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Naik PR
Department of Post Harvest Technology, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India

Dev Raj
Department of Post Harvest Technology, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India

Mayani JM
Department of Post Harvest Technology, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India

Patel NV
Department of Post Harvest Technology, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India

Ashuqullah Atif
Department of Post Harvest Technology, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India

Corresponding Author
Naik PR
Department of Post Harvest Technology, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India

Preservation techniques for minimal processing of fresh-cut carrot pieces

Naik PR, Dev Raj, Mayani JM, Patel NV and Ashuqullah Atif

Abstract
The experiment was conducted to developed a methodology for preservation of minimally processed fresh-cut carrot pieces using sixteen treatment combinations comprised of four levels of potassium sorbate treatment [0 ppm (K_1), 500 ppm (K_2), 1000 ppm (K_3) and 1500 ppm (K_4)] and four levels of UV radiation time treatment [without UV radiation treatment (T_1), 15 min (T_2), 30 min (T_3) and 45 min (T_4)]. The result of present investigation indicated that minimally processed fresh-cut carrot pieces can be prepared by pre-treating pieces with 1000 ppm potassium sorbate followed by UV radiation treatment of packed pieces for 30 minutes and can remain shelf stable on the basis of nutritional as well as sensory quality up to ten days storage in polypropylene bag of 400 gauge. The cost of production per 100 g pack of minimally processed fresh-cut carrot pieces was worked out Rs. 16.01. Thus, prepared product can commercially be explored by food processing industry to ensure better returns to growers, processors and consumers as well.

Keywords: minimal processing. preservation, potassium sorbate, UV radiation

Introduction
Carrot (*Daucus carota* L.) belonging to Apiaceae family is grown throughout the world as an important and popular root vegetable particularly during winter season. It is a diverse coloured crop grown annually for the edible purpose. Carrot contains 86 per cent moisture, 10.6 g carbohydrates, 0.2 g fat, 1.2 g fiber, 1890 µg carotene, 0.04 g thiamine, 0.02 g riboflavin, 0.6 g niacin, 530 mg phosphorus, 1.1 g minerals and 3 mg per 100 g vitamin C (Gopalan *et al.* 2004) [12]. Due to the health and nutritional benefits of the carrot, its commercialization and industrialization in the form of different products is very important in fulfilling the nutrient requirements of the people particularly as a cheap source of vitamin A. The consumption of carrots and their products is increasing steadily due to their recognition as an important source of natural antioxidants having anticancer activity. Carotenoid helps in preventing heart diseases, improve vision, help in reducing blood sugar and reduce colon cancer. They also act as free-radical scavengers (Bast *et al.* 1998 and Bramley 2002) [3, 4]. Carrots are being consumed in various forms *viz.*, salad, soup, stews, curries, pies and sweetmeats. In the past, there have been three traditional forms of food trading; fresh, canned and frozen foods. In recent years, a fourth form called “minimally processed food” has been developed to respond to an emerging consumer demand for convenient, high-quality and preservative-free products with appearance of fresh characteristics, while being less severely processed. Minimally processed food can be used as ready-to-eat, ready-to-use, or ready-to-cook products. They are stored and marketed under refrigeration conditions (Dignan 1994) [9]. Preparation steps of minimally processed fruit and vegetable products which may include peeling, slicing, shredding, etc save labour and time for the purchasers, meanwhile removal of waste material during processing reduce transport costs. In addition, the production of such products will make year-round availability of almost all vegetables and fruits possible in fresh form around the world (Baldwin *et al*. 1995) [2]. Minimally processed vegetables that maintain firmness and crunchy texture are highly desirable because consumers associate these attributes with freshness and wholesomeness (Fillion and Kilcast 2002, Szczesniak 1998) [10, 22]. Minimal processing involves the principles of post harvest handling *i.e.* restriction in metabolic rate, surface sanitation and restricted moisture loss. In addition to some of concepts of fully processed fresh commodities *i.e.* use of texturizing, anti-microbial and anti-browning agents, modulation of cell physiological conditions to maximize pigment and vitamin retention as well as the judicious use of a thermal process without impeding the fresh-like sensory attributes of the products.

Fresh-cut produce industry has been on a double-digit growth rate in response to an increased demand by consumers, particularly in developed countries. Irradiation is a new physical cold processing food preservation technique which is devoted to investigate the microbiological quality of minimally processed products.

Materials and Methods

Experiment was carried out in Center of Excellence on Post Harvest Technology, Department of Post Harvest Technology, ASPEE College of Horticulture and forestry, N.A.U., Navsari. The fresh carrots were selected and washed with running tap water. The carrots were cut into 15×15 mm±1mm pieces. After that, the carrot pieces were blanched at 85° C temperature for 3 min followed by dipping pre-treatment for 15 minutes in solution of potassium sorbate (0, 500, 1000 and 1500 ppm), drained to remove excess surface moisture and then seal packed in polypropylene bags. The packed samples of fresh-cut carrot pieces were then given UV radiation treatment for different time (0, 15, 30 and 45 min) in laminar air flow. The height of UV light source from plate form was 16 inch. The power of UV light source was 1600 x 2 lumen and total 2 UV light tubes were used. These products after treatments were stored at refrigerated temperature (5±1 °C) for further observations and analysis and record observations. Principal steps used for preparation of minimally processed fresh-cut carrot pieces has been presented in Fig.1.

