Quality and Shelf Life of Minimally Processed Shredded Carrots in Modified Atmosphere Packaging

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Abstract— *Modified atmosphere packaged Ready-to-eat shredded carrots (Daucus carota L., cv. Nantes) are an increasingly popular product, yet sales are restricted due to rapid deterioration during storage. Objective of this study was to investigate the effects of different gas composition on quality and shelf life of minimally processed shredded carrots. A range of physic-chemical and sensory qualities responsible for deterioration of carrot quality was monitored. Shredded carrots of 250 g were packaged in 30cm x 20cmbags, prepared from 20 µ polyethylene(PE), 20 µ polyvinylchloride (PVC), 10 µ micro-porous MY-15 (MY) and 10 µ oriented polypropylene (OPP)films. Packaged shredded carrots were stored at 4 or 10˚Cand quality characteristics were evaluated during storage. An equilibrium modified atmosphere was reached in most packs by 2-3 days of storage. The CO_2 levels ranged from 10-12% in micro-perforated MY-15packs to 35-40% in the OPP bags at 4˚C during state of equilibrium. Levels of CO_2 in other packs were dependent on film permeability and high permeability resulted in low CO_2levels. The in-pack O_2 and CO_2 levels were also affected by storage temperature and levels were lower at 4˚C compared with 10˚C.Ascorbic acid content remained relatively constant in carrots during storage under all treatment conditions, whereas a highly significant decrease (P<0.01) was observed in PVC packs at 10˚C. β-carotene content decreased from 8943 µg/100g during storage in shredded carrots in MA packs with 73% of initial content after 14 days in OPP packs. Carrots packed in MY-15 films of which the ˚Brix increased from 6.45 to 6.74 during storage at 4°C indicated an increase in total soluble solids. Based on results, Micro-porous MY-15 films with high permeability of oxygen and carbon dioxide at storage temperature of4°C, should be considered together in order to maintain quality and to extend shelf life of shredded carrots for 14 days.*

Keywords— *Carrots, Film Permeability, Modified Atmosphere Packaging, Quality*

I. INTRODUCTION

Modified atmosphere packaging (MAP) has been shown to be beneficial in maintaining quality and extending the shelf life of several fresh-cut fruits and vegetables products. The mixture is made up primarily of O_2, CO_2, and N_2. Passive MAP is designed for matching of commodity respiratory rates with the gas permeability of package materials so that a suitable Equilibrium Modified Atmosphere (EMA) can passively achieved through the consumption of O_2 and the evolution of CO_2 in the respiration process (Smith *et al*., 2004). Products with natural defense structures can be preserved by MAP; the reduction of ripening of product by MA is beneficial for retaining the integrity of epidermal tissue and thus maintaining resistance to spoilage. Reduction of spoilage has been attributed as result of the inhibition of the activity of enzymes such as polyphenol oxidizes and pectinase (Galliard *et al.*, 2006).

Minimally processed carrots consumed as ready-to-eat vegetables have become increasingly popular nowadays. However, sales are limited owing to its rapid deterioration in quality during storage. The major problems that limit the shelf life of minimally processed carrots is to 4-5 days are of its high respiration rate, development of off-flavors, loss of firmness, discoloration, and microbial spoilage. The quality and shelf life of minimally processed shredded carrots can be extended in combination of modified atmosphere packaging and cold storage by minimizing stress cause quality deterioration. The Packaging materials should provide adequate ventilation and carrots should be kept at chilled conditions during the distribution and storage to maintain the product quality (Gordon *et al*., 2004). The main problems limiting the shelf life of minimally processed shredded carrots were reported as losses of nutrients and discoloration (Zhou *et al.,* 2002). There are only limited research findings on the effect of modified atmosphere packaging on the quality and shelf life of minimally processed carrots and the reports related to low oxygen applications of minimally processed carrots are contradictory. Therefore, the objective of this study was to investigate the effects of commodity generated modified atmosphere packaging on the quality and shelf life of shredded carrots during cold storage. During the study, physic-chemical, nutritional, and sensory quality parameters were monitored during storage.

II. MATERIAL AND METHODS

The mature Carrots (*Daucus carota* L. *cv. Nantes*) were harvested at optimum maturity in the commercial field. Medium-sized carrots having 3-4 cm diameter, free of defects were used for this study. Carrot samples were transported under refrigeration 4˚±1˚C in aerated plastic boxes. The sanitation process was assured by personal hygiene and the utensils used were previously sanitized in chlorine liquid. The carrots were washed in cool water, peeled with sharp stainless steel knives and immersed in cold water at 4˚C for 30 min. Peeled carrots were then topped and tailed using a sharp knife and washed for 5 min with chlorinated water (100 ppm free chlorine, pH 7.0) and rinsed by a tap-water. They were left to drip-dry for 30 min in perforated plastic boxes. Carrots were shredded (2.0 cm strips) using a vegetable shredder (Super Tech Company, Taiwan) equipped with a grating cutter.

