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Effect of minimal processing and packaging on quality and shelf-life of carrots *(Daucus carota)*

Sahil Sharma, Julie Dogra Bandral, Monika Sood and Neeraj Gupta

Abstract
In the present study, peeled carrots were coated with carboxy methyl cellulose and sucrose (1, 2 and 3 per cent), surface dried and packed in polypropylene bags and trays wrapped with shrink wrap films and stored in refrigerated conditions. During storage, physiological loss in weight (PLW) showed a decreasing trend and T_3 (3% CMC) recorded the minimum PLW of 2.24 per cent in polypropylene bags and 2.16 per cent in shrink wrap after 7 days of refrigerated storage. The beta carotene content of minimally processed carrot decreased with advancement in storage period and the highest value was recorded by treatment T_3 (3% CMC), whereas T_1 (control) recorded the lowest value. On comparing the packaging, the total phenols were higher in shrink wrap packed minimally processed carrots. There was a significant increase in total phenols content of minimally processed carrot with application of edible coatings and with advancement in storage period. The treatment T_3 (2% CMC) recorded highest total phenol content of 88.90 mg/100g in polypropylene bags and 89.13 mg/100g in shrink wrap after 14 days of storage. A significant increase in ascorbic acid content was noticed after application of edible coating and highest values were observed in T_3 (2% CMC). Overall T_3 (2% CMC) had higher total phenols, ascorbic acid, beta carotene content and lower PLW in shrink wrap packed minimally processed carrots

Keywords: Carrot, minimal processing, carboxy methyl cellulose, sucrose, total phenol

Introduction
Minimal processing describes non thermal technologies to process food in a manner to guarantee the food safety and preservation as well as to maintain as much as possible the fresh-like characteristics of fruits and vegetables (Manvell, 1997) [21]. Among others, visual properties of fresh-cut fruit and vegetable commodities are one of the most important parameter to evaluate the total quality of the product by consumers. Minimally processed food and vegetables imply that fresh cut products have been freshly cut, washed packaged and maintained with refrigeration. The main changes in the products are increased metabolic activity, enzymatic browning and presence of microorganisms and pathogens in the plant tissues that have been processed. Most food processing techniques stabilize the products and lengthen their storage and shelf life, fresh-cut processing of fruits and vegetables increases their perishability. Due to this and the need for strict sanitation, preparation and handling of these products require an integration of production, postharvest, and food science technologies and marketing expertise.

An edible film is defined as a thin layer or solid sheets of edible material placed on or between food components (Krochta and Mulder-Johnston, 1997) [17]. The concept of using edible coating is to extend shelf life of fresh and minimally processed produce and protect them from harmful environmental effects. The need is basically emphasized based on the increasing demand for high quality minimal processed food and storage technologies. By regulating the transfer of moisture, oxygen, carbon dioxide and taste compounds in a food system, edible coating have demonstrated the capability of improving food quality and prolonging shelf life of fresh produce (Baldwin et. al., 2002) [6]. In addition edible coating can carry functional ingredients like antioxidants, antimicrobials, nutrients and flavour. Minimal processed carrots (*Daucus carota* L.) are ready to eat products with a limited shelf life due to physiological disorder called “white blush”. Formation of whitish appearance on the surface of the peeled carrots has been attributed to dehydration and possible formation of lignin in response to peeling (Baldwin *et al.*, 1995) [7]. Therefore, some dipping treatments and edible coatings or acidic environment can be used to inactivate the lignification process which is enzyme mediated Also, losses of carotene have been reported in fresh cut carrots and with application of edible coatings, about 50 per cent retention can be obtained. Therefore, the present study was undertaken in the Divis Division of Food Science and Technology, Sher-e-Kashmir

University of Agricultural Sciences and Technology of Jammu to study suitability of edible coatings combined with packaging to prevent the quality loss during storage of fresh cut minimally processed carrot.

