Effect of treatments and packaging on the quality of dried carrot slices during storage

S. K. Sra · K. S. Sandhu · P. Ahluwalia

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Abstract The present investigation was undertaken to study the effect of treatments and packaging on the quality of dried carrot slices during storage. Carrot cultivar ‘Nantes’ was sliced into 4.5 mm thick slices which were blanched in water at 95 °C for 4 min followed by dipping in 6% potassium metabisulphite (KMS) solution for 40 min and 350 ppm potassium sorbate solution for 10 min prior to two stage phase drying i.e. at 90±5 °C for 2 h and further drying at 60±5 °C for 7 h in a cross-flow hot air cabinet dryer. The dried carrot slices were packed in 50 g packages of aluminium foil laminate (AFL) (polyethylene, aluminium foil and polyester) and high density polyethylene (HDPE) pouches having 32.5 µm and 56.0 µm thickness respectively and stored under ambient conditions i.e. 18.5–29.1 °C temperature and 44.4–60.4% relative humidity for 6 months. Significant ($p \leq 0.05$) increase was observed in the moisture content, water activity, reducing sugars and non-enzymatic browning while total solids, total soluble solids, titratable acidity, ascorbic acid, total sugars, pectin, rehydration ratio, sulphur dioxide, sorbic acid and carotenoids decreased significantly ($p \leq 0.05$) during storage. Carrot slices pre-treated with 6% KMS and packed in AFL pouches were found to retain best physico-chemical quality. The curried product and soup prepared from dried slices from the same had highly acceptable sensory quality with initial overall

acceptability scores 8.2 and 8.5 for curried slices and soup respectively on 9-point hedonic scale. The overall acceptability scores decreased from 8.2 to 7.9 and 8.5 to 7.7 in curried product and soup respectively after 6 months storage. All the samples were microbially safe during 6 months of storage.

Keywords Dried carrot slices · Physico-chemical quality · Potassium metabisulphite · Potassium sorbate · Packaging · Storage · Sensory quality

Carrot (*Daucus carota*) is one of the most versatile crops grown extensively in various countries. Carrot is valued as nutritive food mainly because, it is a rich source of β -carotene and contains appreciable amounts of thiamine and riboflavin. It has been reported that carrot has diuretic and nitrogen balancing properties as well as being effective in elimination of uric acid (Anon 1995). It is an excellent source of pectin, the fibre that has been found to have cholesterol-lowering properties. Carrot is available in plenty in Punjab from December to March resulting in glut in the local market which lowers its price during peak production season causing loss to the growers. However, during the off season the carrots are available at exorbitant cost. The common practice for extending availability is cold storage. Though the carrot can be stored at 0 °C with RH 98–100% for few months, but during storage there is problem of rooting of tubers and bitterness due to high levels of 6-methoxymellein which is not desirable. So, due to their short availability period and non availability during lean period, it necessitates the preservation of carrot in dehydrated form for extending the availability of product as compared to cold storage or canned products which require a lot of high cost infrastructure.

Carrots are dehydrated in the form of slices, cubes and strips. High solids and freedom from woody fiber are desired

S. K. Sra (✉) · K. S. Sandhu
Punjab Horticultural Postharvest Technology Centre,
Punjab Agricultural University,
Ludhiana 141 004, India
e-mail: sarabsra27@gmail.com

P. Ahluwalia
Department of Food Science & Technology,
Punjab Agricultural University,
Ludhiana 141 004, India

qualities of carrots to be dehydrated. Removal of biologically active water is the main task while preserving food (Lenart 1996) by reducing the moisture contents to a level, which allows safe storage over an extended period of time with microbial safety. This also reduces the rate of enzymatic and chemical reactions. It has been reported that dehydrated carrot with 4–6% moisture content and 1500 ppm SO₂ (Indian Standard IS: 4625 1968) make it shelf stable. Dehydrated carrot is used by defence services in sizeable quantities due to saving in transportation and ease in storage at different altitudes. They have also high potential for preparation of curried and other products at home scale in off season. Dehydrated vegetables are excessively used in these foods such as dry soup mixes, canned soups and sauces, frozen entrees, processed meats, baby foods, dairy products and seasoning blends (Luh and Woodroof 1988).