The shredded carrots were packaged in lots of 250g in bags comprising 20cm x 20cm, prepared from different packaging films as given in Table 1. Bags were sealed using a Multivac AD A3200 packaging machine (Multivac International Ltd., France).The bagged carrots were stored at 4 or 10˚C and the quality characteristics and shelf life were evaluated during storage.

Table 1. Composition, Thickness and Gas Permeability of the Packaging Films used.

Treatments	Composition and Thickness	Gas Permeability (cm^3/m^2 day)	
		O_2	CO_2
T_1	Polyethylene (20 µ)	5426	14,240
T_2	Polyvinylchloride (20 µ)	11,500	44,000
T_3	Micro-porous MY-15 (10 µ)	3500	8500
T_4	Polypropylene (10 µ)	39	49

Gas Permeability values were measured with Lyssy Manomeric Gas Permeability Tester (Model: LC-8000, UK).

A In-Pack Gas Composition

The in-pack O_2 and CO_2 concentration inside the modified atmosphere packages was measured using (Servomex Gas Analyzer-2400, UK), at 2 days intervals. The needle of the gas analyzer was pierced in the head space and the gas composition was expressed as % O_2 and % CO_2 was directly noted from the instrument digital display.

B. Physico-chemical analysis

Titratable acidity of the carrots sample was measured with sodium hydroxide at 0.01N and the results were expressed as % of malic acids and the pH of the sample was determined by using a microprocessor based pH Meter-EC 2000 (Harrison Instruments Pvt., Ltd., Germany) and the stabilized pH reading was recorded. The Ascorbic acid content was determined by 2, 6-dichlorophenol indophenol dye titration method (AOAC, 2002) and was expressed as mg/100g. The Total soluble solids (TSS) of the sample was recorded in ˚Brix by using a Hand held Refractometer (Optica Works Ltd., Japan) with necessary temperature corrections. Determination of β-carotene content was measured using a spectrophotometer. The results were expressed in milligrams of β-carotene in 100 g of the sample.

C. Sensory Analysis

In sensory evaluation, the shredded carrot samples under refrigerated storage were subjected to nine-point hedonic scale test and the acceptability of samples was judged by 30 trained panelists to determine sensory preference. The sensory characteristics such as colour, aroma, white blushing, texture, appearance and overall acceptability of the shredded carrots were judged by the panelists.

D. Statistical Analysis:

Data obtained in Physico-chemical analysis were subjected to Analysis of Variance (ANOVA) and mean separation was done with Duncan's Multiple Range Test (DMRT). Descriptive statistics was done on sensory attributes and the means were compared using the *Friedman test*.

III. RESULTS AND DISCUSSION

A. Head Space O_2 and CO_2 Concentrations

The goal of an Equilibrium Modified Atmosphere (EMA) is to establish constant O_2 and CO_2 concentrations during the entire shelf life study. To check the appropriateness of the selected packaging configurations, a periodic monitoring of the concentration of these gases was carried out. In most of the packs, an equilibrium modified atmosphere was reached by 2-3 days of storage. The levels of CO_2 in the other bags were dependent on film permeability; high permeability resulted in low CO_2

levels. The CO_2 levels were also affected by storage temperature; levels were lower at 4˚C compared with 10˚C. The micro-porous MY-15 film has EMAs of 4-5% oxygen and 10-12% carbon dioxide at 4˚C. The designed bags were able to maintain an acceptable O_2 level for the whole period of the shelf life. The mean concentration of CO_2 through the shelf life was around 10% and then stabilized without accumulation. Therefore, the designed EMA was able to keep O_2 and CO_2 concentrations at the desired levels enough to retard respiration without causing fermentation.

The CO_2 concentration ranged from 35-40% in polypropylene bags to 2-3% in the polyethylene packs under cold storage. The equilibrium carbon dioxide levels in PP packs were sufficiently high to injure the cells and cause physiological damage. The oxygen concentration in the polypropylene bags were <1% and these samples were at hypoxic level (Emmambux *et al*., 2008) and had to be discarded. According to Hussein and Odumeru (2002), the CO_2 levels above 1% induced brown stain in Crisp head shredded lettuce and that levels above 15% produced off-flavors and off-odours. The O_2 levels in the bags made from the polyvinylchloride, approximately 18%, were too high to give a technically beneficial EMA. Excessively low levels of O_2 (below 1%) can result in anaerobic respiration and the development of off-odors. Absence of O_2 could facilitate growth and toxin production by pathogenic microbes (Singh *et al.,* 2002).