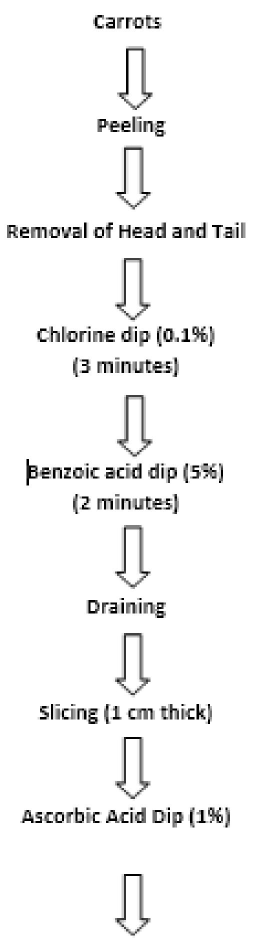
Material and methods

Procurement of raw materials, packaging material and edible coatings

Good quality fresh carrot vegetables were purchased from local market of Jammu and transported to processing hall of Division of Food Science and Technology, SKUAST-Jammu. They were visually inspected for freedom of defects and blemishes. Two packaging materials viz. polypropylene bags of 0.02mm thickness and polystyrene trays with shrink wrap covering were used for packaging of minimally processed carrots in 250 gm packaging. Two edible coatings viz. carboxy methyl cellulose (CMC) and sucrose were used for coatings of minimally processed carrots. Prior to coating, the carrots were given chlorine dip, ascorbic acid dip and finally benzioic acid dip.

Preparation of minimally processed carrots

The whole carrots were peeled and the head and tail were be removed. The prepared carrots were washed thoroughly and given chlorine dip (0.1%) for 3 minutes followed by benzoic acid dip (1%) for 2 minutes and drained properly. After dip, the minimally processed carrots (MPC) were sliced into slices (1cm thick) and given ascorbic acid (1%) dip for 3 minutes then subjected to below mentioned treatments. The flow sheet for preparation of minimally processed carrots is given in Figure 1.



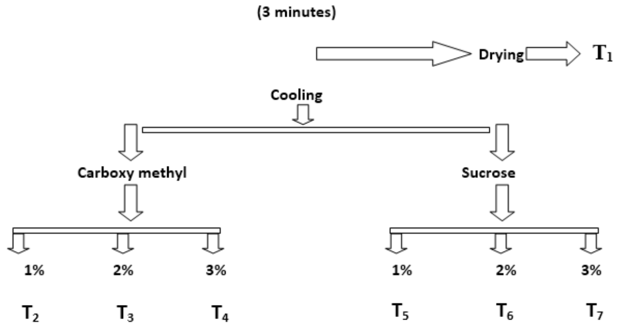


Fig 1: Flow sheet for Preparation of Edible Coated minimally processed carrots

Packaging and storage of edible coated minimally processed carrots

The edible coated carrots were packed in polypropylene bags and polystyrene trays covered with shrink wrap film in 250 gm packing. Edible coated minimally processed carrots prepared using different concentrations of carboxy methyl cellulose and sucrose coatings were packed and stored under refrigerated conditions and analysed for physico-chemical changes and sensory characteristics at a regular interval of 0, 7, 14 and 21 days.

Physiological loss in weight (PLW)

The Physiological loss in weight (PLW) was estimated according to the method described by Ngure *et al.* (2009). The percent weight loss was determined according to the following expression:

$$\text{Weight Loss (\%)} = \frac{W_o - W_t}{W_0} \times 100$$

Where, W_0 is the initial sample weight and W_t is the sample weight at time t. The weight was determined by a digital precision balance. At each sampling time, the weight was measured twice, on two different batches.

Ascorbic acid

The titrimetric method using 2,6- dichlorophenol indophenol dye was used to estimate ascorbic acid (AOAC, 2002).

Dye factor (i.e.mg of ascorbic acid per ml of dye) determined by titrating 5 ml of standard ascorbic acid solution and 5 ml of 0.4% oxalic acid against dye solution till pink colour.