The process of dehydration if optimized appropriately, the dry product retains good food value, natural flavour and characteristic cooking quality of fresh material. With the changing lifestyle and increasing awareness regarding healthy and hygienic food, the demand of packaged and ready to serve food is increasing. The low rehydration ratio, discolouration and development of off-flavour are the commonly reported problems with dehydrated carrot products. Zhao and Chang (1995) reported that redness and total alpha and beta carotenes decreased as storage time increased in starch treated, sulphite treated and untreated carrot samples. Very few studies have been reported (Sagar and Neelavathi 2005) on the shelf life studies of dehydrated carrots. The present investigation was therefore, undertaken to study the effect of treatment, packaging and storage on the quality of dehydrated carrot slices.

Materials and methods

Carrot cultivar ‘Nantes’ was procured from the local market of Ludhiana, India. The carrots were weighed, washed thoroughly under running tap water and surface water was dried. These were sliced into 4.5 mm thick slices with a food processor and were blanched in hot water (95 °C) for 4 min and the blanched slices were divided into 3 lots of 20 kg each for different treatments. i) Dipping in 6% potassium metabisulphite (KMS, K₂S₂O₅) solution for 40 min. ii) Dipping in 350 ppm potassium sorbate (C₆H₇KO₂) solution for 10 min and iii) No dipping treatment was given to control after blanching. The ratio of carrot slices to dipping solution was 1:2. The slices were drained and spread in a single layer on aluminium trays (90×60 cm) prior to two stage phase drying in a cross-flow hot air cabinet dryer (Frederick Herbert-Design 20, Bombay, India) at 90±5 °C for 2 h and further drying at 60±5 °C for 7 h to constant weight for final product preparation. The bulk

sample was prepared according to the findings of Sra et al (2011).

Packaging and storage: The dried carrot slices were packed in aluminium foil laminate (AFL) (polyethylene, aluminium foil and polyester) and high density polyethylene (HDPE) pouches having 32.5 µm and 56.0 µm thickness respectively and were sealed using heat impulse sealer. Each package contained 50 g dried slices. The packages were stored under ambient conditions i.e. 18.5–29.1 °C temperature and 44.4–60.4% relative humidity (RH) for 6 months.

Physico-chemical analysis The dried carrot samples were analyzed for moisture content, total soluble solids (TSS), titratable acidity, ascorbic acid and sugars by AOAC (2005) methods. The pectin, total carotenoids and non-enzymatic browning (as optical density i.e. OD of alcoholic extract of sample) were determined by the methods given by Ranganna (1997). Hunter Lab Colour Difference Meter (Model: MiniScan XE Plus, USA) was used to measure the colour. The water activity of the dried sample was measured using Water Activity Meter (Aqualab CX-3 TE, USA) based on principle of chilled-mirror dew point technique. Sulphur dioxide (SO₂) estimation was done by the method given by Ruck (1969). Potassium sorbate was estimated by the method given by Mota Fernando et al (2003). Modified USDA method (Ranganna 1997) was used for measuring the rehydration ratio of dried slices. The dried carrot slices were analysed for total plate count and yeast and mould count as per APHA (1992) methods. The physico-chemical analysis was conducted in triplicate (*n*=3).

Sensory evaluation The rehydrated dried carrot slices were used for preparation of cooked curried product and soup, which were subjected to sensory evaluation by the semi-trained panel of 10 judges at 9-point hedonic scale (Amerine et al. 1965).

Statistical analysis Factorial in completely randomized design (CRD) was adopted to calculate the statistical significance (Snedecor and Cochran 1968).

Results and discussion

Changes in physico-chemical parameters during storage The initial and final physico-chemical characteristics of dried carrot slices are given in Tables 1 and 2. As is obvious from table an increase was observed in the moisture content during 6 months of storage, which might be due to the hygroscopic nature of the dried product. The moisture content of carrot slices packed in AFL was significantly

Table 1 Effect of treatments, packaging and storage (18.5–29.1 °C, 44.4–60.4% RH) on the physical properties of dried carrot slices