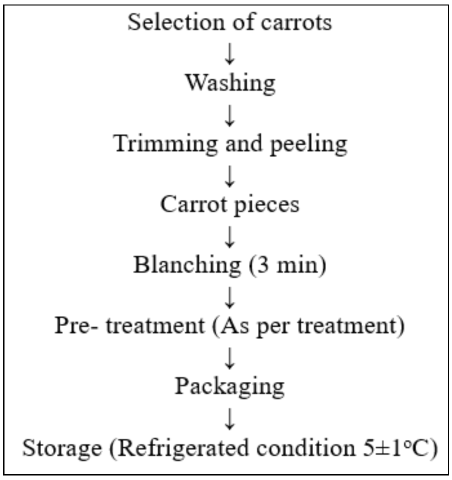

Fig 1: Principal steps used for preparation for minimal processing of carrots

Result and Discussion

Physico-chemical parameters

TSS

The perusal of data pertaining to effect of potassium sorbate pre-treatment, UV radiation treatment, storage and their interactions on TSS content of minimally processed fresh-cut carrot pieces has been presented in Table 1.

Effect of potassium sorbate: Data shows that among different potassium sorbate dipping pre-treatments. Minimum TSS was observed in minimally processed fresh-cut carrot pieces potassium sorbate pre-treatment was not given (K_1) and maximum TSS in minimally processed fresh-cut carrot pieces pre-treated with 500, 1000 and 1500 ppm potassium sorbate pre-treatment (K_2, K_3 and K_4). Almost similar observation was recorded by (Zhang *et al.* 2006) [26]. Potassium sorbate is promising as an effective agent against most yeast and moulds but its inhibitory effect against bacteria is lower. Dipping of strawberries in a solution of potassium sorbate for 1 minute greatly reduced all microbial counts (Wisal *et al.* 2013) [24].

Effect of UV radiation: Data showed that among different UV radiation treatments, mean TSS of minimally processed fresh-cut carrot pieces (T) varied significantly from 6.45 °Brix to 6.86 °Brix when packed fresh-cut carrot pieces were given UV radiation for different time. Minimum TSS was observed in minimally processed carrot pieces when no UV radiation treatment was given (T_1) and maximum TSS in minimally processed fresh-cut carrot pieces when UV radiation treatment was given for 30 minutes (T_3). Similar observation was recorded by Pan, Y. G. and Zu, H. (2012) for fresh-cut pineapple. Decreases in fruit TSS were observed with increasing UV-C intensity for storage conditions.

Effect of storage period: Data depicts that storage of minimally processed fresh-cut carrot pieces resulted significant decrease in mean TSS (S) from initial value of 6.16 °Brix to 7.13 °Brix after fifteen days of storage. Similar observation was reported by (Cortez-Vega *et al.* 2014) [7]. The reduction in soluble solids is a result of breathing which is the oxidative decomposition of complex substances (polysaccharides, simple sugars, organic acids, proteins and lipids) into simple molecules (CO_2 and H_2O) and energy.

Effect of interactions: Interaction of potassium sorbate dipping pre-treatment and storage depicted variations in TSS between 6.28 °Brix and 7.17 °Brix, with minimum decrease in TSS from 7.10 °Brix (K_3S_1) to 6.34 °Brix (K_3S_4) in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and maximum decrease from 7.15 °Brix (K_1S_1) to 5.68 °Brix (K_1S_4) in minimally processed fresh-cut carrot pieces which were not given potassium sorbate pre-treatment. Interaction of UV radiation treatment and storage depicted variations in TSS between 6.28 °Brix and 7.13 °Brix, with minimum decrease in TSS from 7.12 °Brix to 6.51 °Brix in minimally processed fresh-cut carrot pieces when UV radiation treatment was given for 30 minutes (T_3S_1 to T_3S_4), whereas maximum decrease in TSS was observed from 7.13 °Brix to 5.51 °Brix in minimally processed fresh-cut carrot pieces without UV radiation treatment (T_1S_1 to T_1S_4) after fifteen days of storage. Interaction of potassium sorbate pre-treatment and UV radiation treatment depicted variations in mean TSS in minimally processed fresh-cut carrot pieces from 6.26 °Brix to 6.94 °Brix, with minimum TSS (6.26 °Brix) in minimally processed fresh-cut carrot pieces packed with no pre-treatments were given (K_1T_1) and maximum TSS (6.94 °Brix) in minimally processed fresh-cut carrot pieces pre-treated with 1000 ppm potassium sorbate and UV radiation treatment was given for 30 minutes (K_3T_3).

Further, interaction of potassium sorbate pre-treatment, UV radiation treatment and storage depicted variations in TSS from 5.13 °Brix to 7.19 °Brix in minimally processed fresh-cut carrot pieces during a period of fifteen days, with minimum decrease 7.09 °Brix to 6.71 °Brix in minimally processed fresh-cut carrot pieces pre-treated 1000 ppm potassium sorbate and packed fresh-cut carrot pieces were given UV radiation treatment for 30 minutes ($K_3T_3S_1$ to $K_3T_3S_4$) and maximum decrease 7.16 °Brix to 5.13 °Brix in minimally processed fresh-cut carrot pieces without potassium sorbate and packed without giving UV radiation treatment ($K_1T_1S_1$ to $K_1T_1S_4$).