A Known volume of sample (10ml) was made to 100ml using 0.4 percent oxalic acid filtered through Whatman no.4 filter paper. A known volume of aliquot (10ml) was mixed with 15 ml of oxalic acid (0.4%) and titrated against standardized dye solution to a faint pink colour persisting for at least 15 seconds. Fresh dye solution and standardized ascorbic acid was prepared before each analysis.

$$\text{Dye factor} = \frac{0.05}{\text{Titre}}$$

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre x Dye factor x volume made up}}{\text{Aliquot of extract taken x weight of sample}} \text{ x } 100$$

β-carotene

B-carotene was determined by soaking 5g sample in 15ml of AR grade acetone for 2 hours at room temperature under dark condition in order to get complete carotene extraction. The carotene layer was separated using petroleum ether through separating funnel. The volume was made up to 100ml with petroleum ether through separating funnel. The volume was made up to 100ml with petroleum ether and then this layer was again passed through sodium sulphate over the funnel in order to remove moisture from the layer. The optical density of the layer was measured at 452 nm using petroleum ether as blank (Srivastava and Kumar 2003) [28]. The β-carotene was calculated using the following formula.

$$\beta\text{-carotene (mg/100g)} = \frac{\text{O.D of sample} \times 13.9 \times 10^4 \times 100}{\text{Weight of sample} \times 560 \times 1000}$$

Antioxidant activity

Free radical scavenging activity was determined by DPPH (diphenylpicryl hydrazyl) method. Five hundred micro litres of 0.5 Mm DPPH solution and 2ml of 80 per cent methanol aqueous solution were mixed with 25 µL of methanolic extract of sample, and absorbance was determined under 517 nm blank as 80 per cent methanol and tris buffer) after maintaining at 20^0 C for 30 minutes. The free radical scavenging activity was evaluated by comparing the absorbance of the sample solution with control solution to which distilled water was added instead of sample (Abe *et al*., 1998).

$$\text{Radical scavenging activity (\%)} = \frac{\text{Control OD (0 min) - Sample OD (30 min)}}{\text{Control OD (0 min)}} \times 100$$

Total phenols

The total phenols extracted in 10-15 times volume of 80 per cent ethanol were estimated on the basis of their reaction with an oxidizing agent phosphomolybdate in Folin–Ciocalteau reagent under alkaline conditions in boiling water bath for one minute. The developed blue colour was measured at 650nm in a calorimeter. The standard curve was prepared using different concentrations ($20\text{-}100_{\text{ug/ml}}$) of catechol and the results were expressed as mg per cent on fresh weight basis (Malick and Singh, 1980) [20]

Statistical analysis

The results obtained were statistically analyzed using (Gomez and Gomez, 1984) completely randomized design (CRD) and CRD factorial for interpretation of results through analysis of variance.

Result and Discussion

Physiological loss in weight (PLW)

The physiological loss in weight of minimally processed carrot in both packaging showed an increasing trend during 21 days of storage. The physiological loss in weight increased from initial mean value of 3.08 to 3.81 per cent in polypropylene bags and 2.91 to 3.46 per cent in shrink wrap. T_1 (control) recorded the highest physiological loss in weight of 3.82 per cent in polypropylene bags and 3.58 per cent in shrink wrap, while T_3 (2% CMC) recorded the lowest value of 2.24 per cent in polypropylene bags and 2.16 per cent in shrink wrap packed minimally processed carrots after 7 days of storage. Edible films act as a barrier to transport of gas and water vapour in the product, modifying the internal atmosphere, which delays dehydration and senescence and thus prolongs shelf life (Wang, 2011) [30]. Vicini (2002) [27] and Wang *et al.* (2015) [31] also reported slower rate of water loss in carrots coated with coatings like starch, gelatin, glycerol, chitosan etc. Ilic (2013) also reported loss in weight during storage of carrots due to transpiration resulting in shrivelling, loss of colour and risk of post harvest decay. The results are in agreement with those of Menezes and Athmaselvi (2016) [23]; Karande *et al.* (2014) [14]. The loss in weight may be due to enhancement of respiration rate after shredding and slicing activities where fruits no longer remain intact.

