showed the significant difference except T_7, T_6, T_5 and T_4 (6.19mg, 6.21mg, 6.09 mg and 6.12 mg) followed by T_3, T_2 and T_1 (5.74 mg, 5.77 mg and 5.68 mg) respectively. Chitosan caused degradation of ethylene into carbon dioxide and water (Wills *et al*., 1989a) resulting in a decrease in oxygen level in storage which might be lead to less loss of ascorbic acid from fruits and vegetables. The maximum ascorbic acid value has shown in non treated carrots. These results are in line with the findings of Summu and Bayindirli (1995). The general trend was observed in ascorbic acid decreased with the advancement of time (Fig. 3). The loss of ascorbic acid at first day of storage was 71 mg/100g and decreased at last day of storage 5.19 mg/100g in carrot vegetables. This confirmed the results by Yagi (1980) and Kropp and Bin (1985) who found slight decrease in ascorbic acid of fruits treated with different coating and packaging materials.

Beta Carotene (µg/100g)

Beta carotene during storage and processing of vegetables show no definite trend of nutrient retention, but fluctuate among samples analyzed in different laboratories. When total carotenoids were measured slightly or markedly loss of respiration rate was not observed (Martin *et al*., 1960; Wu *et al*., 1992). The consumption of carrot and its related products has increased steadily due to the recognition of antioxidant and anticancer activities of b-carotene in carrot, which is also a precursor of vitamin A (Speizer *et al*., 1999; Dreosti, 1993).

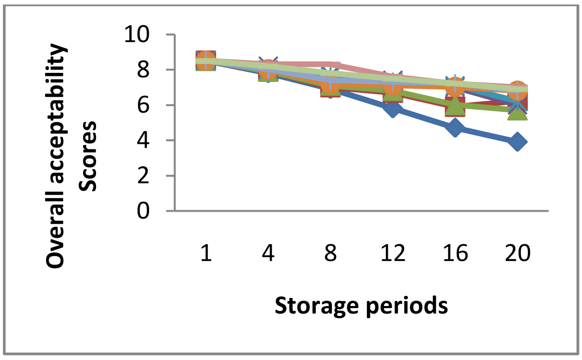

Fig. 9. Effect of edible coating on storage intervals of on overall acceptability (scores) of carrot.

The data depicted in Table 1 shows the effect of different treatments on beta carotene. In Table 1, there was highest mean value observed in T_9 (8053.2%) as compared to control (T_1) was 6972.6 µg. The interaction among treatments and storage intervals showed the significant difference were found T_8, T_7, T_6, T_5, T_4,T_3,T_2 (7979.7 µg,7772.7 µg,7731.0 µg, 7734.8 µg,7618.2 µg, 7242.2 µg, 7421.2 µg) respectively. There is high beta carotene value in treated carrots this might be due to the coatings (Chitosan) served as a semi permeable around the vegetables and packaging decreased the rate of respiration by degrading ethylene produced by the fruits into carbon dioxide and water.

Beta carotene decreased with the passage of time (Fig. 4). At first day 9797.7 µg was observed and at last it was 5793.4 µg. Although it is possible that some interconversion of carotenoids occurs as plant cells deteriorate during storage, the apparent increase in beta carotene level that we observed may also be the result of day to day variation in the chromatographic system due to instability of the standard. This confirmed the results by Hart and Scott (1995).

Sensory Evaluation

Colour

Fruits and vegetables contain 5 major pigments, including chlorophylls, carotenoids, anthocyannins, anthoxanthins and betalains. The bright orange red color of fresh carrots can disappear in storage. Once the carrots are exposed to air they easily dehydrate and white layer formed on the carrot surface. The data depicted in Table 2 shows the effect of different treatments on the colour. Colour score was observed in T_7, T_6, T_5 and T_4 (7.07, 7.26, 7.08, 7.15) respectively there is a non significant difference between all these treatments other treatments T_8, T_3, T_2 and T_1 (7.65, 6.88, 7.41, 6.26) respectively are significantly different from each other. The colour retention might be due to the coatings edible have been shown to protect carrot from this quality defect (Kırca *et al*., 2007). Sensory results showed preference for coated carrots due fresh appearance (Howard and Dewi. 1995).

Colour score of carrot vegetables decreased with increase in storage period. The mean value of colour score at first was 9.00 decreased to 5.35 at last day of storage (Fig. 5). Storage intervals showed that all the storage intervals different significantly. Colour changes have been correlated by the consumer with the conversion of starch to sugar that is, sweetening and the development of other desirable attributes so that the correct skin colour is often all that is required for a decision to purchase the commodity (Wills *et al*., 1989a).