Table 1: Effect of potassium sorbate and UV radiation on TSS of minimally processed carrot pieces

Potassium sorbate (K)	TSS (ºB)						
	Storage period (S)						
	UV radiation time (T)	S_1 - 0 day	S_2 -5 days	S_3-10 days	S_4-15 days	Mean (KT) Mean (K)	Mean (T)
K_1 – control	T_1 - control	7.16	6.46	6.30	5.13	6.26	6.45
	T_2 - 15min	7.20	6.56	6.59	5.25	6.40	6.79
	T_3 - 30 min	7.13	6.83	6.66	6.14	6.69	6.86
	T_4 - 45 min	7.10	6.87	6.64	6.18	6.70	6.76
	Mean (KS)	7.15	6.68	6.55	5.68	6.51	
K_2 - 500 ppm	T_1- control	7.16	6.66	6.56	5.49	6.47	
	T_2 – 15 min	7.19	7.02	6.88	6.56	6.91	
	T_3 - 30 min	7.16	6.99	6.86	6.56	6.89	
	T_4- 45 min	7.16	6.97	6.73	6.49	6.84	
	Mean (KS)	7.17	6.91	6.76	6.28	6.78	
K_3-1000 ppm	T_1 - control	7.12	6.72	6.56	5.49	6.47	
	T_2 - 15min	7.10	7.00	6.90	6.70	6.93	
	T_3 - 30 min	7.09	7.00	6.95	6.71	6.94	
	T_4 - 45 min	7.09	6.90	6.70	6.46	6.79	
	Mean (KS)	7.10	6.91	6.78	6.34	6.78	
K_4 - 1500 ppm	T_1 - control	7.10	6.72	6.59	5.94	6.59	
	T_2 - 15min	7.13	6.96	6.91	6.61	6.90	
	T_3 - 30 min	7.10	6.98	6.90	6.63	6.90	
	T_4 - 45 min	7.10	6.90	6.66	6.20	6.71	
	Mean (KS)	7.11	6.89	6.76	6.34	6.78	
	Mean (S)	7.13	6.85	6.71	6.16		
T×S	T_1	7.13	6.64	6.50	5.51		
	T_2	7.16	6.88	6.82	6.28		
	T_3	7.12	6.95	6.84	6.51		
	T_4	7.11	6.91	6.68	6.33		
	K	T	K×T	S	K×S	T×S	K×T×S
S.E m. ±	0.039	0.039	0.079	0.029	0.059	0.059	0.118
CD at 5 %	0.114	0.114	0.228	0.083	0.165	0.165	0.332
CV%	4.11			3.06			

Total Sugar

The perusal of data pertaining to effect of potassium sorbate pre-treatment, UV radiation treatment, storage and their interactions on total sugars content of minimally processed fresh-cut carrot pieces has been presented in Table 2.

Effect of potassium sorbate: Data shows that among different potassium sorbate dipping pre-treatments, the mean total sugars of minimally processed fresh-cut carrot pieces (K) varied significantly from 4.30 per cent to 4.72 per cent. Minimum total sugars was recorded in minimally processed fresh-cut carrot pieces without potassium sorbate (K_1) and maximum total sugars in minimally processed fresh-cut carrot pieces pre-treated 1000 ppm potassium sorbate pre-treatment (K_3). Similar observation was recorded by (Zhang *et al.* 2006) [26]. Potassium sorbate is promising as an effective agent against most yeast and moulds but that its inhibitory effect against bacteria is lower.

Effect of UV radiation: Data showed that among different UV radiation treatments, mean total sugars of minimally processed fresh-cut carrot pieces (T) varied significantly from 4.24 per cent to 4.70 per cent when packed fresh-cut carrot pieces given UV radiation for different time, with minimum total sugars in minimally processed carrot pieces without UV radiation treatment (T_1) and maximum total sugars in minimally processed fresh-cut carrot pieces when UV radiation treatment was given for 30 minutes (T_3). Almost similar observation was recorded by Pan, Y. G. and Zu, H. (2012) for fresh-cut pineapple. The reduction in the total sugar content compared to controls may be because sugars (glucose, fructose, and sucrose) have high ultraviolet absorption in the range of 240 to 360 nm and fructose from 260 to 280 nm, which can lead to significant amounts of fructose losses in fruit juices after treatment with ultraviolet light. A similar effect was found in pear juice's ultrasonic treatment at a 25 kHz frequency for 45 and 60 minutes. (Saeeduddin *et al.* 2016) [20] for pear.

Effect of storage period: Data depicts that storage of minimally processed fresh-cut carrot pieces resulted significant decrease in mean total sugars (S) from initial value of 3.40 per cent to 6.45 per cent after fifteen days of storage. Similar observation was reported by (Cortez-Vega *et al.* 2014) [7].

Effect of interactions: Interaction of potassium sorbate dipping pre-treatment and storage depicted variations in total sugars between 3.18 per cent and 6.48 per cent, with minimum decrease in total sugars from 6.43 per cent (K_3S_1) to 3.67 per cent (K_3S_4) in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and maximum decrease from 6.47 per cent (K_1S_1) to 3.18 per cent (K_1S_4) in minimally processed fresh-cut carrot pieces which were not given potassium sorbate pre-treatment. Interaction of UV radiation treatment and storage depicted