Storage period (months)	6% KMS		350 ppm Pot. sorbate		Control		Mean
	AFL	HDPE	AFL	HDPE	AFL	HDPE	
Water activity, a _w							
0	0.365	0.365	0.362	0.362	0.367	0.367	0.365
3	0.391	0.398	0.389	0.396	0.401	0.404	0.396
6	0.426	0.435	0.423	0.430	0.437	0.440	0.432
Mean	0.394	0.399	0.391	0.396	0.402	0.404	
CD at 5% T=0.001 P=0.001 S=0.001 T×P=0.002 T×S=0.002 P×S=0.002 T×P×S=NS							
Non-enzymatic browning, OD							
0	0.001	0.001	0.102	0.102	0.105	0.105	0.069
3	0.049	0.055	0.118	0.121	0.119	0.123	0.098
6	0.071	0.079	0.129	0.136	0.134	0.139	0.115
Mean	0.040	0.045	0.116	0.120	0.119	0.122	
CD at 5% T=0.001 P=0.0009 S=0.001 T×P=NS T×S=0.002 P×S=0.001 T×P×S=NS							
L colour value							
0	66.3	66.3	65.8	65.8	65.6	65.6	65.9
3	64.1	63.3	62.7	62.1	62.5	61.6	62.7
6	63.5	62.5	62.0	61.2	61.7	60.7	61.9
Mean	64.6	64.0	63.5	63.0	63.3	62.6	
CD at 5% T=0.02 P=0.01 S=0.02 T×P=0.02 T×S=0.03 P×S=0.02 T×P×S=0.04							
a colour value							
0	26.7	26.7	25.3	25.3	24.3	24.3	25.4
3	23.9	22.9	20.9	19.7	18.5	16.3	20.4
6	22.8	21.6	19.8	18.4	16.9	14.4	19.0
Mean	24.5	23.7	22.0	21.1	19.9	18.3	
CD at 5% T=0.01 P=0.01 S=0.01 T×P=0.02 T×S=0.03 P×S=0.02 T×P×S=0.04							
b colour value							
0	29.5	29.5	27.5	27.5	26.5	26.5	27.8
3	27.6	27.0	25.9	24.6	22.4	21.0	24.8
6	26.1	25.6	24.5	23.1	21.1	18.9	23.2
Mean	27.7	27.4	26.0	25.1	23.3	22.1	
CD at 5% T=0.02 P=0.02 S=0.02 T×P=0.03 T×S=0.03 P×S=0.03 T×P×S=0.05							
Rehydration ratio							
0	6.4	6.4	6.3	6.3	5.9	5.9	6.2
3	6.3	6.3	6.3	6.2	5.8	5.8	6.1
6	6.3	6.2	6.2	6.2	5.7	5.7	6.0
Mean	6.3	6.3	6.3	6.2	5.8	5.8	
CD at 5% T=0.007 P=0.005 S=0.007 T×P=0.009 T×S=0.01 P×S=0.009 T×P×S=NS							

($n=3$), NS: Non-significant, KMS: Potassium metabisulphite, T: Treatment, P: Packaging, S: Storage

lower ($p \leq 0.05$) than the slices packed in HDPE; it may be due to higher permeability of HDPE to moisture as compared to AFL pouches. This shows that AFL pouches provided better barrier to moisture transfer than HDPE pouches. Similar observations were reported by Bailey (1990) who suggested the use of flexible laminate for packaging of hygroscopic foods, especially dried fruits as multilayers provide high impermeability to gas and water vapours. As a result of increase in the moisture content, total solids and total soluble solids decreased during

storage. The water activity of dried carrot slices increased from 0.365 to 0.432 during 6 months of storage. Significant difference ($p \leq 0.05$) was observed in the treatment, packaging and storage but the interaction of treatment, packaging and storage was non-significant ($p \leq 0.05$). Treatments were found to have a significant ($p \leq 0.05$) effect on the acidity of dried slices. The titratable acidity was higher in case of KMS treated samples as compared to potassium sorbate treated and untreated samples. During storage, there was a noticeable decline in the titratable acidity. The

Table 2 Effect of treatments, packaging and storage (18.5–29.1 °C, 44.4–60.4% RH) on the chemical properties of dried carrot slices