Flavour

In Table 2, there was highest value of flavour was observed in T_9 and T_8 (7.38, 7.30) as compared to control T_1 was 6.11. The interaction among treatments and storage intervals showed the significant difference were found in T_7, T_6, T_5, T_4, T_3 and T_2 (7.20, 7.11, 6.95, 6.83, 6.51 and 6.30) respectively. During storage, flavour score was decreased with the passage of time (Fig. 6). At 1st day of storage (7.80) flavour scores was observed in all treatments. Similarly at 4th day (7.34), 8th day (7.0), 12th day (6.68), 16th day (6.30) and 20th day (5.95) was observed. The decreased in flavour score during storage might be due to the degradation of organic acid, alcohols, soluble sugars and other volatile essential compounds into CO_2, water, ethylene and other phenolic compounds. These results are in agreement with Arthey and Philip (2005).

Texture

The data showed that the effect of treatments on texture scores differ except T_7, T_6, T_5 having (6.4, 6.4 and 6.3) respectively show similar score, T_3 and T_2 also show similar results that is (6.05 and 6.08) whereas the maximum retention in texture score was observed in T_9 (6.7) followed by T_8 (6.6) as compared to control having lower texture score (5.7) during storage. The maximum retention of texture score might be due to the coatings (Chitosan) and polyethylene packaging and as a result the speed of changes was slow during storage. These treatments helped in retention of texture and maintained the quality for long period of up to the end of storage. These results are in line with those of Moghadam and Eslani (2005) and Zora-Singh *et al*. (2000). Fig. 7 is related to the texture scores of carrots during its storage period and data shows gradually decreased of texture scores in all treatments with the passage of time. The highest texture score 8.0% was observed in fresh carrot at first day of storage was reduced to texture score of 6.5% at 20th day of storage. In our studies the reduction of texture score during storage is might be due to the degradation of pectic substances and the maximum changes may be attributed to minimum texture that is an agreement to those of (Arthey and Philip, 2005).

Taste

The data depicted in Table 2 shows the effect of different treatments on the taste. In Table 2, the highest mean value of taste score was observed in T_9, T_8 and T_7 (8.37, 8.23, 8.15) respectively, as compared to control T_1 (6.70). The interaction among treatments and storage intervals showed the significant difference were found except T_6, T_5, T_4, (7.96, 7.87, 7.91) followed by T_3 and T_2 (7.71, 7.80) respectively. The highest taste value is observed in treated carrots this might be due to the coatings (Chitosan) served as a semi permeable around the vegetables and packaging decreased the rate of respiration by degrading ethylene produced by the fruits into carbon dioxide and water. This confirmed the results by Zora-Singh *et al*. (2000), Akbudak and Eris (2004). The data regard to taste showed that there was a general trend of taste change during storage. At first day taste score was observed 8.80 and decreased to last day 6.78 (Fig. 8). But the minimum of loss taste has shown in treated carrots. This might be due to the coatings (Chitosan) and polyethylene packaging and as a result the speeds of changes were slow during storage. These treatments helped in retention of overall acceptability and maintained the quality for long period of up to the end of storage. These results are in line with those of Moghadam and Eslani (2005) and Zora-Singh *et al*. (2000).

Overall acceptability

Table 2 shows mean values for the overall acceptability of carrots at room temperature during the storage period. Results pertaining to overall acceptability decreased with the passage of storage time (Fig. 9). The value observed in fresh uncoated and coated carrot was 8.5 at first day of storage. The reduction in overall acceptability of carrot might be due to the metabolic changes occur in structural polysaccharides and reduction of sugar organic acid etc might have reduced the taste of the vegetable during storage. The evaporation of water from fruits and vegetables during storage in some of the treatments may be the other reason of the reduction of overall acceptability. The data depicted in Table 2 shows the effect of different treatments on the overall acceptability. In Table 2, the highest mean value observed in T_9 (7.68) as compared to control T_1 was 6.26. The interaction among treatments and storage intervals showed the significant difference were found except T_8 and T_7 (7.75, 7.53) followed by T_6, T_5 and T_4 (7.43, 7.45 and 7.46) also followed by T_3 and T_2 (7.00 and 7.03) respectively. The highest value of overall acceptability was in treated carrots this might be due to the coatings (Chitosan) and polyethylene packaging and as a result the speed of changes were slow during storage. These treatments helped in retention of overall acceptability and maintained the quality for long period of up to the end of storage. These results are in line with those of Moghadam and Eslani (2005) and Zora-Singh *et al*. (2000).

Conclusions

The effect of different coating on storage life of carrot packaged in sealed Polyethylene bags was investigated at ambient temperature during storage. The physico-chemical characteristics and sensory parameters were studied at an interval of 4 days for a total period of 20 days during storage. All of the treatments had shown a significant effect on storage life of carrots. However, the treatment T_9 was most effective in the retention of higher contents of vitamin C, Total soluble solids, Titratable acidity, pH, Beta carotene and sensory parameters like texture, taste, flavour, color and over all acceptability with minimum weight loss during storage.

Whereas,T_9 (2% Chitosan in 0.25N HCl and 0.50mL glycerol + Polyethylene.) was found better to all other treatments. These treatments have increased storage life of carrot vegetable which is very hopeful information for those farmers produce carrot and may be recommended as fungicides to increase the storage life of carrot vegetable.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Acknowledgments

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