variations in total sugars between 3.11 per cent and 6.47 per cent, with minimum decrease in total sugars from 6.44 per cent to 3.62 per cent in minimally processed fresh-cut carrot pieces when UV radiation treatment was given for 30 minutes (T_3S_1 to T_3S_4), whereas maximum decrease in total sugars was observed from 6.47 per cent to 3.11 per cent in minimally processed fresh-cut carrot pieces with no UV radiation treatment was given (T_1S_1 to T_1S_4) after fifteen days of storage. Interaction of potassium sorbate pre-treatment and UV radiation treatment depicted variations in mean total sugars in minimally processed fresh-cut carrot pieces from 4.18 per cent to 5.06 per cent, with minimum total sugars (4.18 per cent) in minimally processed fresh-cut carrot pieces packed without pre-treatments were given (K_1T_1) and maximum total sugars (5.06 per cent) in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and UV radiation treatment was given for 30 minutes (K_3T_3) and carrot pieces pre-treated with 500 ppm and UV radiation treatment was given for 15 minutes (K_2T_3).
Further, interaction of potassium sorbate pre-treatment, UV radiation treatment and storage depicted variations in total sugars from 3.03 per cent to 6.50 per cent in minimally processed fresh-cut carrot pieces during a period of fifteen days, with minimum decrease 6.40 per cent to 4.17 per cent in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and packed fresh-cut carrot pieces were given UV radiation treatment for 30 minutes ($K_3T_3S_1$ to $K_3T_3S_4$) and maximum decreased 6.45 per cent to 3.03 per cent in minimally processed fresh-cut carrot pieces packed with no pre-treatments were given ($K_1T_1S_1$ to $K_1T_1S_4$).

Table 2: Effect of potassium sorbate and UV radiation on total sugars of minimally processed carrot pieces

Potassium sorbate (K)	**Total sugars (%)**						
	Storage period (S)						
	UV radiation time (T)	**S_1 - 0 day**	**S_2 -5 days**	**S_3-10 days**	**S_4-15 days**	**Mean (KT) Mean (K)**	**Mean (T)**
K_1 – control	T_1 - control	6.45	4.05	3.21	3.03	4.19	4.24
	T_2 - 15min	6.50	4.10	3.28	3.09	4.24	4.67
	T_3 - 30 min	6.48	4.25	3.36	3.30	4.35	4.70
	T_4 - 45 min	6.46	4.34	3.52	3.30	4.41	4.49
	Mean (KS)	6.47	4.19	3.34	3.18	4.30	
K_2 - 500 ppm	T_1 - control	6.50	4.11	3.30	3.09	4.25	
	T_2 - 15min	6.48	4.54	4.22	3.51	4.69	
	T_3 - 30 min	6.46	4.52	4.22	3.51	4.68	
	T_4 - 45 min	6.46	4.39	4.04	3.33	4.55	
	Mean (KS)	6.48	4.39	3.94	3.36	4.54	
K_3 - 1000 ppm	T_1 - control	6.46	4.11	3.29	3.10	4.24	
	T_2 - 15min	6.46	5.29	4.37	4.14	5.06	
	T_3 - 30 min	6.40	5.34	4.33	4.17	5.06	
	T_4 - 45 min	6.40	4.33	4.07	3.29	4.52	
	Mean (KS)	6.43	4.77	4.01	3.67	4.72	
K_4 – 1500 ppm	T_1 - control	6.45	4.14	3.32	3.22	4.28	
	T_2 - 15min	6.43	4.53	4.23	3.47	4.67	
	T_3 - 30 min	6.43	4.57	4.28	3.50	4.69	
	T_4 - 45 min	6.42	4.30	3.96	3.26	4.49	
	Mean (KS)	6.43	4.38	3.95	3.36	4.53	
	Mean (S)	6.45	4.43	3.81	3.40		
T×S	T_1	6.47	4.10	3.28	3.11		
	T_2	6.47	4.61	4.02	3.55		
	T_3	6.44	4.67	4.05	3.62		
	T_4	6.44	4.34	3.90	3.30		
	K	T	K×T	S	K×S	T×S	K×T×S
S.E m. ±	0.025	0.025	0.051	0.023	0.047	0.047	0.094
CD at 5 %	0.073	0.073	0.147	0.066	0.131	0.131	0.263
CV%	3.96			3.61			

Reducing Sugars
The perusal of data pertaining to effect of potassium sorbate pre-treatment, UV radiation treatment, storage and their interactions on reducing sugarss content of minimally processed fresh-cut carrot pieces has been presented in Table 3.

Effect of potassium sorbate: Data shows that among different potassium sorbate dipping pre-treatments, the mean reducing sugars of minimally processed fresh-cut carrot pieces (K) varied significantly from 2.47 per cent to 2.58 per cent. Minimum reducing sugars was reported in minimally processed fresh-cut carrot pieces without potassium sorbate (K_1) and maximum reducing sugars in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate pre-treatment (K_3). Similar observation was recorded by (Pan, Y. G. and Zu, H.) for fresh-cut pineapple. Potassium sorbate is promising as an effective agent against most yeast and moulds but that its inhibitory effect against bacteria is lower (Zhang *et al.* 2006) [26].

Effect of UV radiation: Data showed that among different UV radiation treatments, mean reducing sugars of minimally processed fresh-cut carrot pieces (T) varied significantly from 2.44 per cent to 2.60 per cent when packed fresh-cut carrot pieces given UV radiation for different time. Minimum reducing sugars was observed in minimally processed carrot pieces without UV radiation treatment (T_1) and maximum reducing sugars in minimally processed fresh-cut carrot pieces when UV radiation treatment was given for 30 minutes (T_3). Almost similar observation was recorded by (Pan, Y. G. and Zu, H. 2012) for fresh-cut pineapple. The increase in sucrose content during ultrasonic treatment may be due to the rupture of plant cells by the shear force caused by the mechanical effect of ultrasound, which in turn improves the diffusion rate of the solvent from the material to the solvent, leading to extraction of intracellular sugars (Abid *et al.* 2014) [1] for apple. The effect is related to UV-B-induced changes in the activity of sucrose-hydrolyzing and -synthesizing enzymes: invertase, sucrose syntheses and sucrose phosphate synthase (Interdonato *et al*. 2011) [13] for fresh lemon.