Ascorbic acid

Ascorbic acid content showed a decreasing trend in all treatments over storage period of 21 days at refrigerated condition. The mean ascorbic acid content declined significantly from the initial value of 6.64 to 6.36 mg/100g in polypropylene bags and 6.64 to 6.45 mg/ 100 gm in shrink wrap during 21 days of storage. After 21 days of storage, the highest ascorbic acid content of 6.62 mg/100g in polypropylene bags and 6.69 mg/100g in shrink wrap were recorded by T_3 (2% CMC) whereas, T_1 (control) recorded the lowest value of 5.97 mg/100g in polypropylene bags and 6.03 mg/100g in shrink wrap, respectively. Ilic *et al.* (2013) also reported significant reduction in vitamin C content of carrot due to respiration process and ascorbic acid oxidation to L-dehydro ascorbic then L-diketogulonase (Carrillo *et al.*, 2000) [9]. Pilon *et al.* (2006) [26] also reported decrease in ascorbic acid content of minimally processed carrots cubes during refrigerated storage and packed in polymeric film bags. The rate of decrease of ascorbic acid content in coated carrot was slower as compared to control due to retailed oxidation process and hence rate of conversion of ascorbic acid to dehydro ascorbic acid. The findings are in conformity with those of Manoj *et al.* (2016) and Yahia *et al.* (2007) [32] in bell pepper and tomatoes.

B-carotene

Storage period significantly affected the β-carotene content of minimally processed carrot. During storage for 21 days there was a significant decrease in β- carotene content from initial mean value of 14.65 to 13.89 mg/100g in polypropylene bags and 14.65 to 13.95 mg/100g in shrink wrap. At 7 days of storage, treatment T_3 (2% CMC) recorded the highest β-carotene of 14.69 mg/100g in polypropylene bags and 14.73 mg/100g in shrink wrap packed carrots. On the other hand, after 21 days of storage, treatment T_1 (control) recorded the lowest value of 13.16 mg/100g in polypropylene bags and 13.30 mg/100g in shrink wrap. Amorim-Carrilho *et al.* (2014) [3] reported that fresh cut carrots with coating had less contact with oxygen than the uncoated which prevented the decrease of total carotenoids to some extent. Geetha (2015) [10]; Mahendran (2015) [19] observed that α and β carotene concentration decreased in minimally processed carrots. Degradation might have probably been initiated by peeling and further accumulation due to cutting. This process also increased the exposed surface area of carrots to oxidative degradation. Lipoxygenase catalyses the co-oxidation of pigments, can bleach carotenoids. According to Koukounaras *et al.* (2007) [16] lower total carotenoids contents in peach fruits during storage may be due to exposure to oxygen, temperature and alteration in structure and bioactivity of carotenoids in terms of isomerisation, oxidation or degradation.

Antioxidant

Antioxidant activity of minimally processed carrots showed a decreasing trend during refrigerated storage. T_3 (2% CMC) recorded maximum antioxidant activity of 78.61 per cent in polypropylene bags and 79.01 per cent in shrink wrap packed minimally processed carrots whereas, lowest values of 73.82 per cent in polypropylene bags and 74.31 per cent in shrink wrap were noticed in T_5 (1% sucrose) at the 7 days of storage period. After 21 days of storage, highest antioxidant activity of 72.95 per cent in polypropylene bags and 74.66 per cent in shrink wrap were recorded by T_3 (2% CMC) where as a minimum antioxidant activity of 65.28 per cent in polypropylene bags and 67.80 per cent in shrink wrap were recorded in T_1 (control). Venneria *et al.* (2012) [29] and Caro *et al.* (2004) [2] also gave similar findings of reduction in the total antioxidant activity of minimally processed three leaf crops and different citrus segments during refrigerated storage.

Total phenol

The maximum total phenol content of 85.82 mg/100g in polypropylene bags and 86.20 mg/100g in shrink wrap were recorded in T_3 (2% CMC), while the lowest of 84.26 mg/100g in polypropylene bags and 84.33 in shrink wrap were recorded in T_1 (control) at 7 days of storage. However, after 21 days of storage the highest total phenol content of 91.61 mg/100g in polypropylene bags and 92.11 mg/100g in shrink wrap were noticed in treatment T_3 (2% CMC) and the lowest of 89.76 mg/100g in polypropylene bags and 90.36 mg/100g in shrink wrap were noticed in T_1 (control). Accumulation of phenols during the storage of minimally processed carrots has been observed by some researchers (Klaiber *et al.* 2005) [15]. A greater accumulation of total phenols is induced by the wound in minimally processed carrot. Moreover, the accumulation of total phenols in wounded carrots during storage is dependent on wound intensity and stimulation of phenylpropanoid pathway (Heridia and Cisneros-Zevallos, 2009) [12].