B. Nutritional Composition of the shredded Carrots

The contents of ascorbic acid for the samples of shredded carrots did not present significant differences among treatments. Ascorbic acid was retained until 14 days of storage for carrots in all treatments carried out (Table: 2). Application of modified atmosphere packaging for carrots permitted that ascorbic acid content was the most maintenance during storage. Similar results were found by Carlin *et al.* (2000) in ready-to-use grated carrots packed in expanded polystyrene trays and wrapped in PVC (polyvinylchloride) film stored at 5˚C for 10 days.

The contents of titratable acidity were affected by the modified atmosphere gas storage and showed statistical differences among treatments for the shredded carrots (Table: 2). Jacksens *et al*. (2002) found an increase in acidity from 0.08 to 0.26 mg 100 g of mailc acid in sliced carrots packed in polystyrene trays and stored for 10 days under temperatures of 5 and 10˚C and Piga *et al.* (2003) reported a increase in in malic acid in grated carrots packed under modified atmosphere of 10% O_2 and 40% CO_2 and stored for 10 days at 10˚C. Kakiomenou *et al*. (2002) reported that the cactus pear fruits (*Opuntia ficus indica Mill*, cv. 'Gialla') stored in plastic boxes sealed with a polyvinyl chloride film with high permeability to gases, and kept at 4˚C for 9 days, showed significant increase in titrable acidity which adversely affecting the sensorial properties.

Table 2. Physico-chemical composition of the shredded carrots after 14 days of storage at 4˚C

Treatments	Ascorbic acid (mg/100g)	Titratable acidity (% malic acid)	pH
T_1	6.86^a	0.087^c	6.12^b
T_2	6.81^a	0.017^a	6.26^{bc}
T_3	6.94^{ab}	0.043^b	6.40^c
T_4	6.84^a	0.091^c	5.66^a

The values are means of triplicates

Means in the same column followed by different letters are significantly (P≤0.05) different.

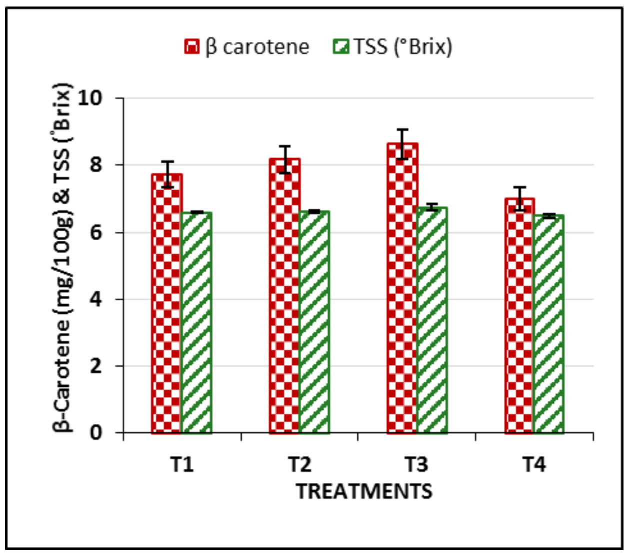

Figure 1. β-carotene and TSS of the of the MA stored shredded carrots after 14 days at 4˚C

There was no statistical change in tissue pH up to 4 days of storage at 4˚C; this fall was delayed until after 6 days at 4˚C for MY-15 and PE packs-stored carrots, after which it fell in all packs. The decrease of pH was possibly due to formation of acid by the reaction between enzymes and carbohydrates found in the cell. Similar results were obtained by Baydar *et al.* (2002), they found a pH decrease with minimally processed carrots packed under modified atmosphere (3% O_2 and 97% N_2) and stored under temperatures of 5˚C. Gil *et al.* (2002) observed, in a mixed salad made of carrots, lettuce and purple cabbage, a pH decrease from 6.7 to 4.9 after 9 days of storage at 15˚C, concluding that this reduction could be related to the higher concentration of CO_2 found at this temperature. According to the review by Chen *et al*. (2002), due to the enzymes release during the cell damage, carbohydrates form carboxylic acids during the extended storage period. The decrease of pH during storage is probably due to the production of acids by the psychrotrophic microorganisms in the samples.

The β-carotene content decreased from 8.94mg/100g during the storage in shredded carrots in MA packs with 73% of the initial content after 14 days at 10˚C in polypropylene packs (Figure 1). Similarly, Hussein *et al*., (2000) reported that the contents of -carotene decreased continuously during the storage at 4˚C in shredded carrots packed in polymeric film bags, with 33% of the initial content after 28 days of storage.