Effect of storage period: Data depicts that storage of minimally processed fresh-cut carrot pieces resulted significant decrease in mean reducing sugars (S) from initial value of 2.34 per cent to 2.71 per cent after fifteen days of storage. Similar observation was reported by (Cortez-Vega *et al.* 2014) [7].

Effect of interactions: Interaction of potassium sorbate dipping pre-treatment and storage depicted variations in reducing sugars between 2.21 per cent and 2.73 per cent, with minimum decrease in reducing sugars from 2.71 per cent (K_3S_1) to 2.45 per cent (K_3S_4) in minimally processed fresh-cut carrot pieces which were with pre-treated with 1000 ppm potassium sorbate and maximum decrease from 2.73 per cent (K_1S_1) to 2.21 per cent (K_1S_4) in minimally processed fresh-cut carrot pieces with no potassium sorbate pre-treatment was given. Interaction of UV radiation treatment and storage depicted variations in reducing sugars between 2.19 per cent and 2.72 per cent, with minimum decrease in reducing sugars from 2.71 per cent to 2.46 per cent in minimally processed fresh-cut carrot pieces when UV radiation treatment was given for 30 minutes (T_3S_1 to T_3S_4), whereas maximum decrease in reducing sugars was observed from 2.72 per cent to 2.19 per cent in minimally processed fresh-cut carrot pieces with no UV radiation treatment was given (T_1S_1 to T_1S_4) after fifteen days of storage. Interaction of potassium sorbate pre-treatment and UV radiation treatment depicted variations in mean reducing sugars in minimally processed fresh-cut carrot pieces from 2.38 per cent to 2.67 per cent, with minimum reducing sugars (2.39 per cent) in minimally processed fresh-cut carrot pieces with no pre-treatments were given (K_1T_1) and maximum reducing sugars (2.67 per cent) in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and UV radiation treatment was given for 30 minutes (K_3T_3).

Table 3: Effect of potassium sorbate and UV radiation treatment on reducing sugars of minimally processed carrot pieces

Potassium sorbate (K)	Reducing sugars (%)						
	Storage period (S)						
	UV radiation time (T)	S_1 - 0 day	S_2 -5 days	S_3-10 days	S_4-15 days	Mean (KT) Mean(K)	Mean (T)
K_1 – control	T_1 - control	2.74	2.39	2.37	2.04	2.38	2.44
	T_2 - 15min	2.73	2.52	2.37	2.19	2.45	2.57
	T_3 - 30 min	2.72	2.56	2.43	2.31	2.51	2.60
	T_4 - 45 min	2.72	2.60	2.46	2.32	2.52	2.53
	Mean (KS)	2.73	2.52	2.41	2.21	2.47	
K_2 - 500 ppm	T_1 - control	2.72	2.52	2.37	2.23	2.46	
	T_2 - 15min	2.72	2.63	2.60	2.40	2.59	
	T_3 - 30 min	2.72	2.64	2.61	2.41	2.59	
	T_4 - 45 min	2.71	2.62	2.51	2.34	2.54	
	Mean (KS)	2.72	2.60	2.52	2.34	2.55	
K_3 -1000 ppm	T_1 - control	2.71	2.52	2.37	2.22	2.46	
	T_2 - 15min	2.71	2.66	2.64	2.61	2.66	
	T_3 - 30 min	2.71	2.67	2.65	2.63	2.67	
	T_4 - 45 min	2.70	2.61	2.56	2.34	2.55	
	Mean (KS)	2.71	2.62	2.56	2.45	2.58	
K_4 - 1500 ppm	T_1 - control	2.71	2.52	2.41	2.26	2.47	
	T_2 - 15min	2.71	2.63	2.62	2.40	2.59	
	T_3 - 30 min	2.70	2.65	2.63	2.48	2.62	
	T_4 - 45 min	2.70	2.60	2.45	2.30	2.51	
	Mean (KS)	2.71	2.60	2.53	2.36	2.55	
	Mean (S)	2.71	2.58	2.50	2.34		
T×S	T_1	2.72	2.49	2.38	2.19		
	T_2	2.72	2.61	2.56	2.40		
	T_3	2.71	2.63	2.58	2.46		
	T_4	2.71	2.61	2.50	2.32		
	K	T	K×T	S	K×S	T×S	K×T×S
S.E m. ±	0.012	0.012	0.024	0.014	0.029	0.029	0.059
CD at 5%	0.035	0.035	0.070	0.041	0.083	0.083	NS
CV%	3.30			4.03			

Further, interaction of potassium sorbate pre-treatment, UV radiation treatment and storage depicted variations in reducing sugars from 2.04 per cent to 2.74 per cent in minimally processed fresh-cut carrot pieces during a period of fifteen days, with minimum decrease 2.71 per cent to 2.63 per cent in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and packed fresh-cut carrot pieces were given UV radiation treatment for 30 minutes ($K_3T_3S_1$ to $K_3T_3S_4$) and maximum decrease 2.74 per cent to 2.04 per cent in minimally processed fresh-cut carrot pieces packed with no pre-treatments were given ($K_1T_1S_1$ to $K_1T_1S_4$).

Carotene

The perusal of data pertaining to effect of potassium sorbate pre-treatment, UV radiation treatment, storage and their interactions on carotene content of minimally processed fresh-cut carrot pieces has been presented in Table 4.

Effect of potassium sorbate: Data shows that among different potassium sorbate dipping pre-treatments, the mean carotene content of minimally processed fresh-cut carrot pieces (K) varied significantly from 35.70 mg/100 g to 37.08 mg/100 g.Minimum carotene content was revealed in minimally processed fresh-cut carrot pieces with no potassium sorbate pre-treatment was given (K_1) and maximum carotene content in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate pre-treatment (K_3). Similar observation was recorded by (LI and Barth 1998) [16] for lightly processed carrots. The contents of β-carotene decreased continuously during the storage at 1ºC in peeled carrots packed in polymeric film bags during storage days.