Table 1: Effect of edible coatings and packaging on Physiological loss in weight (%) in minimally processed carrots during refrigerated storage

Treatments	Packaging									
	Polypropylene					Shrink wrap				
	Storage (days)					Storage (days)				
	0	7	14	21	Mean	0	7	14	21	Mean
T_1 (Control)	-	3.82	3.99	4.24	3.01	-	3.58	3.76	3.95	2.82
T_2 (1% CMC)	-	2.65	3.17	3.72	2.39	-	2.41	2.62	3.02	2.01
T_3 (2% CMC)	-	2.24	2.61	2.97	1.96	-	2.16	2.38	2.70	1.81
T_4 (3% CMC)	-	2.52	3.01	3.59	2.28	-	2.30	2.54	2.87	1.93
T_5 (1% Sucrose)	-	3.68	3.79	4.21	2.92	-	3.53	3.67	4.06	2.82
T_6 (2% Sucrose)	-	3.14	3.43	3.81	2.60	-	3.00	3.26	3.70	2.49
T_7 (3% Sucrose)	-	3.50	3.64	4.10	2.81	-	3.39	3.45	3.89	2.68
Mean	-	3.08	3.38	3.81		-	2.91	3.10	3.46	
CD $_{(P = 0.05)}$										
Packaging (A) = 0.01 A×B = 0.03										
Storage (B) = 0.02 A×C = 0.04										
Treatments (c) = 0.03 B×C = 0.05										
A×B×C = 0.07										

Table 2: Effect of edible coatings and packaging on ascorbic acid (mg/100g) in minimally processed carrots during refrigerated storage

Treatments	Packaging									
	Polypropylene					Shrink wrap				
	Storage (days)					Storage (days)				
	0	7	14	21	Mean	0	7	14	21	Mean
T_1 (Control)	6.30	6.18	6.09	5.97	6.14	6.30	6.20	6.11	6.03	6.16
T_2 (1% CMC)	6.59	6.48	6.41	6.33	6.45	6.59	6.52	6.45	6.40	6.49
T_3 (2% CMC)	6.86	6.80	6.73	6.62	6.75	6.86	6.82	6.75	6.69	6.78
T_4 (3% CMC)	6.74	6.67	6.58	6.47	6.62	6.74	6.70	6.63	6.57	6.66
T_5 (1% Sucrose)	6.53	6.40	6.31	6.24	6.37	6.53	6.46	6.39	6.33	6.43
T_6 (2% Sucrose)	6.81	6.69	6.55	6.48	6.63	6.81	6.77	6.63	6.59	6.70
T_7 (3% Sucrose)	6.68	6.56	6.48	6.40	6.53	6.68	6.64	6.55	6.51	6.60
Mean	6.64	6.54	6.45	6.36		6.64	6.58	6.50	6.45	
CD $_{(p = 0.05)}$										
Packaging (A) = 0.02 A×B = 0.04										
Storage (B) = 0.03 A×C = N/S										
Treatments (c) = 0.03 B×C = N/S										
A×B×C = N/S										

Table 3: Effect of edible coatings and packaging on β-carotene (mg/100g) in minimally processed carrots during refrigerated storage

Treatments	Packaging									
	Polypropylene					Shrink wrap				
	Storage (days)					Storage (days)				
	0	7	14	21	Mean	0	7	14	21	Mean
T_1 (Control)	14.55	14.05	13.62	13.16	13.85	14.55	14.08	13.67	13.30	13.90
T_2 (1% CMC)	14.61	14.53	14.21	13.94	14.32	14.61	14.60	14.11	13.96	14.32
T_3 (2% CMC)	14.77	14.69	14.52	14.20	14.55	14.77	14.73	14.61	14.29	14.60