Storage period (months)	6% KMS		350 ppm Pot. sorbate		Control		Mean
	AFL	HDPE	AFL	HDPE	AFL	HDPE	
Moisture,%							
0	6.3	6.3	6.3	6.3	6.2	6.2	6.3
3	7.2	7.2	7.0	7.1	6.9	7.0	7.1
6	8.5	8.6	8.4	8.5	8.3	8.3	8.4
Mean	7.3	7.4	7.2	7.3	7.1	7.2	
CD at 5% T=0.01 P=0.01 S=0.01 T×P=NS T×S=0.03 P×S=0.02 T×P×S=NS							
Total solids,%							
0	93.7	93.7	93.7	93.7	93.8	93.8	93.7
3	92.8	92.8	93.0	92.9	93.1	93.0	92.9
6	91.5	91.4	91.6	91.5	91.7	91.7	91.6
Mean	92.7	92.6	92.8	92.7	92.9	92.8	
CD at 5% T=0.02 P=0.02 S=0.02 T×P=NS T×S=NS P×S=NS T×P×S=0.05							
Total soluble solids,%							
0	60.0	60.0	50.0	50.0	55.0	55.0	55.0
3	59.5	57.5	49.5	44.5	54.5	50.0	52.6
6	58.0	56.0	47.0	43.0	53.0	49.0	51.0
Mean	59.2	57.8	48.8	45.8	54.2	51.3	
CD at 5% T=0.002×10−3 P=0.002×10−3 S=0.002×10−3 T×P=0.003×10−3 T×S=0.004×10−3 P×S=0.003×10−3 T×P×S=0.005×10−3							
Titratable acidity, %							
0	2.8	2.8	0.5	0.5	0.8	0.8	1.4
3	2.7	2.7	0.5	0.4	0.8	0.7	1.3
6	2.7	2.6	0.4	0.4	0.7	0.7	1.2
Mean	2.7	2.7	0.5	0.4	0.8	0.7	
CD at 5% T=0.007 P=0.005 S=0.007 T×P=NS T×S=0.01 P×S=0.009 T×P×S=NS							
Ascorbic acid, mg/100 g							
0	22.9	22.9	9.4	9.4	11.5	11.5	14.6
3	12.9	10.7	5.0	4.9	5.0	4.6	7.2
6	11.0	8.4	3.9	3.7	3.3	3.1	5.6
Mean	15.6	14.0	6.1	6.0	6.6	6.4	
CD at 5% T=0.02 P=0.02 S=0.02 T×P=0.03 T×S=0.04 P×S=0.03 T×P×S=0.06							
Reducing sugars, %							
0	16.3	16.3	25.9	25.9	30.2	30.2	24.1
3	17.9	19.1	27.6	28.7	33.0	34.0	26.7
6	17.9	19.4	27.9	29.2	33.3	34.4	27.0
Mean	17.4	18.3	27.1	27.9	32.2	32.9	
CD at 5% T=0.02 P=0.01 S=0.02 T×P=0.02 T×S=0.03 P×S=0.02 T×P×S=0.04							
Non-reducing sugars, %							
0	26.9	26.9	16.2	16.2	12.7	12.7	18.6
3	23.9	22.5	12.7	11.2	8.6	7.4	14.4
6	23.3	21.7	12.0	10.3	7.7	6.4	13.6
Mean	24.7	23.7	13.6	12.6	9.7	8.8	
CD at 5% T=0.02 P=0.01 S=0.02 T×P=0.02 T×S=0.03 P×S=0.02 T×P×S=0.04							
Total sugars, %							
0	43.2	43.2	42.1	42.1	42.9	42.9	42.7
3	41.8	41.6	40.3	39.9	41.5	41.4	41.1
6	41.2	41.1	39.9	39.4	41.0	40.8	40.6
Mean	42.1	42.0	40.8	40.5	41.8	41.7	
CD at 5% T=0.02 P=0.01 S=0.02 T×P=0.02 T×S=0.03 P×S=0.02 T×P×S=0.04							

Table 2 (continued)

Storage period (months)	6% KMS		350ppm Pot. sorbate		Control		Mean
	AFL	HDPE	AFL	HDPE	AFL	HDPE	
Total carotenoids, mg/100 g							
0	219.4	219.4	161.2	161.2	159.8	159.8	180.1
3	190.9	183.3	122.7	118.5	116.2	102.8	139.1
6	172.7	165.9	109.1	101.3	102.7	90.0	123.6
Mean	194.3	189.5	131.0	127.0	126.2	117.5	
CD at 5% T=0.1 P=0.1 S=0.1 T×P=0.2 T×S=0.2 P×S=0.2 T×P×S=0.3							
β-carotene, mg/100 g							
0	72.1	72.1	68.2	68.2	67.8	67.8	69.4
3	60.6	58.9	55.0	51.4	52.8	50.9	54.9
6	55.0	53.3	49.0	45.6	47.3	45.1	49.2
Mean	62.6	61.4	57.4	55.1	56.0	54.6	
CD at 5% T=0.1 P=0.1 S=0.1 T×P=0.2 T×S=0.2 P×S=0.2 T×P×S=0.3							
Pectin, %							
0	10.0	10.0	10.1	10.1	9.8	9.8	10.0
3	10.0	9.9	10.0	10.0	9.7	9.7	9.9
6	9.9	9.9	9.9	9.9	9.7	9.7	9.8
Mean	10.0	9.9	10.0	10.0	9.7	9.7	
CD at 5% T=0.008 P=NS S=0.008 T×P=0.01 T×S=0.01` P×S=0.01 T×P×S=NS							

decrease in the titratable acidity noticed in the present study might have been due to biochemical interactions resulting in binding of acid with the other components with the passage of time. A progressive decrease in the acid content of mango powder was reported by Dabhade and Khedkar (1980) on storage at room temperature ($25 \pm 5^\circ \text{C}$).