Effect of UV radiation: Data showed that among different UV radiation treatments, mean carotene content of minimally processed fresh-cut carrot pieces (T) varied significantly from 35.77 mg/100 g to 37.19 mg/100 g when packed fresh-cut carrot pieces were given UV radiation for different time. Minimum carotene content was recorded in minimally processed carrot pieces when UV radiation treatment given for 45 minutes (T_4) and Maximum carotene content in minimally processed fresh-cut carrot pieces when UV radiation treatment was given for 15 minutes (T_2). Almost similar observation was reported by (Kamat *et al.* 2003) [14]. The increase levels of total carotenoids in fresh-cut carrots with increasing radiation dose might be attributed to radiation induced rupture of covalent bonding between carotenoids pigments and other food constituents resulting in easy extractability of pigments. The doses usually used in postharvest UV-C treatments, a reduction in carotenoid level has been observed in peppers (Vicente *et al*. 2005) [23].

Effect of storage period: Data depicts that storage of minimally processed fresh-cut carrot pieces resulted significant decrease in mean carotene content (S) from initial value of 35.15 mg/100 g to 37.88 mg/100 g after fifteen days of storage. Similar observation was recorded by (De azevedo-Meleiro and Rodriguez-Amaya 2005) [8] for processed endive and New zealand spinach.

Effect of interactions: Interaction of potassium sorbate dipping pre-treatment and storage depicted variations in carotene content between 33.88 mg/100 g and 38.15 mg/100 g, with minimum decrease in carotene content from 37.98 mg/100 g (K_3S_1) to 36.00 mg/100 g (K_3S_4) in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and maximum decrease from 37.57 mg/100 g (K_1S_1) to 33.88 mg/100 g (K_1S_4) in minimally processed fresh-cut carrot pieces with no potassium sorbate pre-treatment was given. Interaction of UV radiation treatment and storage depicted variations in carotene content between 34.21 mg/100 g and 38.48 mg/100 g, with minimum decrease in carotene content from 37.24 mg/100 g to 34.21 mg/100 g in minimally processed fresh-cut carrot pieces when UV radiation treatment was given for 45 minutes (T_4S_1 to T_4S_4), whereas maximum decrease in carotene content was observed from 38.48 mg/100 g to 34.66 mg/100 g in minimally processed fresh-cut carrot pieces when no UV radiation treatment (T_1S_1 to T_1S_4) was given after fifteen days of storage. Interaction of potassium sorbate pre-treatment and UV radiation treatment depicted variations in mean carotene content in minimally processed fresh-cut carrot pieces from 35.53 mg/100 g to 37.99 mg/100 g, with minimum carotene content (35.53 mg/100 g) in minimally processed fresh-cut carrot pieces pre-treated with UV radiation was given for 45 minutes without potassium sorbate (K_1T_4) and maximum carotene content (37.99 mg/100 g) in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and UV radiation treatment was given for 15 minutes (K_3T_2). Further, interaction of potassium sorbate pre-treatment, UV radiation treatment and storage depicted variations in carotene content from 33.41 mg/100 g to 38.96 mg/100 g in minimally processed fresh-cut carrot pieces during a period of fifteen days, with minimum decrease 37.48 mg/100 g to 36.88 mg/100 g in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and packed fresh-cut carrot pieces were given UV radiation treatment for 30 minutes ($K_3T_3S_1$ to $K_3T_3S_4$) and maximum decreased 37.84 mg/100 g to 33.41 mg/100 g in minimally processed fresh-cut carrot pieces with no pre-treatments were given ($K_1T_1S_1$ to $K_1T_1S_4$).

Table 4: Effect of potassium sorbate and UV radiation on carotene of minimally processed carrot pieces

Potassium sorbate (K)	Carotene (mg/100 g) Storage period (S)						
	UV radiation time (T)	S_1 - 0 day	S_2 -5 days	S_3-10 days	S_4-15 days	Mean (KT) Mean(K)	Mean (T)
K_1 – control	T_1 - control	37.84	36.11	35.14	33.41	35.62	36.58
	T_2 - 15min	37.72	36.14	35.32	34.01	35.80	37.19
	T_3 - 30 min	37.56	36.36	35.34	34.19	35.86	36.69
	T_4 - 45 min	37.16	36.00	35.03	33.92	35.53	35.77
	Mean (KS)	37.57	36.15	35.21	33.88	35.70	
K_2 - 500 ppm	T_1 - control	38.48	37.10	36.16	34.78	36.63	
	T_2 - 15min	38.42	37.98	36.62	35.74	37.19	
	T_3 - 30 min	37.21	36.83	35.79	35.13	36.24	
	T_4 - 45 min	37.16	36.34	35.26	34.30	35.77	
	Mean (KS)	37.82	37.06	35.96	34.99	36.46	
K_3- 1000 ppm	T_1 - control	38.96	37.66	36.68	35.31	37.15	
	T_2 - 15min	38.32	38.23	37.92	37.50	37.99	
	T_3 - 30 min	37.48	37.44	37.38	36.88	37.30	