T_4 (3% CMC)	14.68	14.60	14.33	14.07	14.42	14.68	14.62	14.37	14.12	14.45
T_5 (1% Sucrose)	14.59	14.51	14.16	13.87	14.28	14.59	14.55	14.28	13.83	14.31
T_6 (2% Sucrose)	14.73	14.66	14.28	14.05	14.43	14.73	14.70	14.40	14.17	14.50
T_7 (3% Sucrose)	14.64	14.57	14.25	13.96	14.36	14.64	14.58	14.35	14.00	14.39
Mean	14.65	14.52	14.20	13.89		14.65	14.55	14.25	13.95	
CD $_{(P = 0.05)}$										
Packaging (A) = 0.02 A×B = 0.03										
Storage (B) = 0.02 A×C = 0.04										
Treatments (c) = 0.03 B×C = 0.06										
A×B×C = N/A										

Table 4: Effect of edible coatings and packaging on antioxidant activity (%) in minimally processed carrots during refrigerated storage

Treatments	Packaging									
	Polypropylene					Shrink wrap				
	Storage (days)					Storage (days)				
	0	7	14	21	Mean	0	7	14	21	Mean
T_1 (Control)	78.13	75.47	70.99	65.28	72.46	78.13	75.92	72.03	67.80	73.47
T_2 (1% CMC)	78.93	76.00	74.29	71.76	75.26	78.93	76.92	75.00	72.48	75.83
T_3 (2% CMC)	80.74	78.61	76.34	72.95	77.16	80.74	79.01	77.70	74.66	78.03
T_4 (3% CMC)	80.49	78.01	75.28	71.84	76.40	80.49	78.79	76.09	72.93	77.07
T_5 (1% Sucrose)	77.51	73.82	71.46	69.85	73.16	77.51	74.31	72.19	70.40	73.60
T_6 (2% Sucrose)	78.35	75.68	73.00	70.16	74.29	78.35	76.91	74.28	71.58	75.28
T_7 (3% Sucrose)	77.90	74.29	72.63	70.10	73.73	77.90	75.22	73.60	70.41	74.28
Mean	78.86	75.98	73.42	70.27		78.86	76.72	74.41	71.46	
CD $_{(P = 0.05)}$										
Packaging (A) = 0.01 A×B = 0.02										
Storage (B) = 0.02 A×C = 0.03										
Treatments (c) = 0.02 B×C = 0.04										
A×B×C = 0.06										

Table 5: Effect of edible coatings and packaging on total phenols (mg/100g) in minimally processed carrots during refrigerated storage

Treatments	Packaging									
	Polypropylene					Shrink wrap				
	Storage (days)					Storage (days)				
	0	7	14	21	Mean	0	7	14	21	Mean
T_1 (Control)	82.80	84.26	86.90	89.76	85.93	82.80	84.33	87.25	90.36	86.19
T_2 (1% CMC)	82.93	85.01	87.79	90.68	86.60	82.93	85.32	88.17	91.02	86.86
T_3 (2% CMC)	83.25	85.82	88.90	91.61	87.40	83.25	86.20	89.13	92.11	87.62
T_4 (3% CMC)	83.16	85.23	88.45	91.10	86.99	83.16	85.59	88.68	91.52	87.24
T_5 (1% Sucrose)	82.86	84.61	87.09	90.30	86.22	82.86	84.94	87.72	90.95	86.62
T_6 (2% Sucrose)	83.07	85.53	88.34	91.00	86.99	83.07	85.80	88.51	91.39	87.17
T_7 (3% Sucrose)	83.00	85.02	87.51	90.62	86.54	83.0	85.36	87.80	90.76	86.68
Mean	83.01	85.07	87.85	90.72		83.01	85.36	88.18	91.16	
CD $_{(P = 0.05)}$										
Packaging (A) = 0.01 A×B = 0.02										
Storage (B) = 0.02 A×C = 0.03										
Treatments (c) = 0.02 B×C = 0.05										
A×B×C = 0.06										

Conclusion

It is therefore concluded that minimal processing of carrots followed by application of Carboxy Methyl Cellulose @ 2 per cent followed by packing in trays covered with shrink film was the most effective treatment for extension of shelf life and retention of storage quality of carrots under refrigerated conditions. Application of CMC and packaging reduced PLW and retained ascorbic acid, total phenols, antioxidants and beta carotene content of carrots during storage.

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