The maximum mean pH value (6.4) was recorded in potassium sorbate treated carrot slices packed in HDPE and minimum (5.5) was recorded in KMS treated carrot slices packed in AFL. As the titratable acidity increased the pH was found to decrease. The mean pH value of 5.8 was recorded at 0 month and 6.0 after 6 months of storage.

The mean value of ascorbic acid retention for carrot slices pre-treated with KMS solution and packed in AFL pouches was 15.6 mg/100 g which was slightly higher than the slices packed in HDPE pouches (14.0 mg/100 g). Higher retention of ascorbic acid in KMS treated carrot slices might be due to antioxidant effect of KMS (Gould and Russel 1991). As ascorbic acid is a highly oxidizable compound, due to exposure to light and high temperature. Atkinson and Strachan (1962) stated that sulphites minimize losses of ascorbic acid in dried fruits. The lowest ascorbic acid content (6.0 mg/100 g) was observed in carrot slices pre-treated with potassium sorbate and packed in HDPE pouches. There was a significant reduction in the mean ascorbic acid content *i.e.* 50.8% and 62% after 3 and 6 months respectively. The reduction in ascorbic acid content

was comparatively higher during the first 3 months of storage, which might have been due to higher ambient temperature. Loss of ascorbic acid might be due to its oxidation to dehydroascorbic acid followed by further degradation to 2, 3-diketogulonic acid and finally to furfural compounds which enter browning reactions (Reynold 1965). Sagar et al. (1998) observed that retention of ascorbic acid was higher in dehydrated ripe mango slices when stored at low temperature. Significant differences ($p \leq 0.05$) were observed for treatments, packaging and storage and also between their interactions.

Sugars were found to vary significantly for treatments, packaging and storage and for their interactions. The lowest mean reducing sugars (17.4%) were found for slices treated with KMS and packed in AFL pouches; while the highest mean value of 32.9% was observed for the non-treated (control) dried carrot slices packed in HDPE pouches. During storage, the mean reducing sugars increased from 10.8 to 12.1% after 3 and 6 months of storage from the initial value. This increase in reducing sugars is attributable to slow inversion of non-reducing sugars and starch into reducing sugars. Consequently, there were 22.7 and 27.1% decrease in non-reducing sugars after 3 and 6 months respectively. Sagar and Neelavathi (2005) also found that the increase in reducing sugars could be due to partial hydrolysis of starch to sugar during storage of ready-to-eat dehydrated carrot shreds. There was a gradual but equal

decrease in total sugars in both AFL and HDPE pouches during 6 months of storage. The mean highest value (42.1%) was observed in KMS treated carrot slices packed in AFL pouches which was slightly higher than the total sugars found in KMS treated HDPE packed carrot slices (42.0%). The mean total sugars were lowest (40.5%) in potassium sorbate treated sample packed in HDPE pouches. It is evident that KMS had a beneficial effect on the retention of total sugar and it also helped in lowering the inversion of non-reducing sugars to reducing sugars. It was observed that losses of total sugars were less in AFL packed slices as compared to HDPE pouches. This might be due to the better barrier properties of AFL packages. The initial mean total sugars were recorded as 42.7% which decreased by 3.8% after 3 months of storage. After that, the reduction in the total sugars was comparatively less (1.2% in the last 3 months). The reduction in total sugar content indicates the possibility of their participation in biochemical and browning reactions. Significant differences ($p \leq 0.05$) were observed for the treatments, packaging and storage and their interactions. Nanjundaswamy et al. (1978) reported similar trends of decrease in total sugars and increase in reducing sugars in dehydrated pineapple, papaya and apple segments.