	T_4 - 45 min	37.16	36.64	35.32	34.32	35.86	
	Mean (KS)	37.98	37.49	36.83	36.00	37.08	
K_4 – 1500 ppm	T_1 - control	38.64	37.40	36.38	35.14	36.89	
	T_2 - 15min	38.54	38.24	37.50	36.74	37.76	
	T_3 - 30 min	37.96	37.80	36.99	36.67	37.35	
	T_4 - 45 min	37.46	36.46	35.40	34.30	35.91	
	Mean	38.15	37.48	36.57	35.71	36.98	
	Mean (S)	37.88	37.05	36.14	35.15		
T×S	T_1	38.48	37.07	36.09	34.66		
	T_2	38.25	37.65	36.84	36.00		
	T_3	37.55	37.11	36.38	35.72		
	T_4	37.24	36.36	35.25	34.21		
	K	T	K×T	S	K×S	T×S	K×T×S
S.E m. ±	0.160	0.160	0.319	0.198	0.397	0.397	0.794
CD at 5%	0.459	0.459	0.918	0.555	NS	NS	NS
CV%	3.03			3.76			

Acidity

The perusal of data pertaining to effect of potassium sorbate pre-treatment, UV radiation treatment, storage and their interactions on acidity content of minimally processed fresh-cut carrot pieces has been presented in Table 5.

Effect of potassium sorbate: Data shows that among different potassium sorbate dipping pre-treatments, the mean acidity of minimally processed fresh-cut carrot pieces (K) varied significantly from 0.182 per cent to 0.217 per cent. Minimum acidity was observed in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate (K_3) and maximum acidity in minimally processed fresh-cut carrot pieces with no potassium sorbate pre-treatment was given (K_1). Almost similar observation was recorded earlier by (Koh *et al.* 2017). Higher acidity is preferred during storage because they correlated with lower pH values, thereby preventing the early growth of microorganisms in fresh-cut fruits, which is crucial for the quality control and shelf life extension of the products (Mantilla *et al.* 2013) [18].

Effect of UV radiation: Data showed that among different UV radiation treatments, mean acidity of minimally processed fresh-cut carrot pieces (T) varied significantly from 0.179 per cent to 0.223 per cent when packed fresh-cut carrot pieces were given UV radiation for different time. Minimum acidity was reported in minimally processed carrot pieces when UV radiation treatment given for 30 minutes (T_3) and maximum acidity in minimally processed fresh-cut carrot pieces when no UV radiation treatment was given (T_1). Similar observation was recorded by Pan, Y. G. and Zu, H. (2012) for fresh-cut pineapple. Light exposure did not affect the total acidity during the storage (Zappia *et al*. 2018) [25] for minimally processed vegetables.

Effect of storage period: Data depicts that storage of minimally processed fresh-cut carrot pieces resulted significant increase in mean acidity (S) from initial value of 0.110 per cent to 0.265 per cent after fifteen days of storage. Acidity was increased due to increased in organic acid and reduction of the pH during the storage, similar observations were recorded by (Sharma *et al.* 2019) [21].

Effect of interactions: Interaction of potassium sorbate dipping pre-treatment and storage depicted variations in acidity between 0.110 per cent and 0.292 per cent, with minimum increase in acidity from 0.110 per cent (K_3S_1) to 0.249 per cent (K_3S_4) in minimally processed fresh- cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and maximum increase from 0.110 per cent (K_1S_1) to 0.292 per cent (K_1S_4) in minimally processed fresh-cut carrot pieces with no potassium sorbate pre-treatment was given. Interaction of UV radiation treatment and storage depicted variations in acidity between 0.110 per cent and 0.300 per cent, with minimum increase in acidity from 0.110 per cent to 0.249 per cent in minimally processed fresh-cut carrot pieces when UV radiation treatment was given for 30 minutes (T_3S_1 to T_3S_4), whereas maximum increase in acidity was observed from 0.110 per cent to 0.300 per cent in minimally processed fresh-cut carrot pieces when no UV radiation treatment was given (T_1S_1 to T_1S_4) after fifteen days of storage. Interaction of potassium sorbate pre-treatment and UV radiation treatment depicted variations in mean acidity in minimally processed fresh-cut carrot pieces from 0.163 per cent to 0.237 per cent, with minimum acidity (0.163 per cent) in minimally processed fresh-cut carrot pieces pre-treated with 1000 ppm potassium sorbate and UV radiation given for 30 minutes (K_3T_3) and maximum acidity (0.237 per cent) in minimally processed fresh-cut carrot pieces with no pre-treatments were given. (K_1T_1).

Further, interaction of potassium sorbate pre-treatment, UV radiation treatment and storage depicted variations in acidity from 0.110 per cent to 0.305 per cent in minimally processed fresh-cut carrot pieces during a period of fifteen days, with minimum increase 0.110 per cent to 0.218 per cent in minimally processed fresh-cut carrot pieces which were pre-treated with 1000 ppm potassium sorbate and packed fresh-cut carrot pieces were given UV radiation treatment for 30 minutes ($K_3T_3S_1$ to $K_3T_3S_4$) and maximum increase 0.110 per cent to 0.305 per cent in minimally processed fresh-cut carrot pieces with no pre-treatments were given ($K_1T_1S_1$ to $K_1T_1S_4$). The acidity in vegetables is mainly attributed to organic acids which are dissolved in the vacuoles of the cell, either in free form, as combined with salts, esters, glycosides.

