# Minimal Processing and Modified Atmosphere Packaging of Carrot Discs: Effects of Packaging Film and Product Weight

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**Abstract:** Carrot (*Daucus carota* L.) discs were prepared and packaged in low density polyethylene (LDPE) bags with or without aluminium silicate under passive modified atmosphere, and then stored at 4 °C for 21 days. The effects of modified atmosphere packaging (MAP) treatments on oxygen and carbon dioxide concentrations in the headspace, color, texture, mass loss, pH, total titratable acidity (TTA), β-carotene content and sensory quality of packaged carrot discs were determined. Oxygen levels decreased and carbon dioxide levels increased significantly within 7 days and stayed stable for the rest of the storage time. While L* and WI values increased, a* and b* values decreased at the end of the storage. Storage time was the most significant factor affecting physiological, physicochemical and sensory attributes. β-carotene content was 5.89 g $kg^{-1}$ fresh tissue right after processing and decreased in all applications during storage. The shelf-life was determined as 14 days for minimally processed carrot discs for all applications.

**Keywords:** Carrot, Modified atmosphere packaging, Aluminium silicate, Shelf-life.

## 1. INTRODUCTION

Consumer preferences have been changed significantly towards fresh, healthy and convenient food produced in recent years. Therefore, a great deal of research is focused in minimally processed fruits and vegetables to meet this consumer demand. Minimally processed carrots (*Daucus carota*) are one of the most popularly consumed vegetables. Carrot is an important crop for diet and health because of its high β-carotene content [1] among other carotenoids such as α-carotene and lutein. It also contains substantial amounts of vitamin C and phenolic compounds, with chlorogenic acid being the most abundant phenolic compound identified in carrot cultivars [2, 3]. The positive association between carotenoids in human diet and lower risk of atherosclerosis [4], masular degeneration [5] and cancer [6] have been reported.

Modified atmosphere packaging (MAP) is one of the most important food preservation techniques maintaining the natural quality and extending the shelf-life of fresh or minimally processed foods [7-9]. The interaction between the respiration rate of produce and the transfer of gasses through the packaging material alters the package atmosphere dynamically in MAP technique. Suitable headspace gas compositions, that account for low oxygen and high carbon dioxide concentrations, could help to maintain freshness and visual appearance of fresh-cut produce by retarding respiration rate and ethylene production and/or enzymatic deterioration during storage [10, 11].

Previous studies have shown the use of an edible antimicrobial coating containing chitosan [12], MAP for extending the shelf-life [13], edible coating containing chitosan with modified atmosphere [14], effect of processing (slicing, peeling) and MAP on survival of *E. coli* [15] on minimally processed carrots. However, none of the former studies tested the effect of product weight under MAP, which might also influence the physiological, physicochemical and sensory quality of minimally processed carrots.

The objective of this study was to evaluate the influence of product weight on shelf-life of minimally processed carrots discs packaged in LDPE films. To assess the influence of product weight and packaging systems on the investigated carrot discs, physiological (oxygen and carbon dioxide), physicochemical (color, texture, mass loss, pH, total titratable acidity, β-carotene content) and sensory properties were monitored during 21 d of storage at 4 °C.

## 2. MATERIAL AND METHODS

### 2.1. Materials

Freshly harvested carrot (*Daucus carota* L.) was obtained from the wholesale market hall and stored at 4°C before processing. Low density polyethylene (LDPE) and aluminium silicate (Tazetut® masterbatch, PE/F 104010−Tazetut® (MFI 10−12 g (10 min)$^{-1}$ at 190 °C; 2.16 kg) added LDPE films provided by AKSOY

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Plastik Inc. (Istanbul, Turkey) were cut into 15×22 cm and sealed at 120 °C for packaging. Tazetut® masterbatch, an inorganic product containing 50% of various aluminosilicate minerals (zeolite), was used to obtain appropriate permeability properties. Some properties of the packaging films are summarized in Table **1.**

**Table 1: Properties of Packaging Films Used in the Study**

| Property | LDPE | LDPE with Aluminium Silicate |
|---|---|---|
| OTR (ml $m^{-2}$ $day^{-1}$) | 4561 | 4680 |
| $CO_2$TR (ml $m^{-2}$ $day^{-1}$) | 22407 | 26258 |

OTR: oxygen transmission rate at 25 °C and 90% RH; $CO_2$TR: carbon dioxide transmission rate at 25 °C and 90% RH.