The total carotenoids degraded significantly during storage from an initial mean value 180.1 mg/100 g to 123.6 mg/100 g after 6 months of storage indicating 31.4% loss of total carotenoids. Total carotenoids are susceptible to oxidative loss caused by heat and light which are responsible for the losses during storage. Arya et al. (1982) and Lavelli et al. (2007) reported that carotenoids are relatively stable over a water activity range of 0.31–0.57 in freeze-dried carrot. Mean maximum carotenoids content (194.3 mg/100 g) was retained in KMS pre-treated carrot slices packed in AFL pouches, while the minimum value (117.5 mg/100 g) was recorded in untreated slices packed in HDPE pouches. Reduced rate of carotenoids destruction in sulphite treated carrot was reported by Arya et al. (1979) and Zhao and Chang (1995). Baloch et al. (1987) also reported that SO_2 showed a protective effect on the carotenoids of the blanched carrot and effectiveness of SO_2 increased with increase in SO_2 content. There was a significant ($p \leq 0.05$) reduction in the β -carotene content of carrot slices during storage. β -carotene content decreased from initial mean value of 69.4 mg/100 g to 49.2 mg/100 g was recorded after 6 months of storage. Per cent losses were 20.9 to 29.1 after 3 and 6 months respectively. Mean β -carotene content was found to be highest (62.6 mg/100 g) in KMS pre-treated slices packed in AFL pouches while the value was found to be lowest (54.6 mg/100 g) in untreated carrot slices packed in HDPE pouches. Tomkins et al. (1944) reported that the proportion of β -carotene oxidized during storage was higher at 8.2% moisture than at

5.4% moisture. Similar reason may be for losses of β -carotene and other carotenoids during storage.

The dried carrot slices pre-treated with KMS and packed in AFL pouches were found to have highest L value (64.6) followed by KMS treated slices packed in HDPE pouches (L value 64.0). The lowest L value (62.6) was found in untreated sample packed in HDPE pouches. It is evident that KMS pre-treatment had a beneficial effect on the colour of dried carrot slices. Atkinson and Strachan (1962) reported that KMS is widely used for inhibiting browning in foods. Storage also influenced the L values significantly. At the beginning of storage the mean L value recorded was 65.9. A significant decrease in lightness was noticed upto 3 months of storage i.e. 62.7, while slight reduction in the L value was observed during the last 3 months of storage (61.9). The mean a and b colour values were also found highest in case of KMS treated carrot slices packed in AFL pouches i.e. 24.5 and 27.7 respectively after 6 months storage. The lowest a and b colour values were observed in untreated carrot slices (control) packed in HDPE pouches i.e. 18.3 and 22.1 respectively. Baloch et al. (1981) found that dipping in solution of sodium bisulfite improved the color of the dried carrots. During storage, the a values were found to vary from 25.4 (initially) to 19.0 (after 6 months). The a colour value represents degree of redness in the product, which declined during progressive storage. Significant decrease in the b colour value was also observed during storage, which varied from 27.8 (initially) to 23.2 (after 6 months).

KMS pre-treated carrot slices were found to undergo less browning as compared to control and potassium sorbate pre-treated slices. The mean lowest (0.040) and highest (0.122) ODs were recorded for KMS treated slices packed in AFL pouches and untreated slices packed in HDPE pouches respectively after 6 months storage. The mean ODs were higher for potassium sorbate treated carrot slices as compared to KMS treated samples after storage. This might be due to anti-oxidizing effect of KMS. KMS is widely used to inhibit browning in foods (Atkinson and Strachan 1962). Also it has been reported that sulphites act primarily as inhibitors of enzymatic as well as non-enzymatic browning (Gould and Russel 1991). Apart from treatments, storage was also found to have a significant effect on browning of dried carrot slices. The initial average OD observed was 0.069 which increased to 0.098 and 0.115 after 3 and 6 month of storage respectively. The increase in non-enzymatic browning including maillard reaction might be attributed to progressive loss of SO_2 during storage.

The lowest rehydration ratio (5.8) was recorded for untreated sample packed in HDPE pouches while the highest rehydration ratio (6.3) was recorded in 6% KMS treated carrot slices packed in AFL pouches after storage.

Table 3 Effect of packaging and storage (18.5–29.1 °C, 44.4–60.4% RH) on the sulphur dioxide and sorbic acid retention of dried carrot slices

Storage period (months)	AFL	HDPE	Mean
SO ₂ , ppm			
0	1191.2	1189.8	1190.5
3	826.5	754.7	790.6
6	702.6	610.2	656.4
Mean	906.8	851.6	
CD at 5% P=7.72 S=9.45 P×S=13.4			
Sorbic acid			
0	492.4	490.8	491.6
3	227.0	169.0	198.0
6	ND	ND	–
Mean	239.8	219.9	
CD at 5% P=5.47 S=6.70 P×S=9.47			

(n=3), P Packaging, S Storage

Baloch et al. (1981) found that dipping in solution of sodium bisulfite improved the reconstitution of the dried carrots. Rehydration ratio was more in dried slices packed in AFL pouches as compared to those packed in HDPE pouches due to less moisture content in product. As the pectin content in the product decreased, its rehydration ratio also decreased. During storage, the mean rehydration ratio

was recorded to be 6.2 (initially) and 6.0 (after 6 months). The decline in the rehydration ratio during storage might be due to decline in pectin content. Levi et al. (1988) and Madan et al. (2008) reported a significant correlation between pectin and rehydration ratio of dried peaches and dried tomato halves respectively. Weier and Stocking (1949) also reported the loss of rehydration due to changes