Table 5: Effect of potassium sorbate and UV radiation on acidity of minimally processed carrot pieces

Potassium sorbate (K)	Acidity (%)						
	Storage period (S)						
	UV radiation time (T)	S_1 - 0 day	S_2 -5 days	S_3-10 days	S_4-15 days	Mean (KT) Mean (K)	Mean (T)
K_1 – control	T_1 - control	0.110	0.234	0.298	0.305	0.237	0.223
	T_2 - 15min	0.110	0.200	0.298	0.300	0.227	0.185
	T_3 - 30 min	0.110	0.198	0.250	0.294	0.213	0.179
	T_4 - 45 min	0.110	0.160	0.234	0.268	0.193	0.188
	Mean (KS)	0.110	0.198	0.270	0.292	0.217	
K_2 - 500 ppm	T_1 - control	0.110	0.200	0.298	0.298	0.226	
	T_2 - 15min	0.110	0.128	0.220	0.250	0.177	
	T_3 - 30 min	0.110	0.128	0.201	0.250	0.172	
	T_4 - 45 min	0.110	0.150	0.234	0.250	0.186	
	Mean (KS)	0.110	0.152	0.238	0.262	0.190	
K_3 -1000 ppm	T_1 - control	0.110	0.200	0.250	0.298	0.214	
	T_2 - 15min	0.110	0.127	0.200	0.232	0.167	
	T_3 - 30 min	0.110	0.128	0.198	0.218	0.163	
	T_4 - 45 min	0.110	0.150	0.222	0.250	0.183	
	Mean (KS)	0.110	0.151	0.218	0.249	0.182	
K_4 - 1500 ppm	T_1 - control	0.110	0.198	0.250	0.298	0.214	
	T_2 - 15min	0.110	0.128	0.200	0.240	0.170	
	T_3 - 30 min	0.110	0.128	0.200	0.234	0.168	
	T_4 - 45 min	0.110	0.155	0.234	0.258	0.189	
	Mean (KS)	0.110	0.152	0.221	0.258	0.185	
	Mean (S)	0.110	0.163	0.237	0.265		
T×S	T_1	0.110	0.208	0.274	0.300		
	T_2	0.110	0.146	0.230	0.255		
	T_3	0.110	0.145	0.212	0.249		
	T_4	0.110	0.154	0.231	0.257		
	K	T	K×T	S	K×S	T×S	K×T×S
S.E m. ±	0.0009	0.0009	0.0019	0.0009	0.0018	0.0018	0.0036
CD at 5 %	0.0026	0.0026	0.0055	0.0025	0.0050	0.0050	0.0100
CV%	2.88			3.20			

Microbial Parameters

Total Plate Count

The perusal of data pertaining to effect of potassium sorbate pre-treatment, UV radiation treatment and storage on TPC value of minimally processed fresh-cut carrot pieces has been presented in Table 4.

Data depicts that storage of minimally processed fresh-cut carrot pieces resulted increase in mean moisture (S) from initial value of 0.00 CFU/g to 7.52 CFU/g after ten days of storage and after fifteen days of storage TMTC were observed. The standard limit for consumption at acceptable level was reported up to 9.00 × 10^4 CFU/g. Similar observations were reported by (Chaudry *et al.* 2004 and López-Rubira *et al.* 2005) [5, 17] for minimally processed carrots. The use of antibacterial potassium sorbate significantly reduced the microbial loads in cut-fruits. Similar result was reported earlier by Kowalczyk *et al.* (2017) [15] for using potassium sorbate with carboxy methyl cellulose-base in delaying the fungal growth rates of pear fruit. UV radiation reduced the population of spoilage microorganisms like aerobic bacteria, yeast, and molds (reduction of ≥ 3 log CFU/g). UV doses reducing mesophilic, psychrotropic, lactic acid bacteria and entero bacteriaceae counts for minimally processed pomegranate arils.

Table 3: Effect of potassium sorbate and UV radiation on TPC of minimally processed carrot pieces

Potassium sorbate (K)	TPC (× 10^4 CFU/ g)				
	Storage period (S)				
	UV radiation time (T)	S_1 - 0 day	S_2 -5 days	S_3-10 days	S_4-15 days
K_1 – control	T_1 - control	0.00	5.80	7.52	TMTC
	T_2 - 15min	0.00	5.52	6.74	TMTC
	T_3 - 30 min	0.00	5.31	6.49	TMTC
	T_4 - 45 min	0.00	5.26	6.21	TMTC
K_2 - 500 ppm	T_1 - control	0.00	5.71	7.66	TMTC
	T_2 - 15min	0.00	5.49	6.76	TMTC
	T_3 - 30 min	0.00	0.00	6.47	TMTC
	T_4 - 45 min	0.00	0.00	6.32	TMTC
$_3$ -1000 ppm	T_1 - control	0.00	5.50	6.84	TMTC
	T_2 - 15min	0.00	5.31	6.61	TMTC
	T_3 - 30 min	0.00	0.00	6.33	TMTC
	T_4 - 45 min	0.00	0.00	6.36	TMTC
K_4 -1500 ppm	T_1 - control	0.00	5.74	6.70	TMTC
	T_2 - 15min	0.00	0.00	7.10	TMTC
	T_3 - 30 min	0.00	0.00	6.52	TMTC
	T_4 - 45 min	0.00	0.00	6.64	TMTC

Conclusion

The findings summarized above indicate that carrot available in the market during glut season can be utilized more beneficially for preparation of minimally processed fresh-cut carrot pieces. The best quality minimally processed fresh-cut carrot pieces can be prepared by pre-treatment of carrot pieces with 1000 ppm potassium sorbate followed by UV radiation treatment of pack for 30 minutes. The minimally processed fresh-cut carrot pieces obtained from this treatment possess higher carotene content while lower microbial load. Further, fresh-cut carrot pieces exhibited minimum changes in nutritional as well as sensory attributes during fifteen days storage when packed in polypropylene bags of 400-gauge thickness.

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