There was no significant difference observed between modified atmosphere treatments at any given day in terms of Brix (P > 0.05). However, Brix tended to increase during storage in all MA applications. The increase in Brix during storage indicated an increase in total soluble solids.

C. Sensory Analysis during Storage studies

The range of EMAs, resulting from the various film permeabilities and storage temperatures, had direct effects on the sensory quality of shredded carrots and was monitored by the sensory panel. The sensory evaluation of the modified atmosphere stored shredded carrots revealed that there were significant differences in colour, aroma, white blushing, texture, appearance and overall acceptability between the treatments (at the 5% level of significance according to ANOVA). Mean values of treatments were analyzed by Friedman test and the results are shown in Table 3.

The findings of the sensory attributes such **as** colour, white blushing, texture and overall acceptability of the carrots are in the deviated pattern. These different directions of score patterns may be due to the different rates of preference and acceptable values of panelists. Our findings were supported by of the results obtained by Watson *et al.* (2008).

Texture is one of the most important parameters connected to quality of the shredded carrots. It is defined as the sensory manifestation of the structure of food and the manner in which that structure reacts to the applied force (Jean-Xavier and Rossella, 1996). Texture analysis involves measuring the properties related to how a food feels in the mouth (initial bite). According to DMRT, there were significant differences between in texture of the different treatments. The highest appearance scores were given to product packed under 10-12% CO_2 and 4-5% O_2 (MY-15 film) at 4˚C. Samples stored in the PP packs received lowest appearance scores, irrespective of the storage temperature. Loss of the satisfactory appearance in polypropylene packed carrots is generally attributed due to the development of surface whitening in the shredded carrots. There are two possibilities for carrot white blushing or the carotene bleaching. White blushing is a white translucent appearance of cut carrots that has been attributed to tissue dehydration (Nelson *et al*., 2001) and lignification (Augšpole *et al.*, 2012).possibilities for carrot

White blushing is hypothesized to result from drying out effects at the cut surface and may be followed by the synthesis of lignin. Both of these may be directly related to the extent of surface damage inflicted. Bolin and David (2008) showed that processed carrots quickly developed white lignin type material and that the degree of formation of this material was dependent on the severity of the process.

Table 3. Sensory scores of the shredded carrots stored in Modified Atmosphere packs for 14 days at 4˚C

Treatments	**Colour**	**Aroma**	**White blushing**	**Texture**	**Appearance**	**Overall acceptability**
T_1	$8.41±0.20^{c}$	$8.26±0.19^{b}$	$8.22±0.21^{c}$	$8.12± 0.21^{bc}$	$8.04± 0.22^{b}$	$8.48±0.20^{ab}$
T_2	$7.81±0.22^{b}$	$8.04± 0.12^{b}$	$7.68±0.17^{b}$	$7.85± 0.17^{b}$	$7.91± 0.26^{c}$	$8.03±0.22^{c}$
T_3	$8.55±0.18^{c}$	$8.61±0.31^{c}$	$8.70±0.18^{d}$	$8.70±0.18^{d}$	$8.57± 0.28^{d}$	$8.65±0.28^{d}$
T_4	$7.25±0.15^{a}$	$7.80± 0.12^{a}$	$7.49±0.21^{a}$	$7.79± 0.11^{a}$	$7.49± 0.14^{a}$	$7.85±0.15^{a}$

Colour, aroma, texture, taste and overall acceptability scores: 9 - fresh, 1 - spoiled.
White blushing: 9 - none, 1 - severe.
The values are means of three replicates $\pm$ standard error.
Means in the same column followed by different letters are significantly (P≤0.05) different.

IV. CONCLUSIONS

The equilibrium modified atmospheres of 4-5% O_2 and 10-12% CO_2 reduced the respiration rate of the shredded carrot at 4˚C and 10˚C temperatures, and had desirable effects on storage quality, as noted by maintain nutritional and sensory characteristics during storage. Overall, carrot shreds benefited from MA when stored at 4°C but not at 10°C. Carrots stored in the polypropylene packs were affected deleteriously by the gas mixtures used. Thus, O_2 can be allowed to drop down to 4-5% and CO_2 be allowed to increase up to 10-12% in film bags without any consequence on shelf life of the product, providing the temperature is kept near 4°C throughout the entire storage period. The outcome of the present research could be used as valuable information for the development of ready-to-eat shredded carrots under modified atmosphere storage. The results obtained could be very valuable in decision making for industries that want to take advantage to extend the shelf life of shredded carrots without affecting the nutritional and sensorial qualities.

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