Table 4 Effect of treatments, packaging and storage on the sensory quality of curried cooked carrot prepared from dried carrot slices

Storage period (months)	6% KMS		350 ppm Pot. sorbate		Control		Mean
	AFL	HDPE	AFL	HDPE	AFL	HDPE	
Appearance							
0	8.5	8.5	8.1	8.1	8.0	8.0	8.2
3	8.1	7.9	7.5	7.5	7.3	7.1	7.6
6	7.6	7.4	7.0	6.9	6.8	6.5	7.0
Mean	8.1	7.9	7.5	7.5	7.3	7.2	
CD at 5% T=0.2 P=NS S=0.2 T×P=NS T×S=NS P×S=NS T×P×S=NS							
Flavour							
0	7.5	7.5	8.4	8.4	8.3	8.3	8.0
3	8.0	8.3	7.8	7.5	7.5	7.3	7.7
6	8.4	8.5	7.3	7.0	6.8	6.5	7.4
Mean	8.0	8.1	7.8	7.6	7.5	7.3	
CD at 5% T=0.2 P=NS S=0.2 T×P=NS T×S=0.4 P×S=NS T×P×S=NS							
Texture							
0	8.5	8.5	8.1	8.1	8.0	8.0	8.2
3	8.1	7.6	7.5	7.3	7.1	7.0	7.4
6	7.6	7.1	7.1	6.9	6.6	6.5	7.0
Mean	8.1	7.8	7.6	7.4	7.3	7.2	
CD at 5% T=0.2 P=NS S=0.2 T×P=NS T×S=NS P×S=NS T×P×S=NS							
Overall acceptability							
0	8.2	8.2	8.2	8.2	8.1	8.1	8.2
3	8.1	7.9	7.6	7.4	7.3	7.1	7.6
6	7.9	7.7	7.1	6.9	6.7	6.5	7.1
Mean	8.0	7.9	7.6	7.5	7.4	7.2	
CD at 5% T=0.1 P=0.1 S=0.1 T×P=NS T×S=0.2 P×S=NS T×P×S=NS							

(n=10), NS Non-significant, KMS Potassium metabisulphite, T Treatment, P Packaging, S Storage

in macromolecular components, including cellulose, pectin, hemicellulose and protein, which were adversely affected during pre-treatment, dehydration and storage.

The maximum mean pectin content was 10.0% initially which decreased at a faster rate during first three months of storage (0.9% reduction) and later there was slight decline (0.2%) in the later period of 6 months with a total decline of 1.1% which might be due to breakdown of pectin during storage. There was a minor difference in the pectin content of dried carrot slices among the various pre-treated samples and packaging material i.e. AFL and HDPE pouches. Highest mean pectin content (10.0%) was observed in potassium sorbate treated samples, packed in both AFL and HDPE pouches as well as KMS treated carrot slices packed in AFL pouches closely followed by that of KMS treated carrot slices packed in HDPE pouches (9.9%), while lowest pectin content (9.7%) was recorded in control packed in both AFL and HDPE pouches.

Storage period had a considerable effect on the SO₂ retention of dried carrot slices. Substantial amount of SO₂ was lost during storage. The losses were more during first

three months of storage i.e. 33.6% and later decline was not upto that extent (44.9%), due to low environmental temperature as SO₂ losses were more at high temperature. The concentration of total sulphite in papaya slices decreased to 62% and 40% when stored at 5 °C and 25 °C respectively for 5 months (Lopez-Malo et al. 1994). Sulphur dioxide losses were more in case of carrot slices stored in HDPE than the AFL pouches, due to low gas permeability in AFL pouches which might have involved in resisting the loss of SO₂ (Table 3). Statistical analysis indicated that the treatments, packaging as well as storage exhibited a significant influence ($p \leq 0.05$) on the SO₂ content of dried carrot slices.

Significant ($p \leq 0.05$) decline was observed in the sorbic acid concentration (59.7% in 3 and 100% in 6 months) during storage. This might be due to oxidation of sorbic acid. The carrot slices stored in AFL pouches showed mean sorbic acid retention of 239.8 ppm, while in case of carrot slices packed in HDPE pouches the value was recorded as 219.9 ppm (Table 2). This might be due to permeable nature of HDPE pouches which resulted in the accelerated oxidation of sorbic acid. Lopez-Malo et al. (1994) reported that potassium sorbate concentration reduced to 66% and

Table 5 Effect of treatments, packaging and storage on the sensory quality of carrot soup prepared from dried carrot slices

Storage period (months)	6% KMS		350 ppm Pot. sorbate		Control		Mean
	AFL	HDPE	AFL	HDPE	AFL	HDPE	
Appearance							
0	8.6	8.6	8.4	8.4	8.1	8.1	8.4
3	8.1	7.9	7.6	7.5	7.4	7.3	7.6
6	7.5	7.4	7.1	7.0	6.9	6.8	7.1
Mean	8.1	8.0	7.7	7.6	7.5	7.4	
CD at 5% T=0.2 P=NS S=0.2 T×P=NS T×S=NS P×S=NS T×P×S=NS							
Flavour							
0	8.5	8.5	8.4	8.4	8.3	8.3	8.4
3	8.1	7.9	7.8	7.6	7.5	7.4	7.7
6	7.9	7.5	7.4	7.1	7.0	6.9	7.3
Mean	8.2	8.0	7.8	7.7	7.6	7.5	
CD at 5% T=0.2 P=NS S=0.2 T×P=NS T×S=NS P×S=NS T×P×S=NS							
Texture							
0	8.4	8.4	8.3	8.3	8.1	8.1	8.3
3	8.0	7.6	7.5	7.3	7.3	7.1	7.5
6	7.6	7.3	7.1	6.9	6.6	6.5	7.0
Mean	8.0	7.8	7.6	7.5	7.3	7.3	
CD at 5% T=0.2 P=NS S=0.2 T×P=NS T×S=NS P×S=NS T×P×S=NS							
Overall acceptability							
0	8.5	8.5	8.3	8.3	8.2	8.2	8.3
3	8.1	7.8	7.6	7.5	7.4	7.3	7.6
6	7.7	7.4	7.2	7.0	6.8	6.7	7.1
Mean	8.1	7.9	7.7	7.6	7.5	7.4	
CD at 5% T=0.1 P=0.1 S=0.1 T×P=NS T×S=NS P×S=NS T×P×S=NS							

($n=10$), NS Non-significant, KMS Potassium metabisulphite, T Treatment, P Packaging, S Storage

60% of the initial concentration when stored at 5 and 25 °C for 5 months.

Microbiological analysis Dried carrot slices treated with KMS, potassium sorbate solutions and untreated carrot samples when packed in AFL and HDPE pouches exhibited slight variation in the microbial counts. It was observed that the total plate count was below the detectable limits in all the three samples packed in either AFL or HDPE pouches during storage. This might be due to the preservative effect of SO₂ and sorbic acid (Table 3) and low water activity that ranged from 0.365 to 0.432 during 6 months of storage (Table 1) at which the growth of microorganisms was not possible. However, very low yeast and moulds counts were found after 6 months of storage i.e. 10 and 30 cfu/g in untreated samples packed in AFL and HDPE pouches respectively; while 10 cfu/g were detected in KMS treated slices packed in HDPE pouches. But in potassium sorbate treated samples packed in both AFL and HDPE pouches, no yeast and mould count was detected even after six months of storage. However, the very low counts noticeable in the present study might also be attributable to environmental contamination, since the water activity of the dried samples was very low. Nonetheless, the yeast and mould counts observed in the present samples were below the permissible limits (10³/g and 10⁴/g, respectively) set by the International Commission for Microbial Specifications for foods.

Sensory evaluation of cooked curried carrot and carrot soup The organoleptic scores varied with the treatment and packaging during storage. The appearance and texture scores of curried slices were highest in KMS treated AFL packed samples, while the flavour score was highest for KMS treated HDPE packed samples after 6 months of storage. The overall acceptability score (7.9) was highest for curried slices after 6 months of storage for KMS treated AFL packed samples (Table 4). In case of soup, the scores for appearance, flavour, texture and overall acceptability were highest after 6 months storage in KMS treated AFL packed samples. The overall acceptability score for soup reduced from 8.5 to 7.7 after storage (Table 5).

Conclusion

It was concluded that the dried carrot slices can be stored upto 6 months under ambient conditions with acceptable quality. Out of two packages, aluminium foil laminate retained better quality of dried slices during storage. Between two treatments, 6% KMS dipping before drying resulted in better retention of physico-chemical characteristics of slices after 6 months of storage. All samples were microbiologically safe during storage. The curried product

and soup had higher organoleptic scoring from KMS treated AFL packed samples after storage.

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