## 2.2. Processing and Packaging Procedure

Carrots at uniform size and visual appearance, and free of defect were washed with tap water then topped and tailed using a sharp knife and sliced in the thickness of 5 mm discs with the slicing equipment (Scharfen es 300, Germany) under hygienic conditions. The carrot slices were immersed in chlorinated water (100 µl $l^{-1}$) then left to dry at air. Sliced carrot was weighed in 150 g (W1) or 200 g (W2) and packaged in LDPE (M1) and aluminium silicate added LDPE (M2) under passive MAP (air) using Constant Heat Sealer equipment (Taiwan). Packaged carrot samples were stored at 4 °C and 90% RH for 21 days. The physiological, physicochemical and sensory properties were analysed at 0, 7, 14 and 21 d.

## 2.3. Headspace Gas Analysis

Oxygen and carbon dioxide concentrations (% v $v^{-1}$) in the package headspace were monitored by means of a portable PBI Dansensor (CheckPoint $O_2$/$CO_2$, Ringsted, Denmark) analyser by sampling 15 ml gas from the package headspace. Three measurements were carried out for each application.

## 2.4. Physical Analysis

### *2.4.1. Color*

Color of sliced carrot samples was measured with a Minolta CR-400 chromameter (Konica Minolta Sensing, Inc. Osaka, Japan), using the CIE L*a*b* scale. The equipment was set up for illuminant C and 2° angle of observation and calibrated using a standard white reflector plate. L* indicates brightness, a* chromacity on a green (-) to red (+) axis and b* chromacity on a blue (-) to yellow (+) axis. L*, a* and b* color parameters were also expressed as whiteness index using the equation $WI = 100-[(100-L^*)^2 + a^{*2} + b^{*2}]^{1/2}$ [16]. Total of 30 readings were taken from 3 packages (10 discs per package) for each treatment.

### *2.4.2. Texture*

The maximum force (N) indicating firmness/softness of the product was determined with a TA-XT Plus texture analyser (Stable Micro Systems, Surrey, England) equipped with a Guillotine blade penetrating at a velocity of 4 mm $s^{-1}$ to a final depth of 20 mm. Total of 30 readings were taken from 3 packages (10 discs per package) for each treatment.

### *2.4.3. Mass Loss (%)*

Mass loss during storage was calculated by subtracting sample mass from their initial mass and presented as percentage of mass loss compared to initial mass.

## 2.5. Chemical Analysis

### *2.5.1. Moisture Content, pH and Total Titratable Acidity (TTA)*

The moisture content of carrot discs were determined at the beginning (0. day) and on each sampling day during storage [17]. Three measurements were performed for each application.

The measurement of pH was carried out using a WTW-315i pH meter (Weilheim, Germany). Total titratable acidity (TTA) of the carrot disc was measured by titrating it against 0.1 N NaOH to the end point of pH 8.1, monitored with a pH meter. The results were expressed as percentage of malic acid. Three measurements from each package were performed and average of nine measurements was taken for each application on each analysis day for pH and TTA.

### *2.5.2. β-carotene Content*

β-carotene content was calculated according to Muftuoglu *et al.* [18]. Final results were expressed as g $kg^{-1}$ fresh tissue. Extractions were performed in triplicate.

## 2.6. Sensory Evaluation

The sensory attributes of carrot samples were evaluated by 10 trained judges. Panelists were asked to evaluate color, firmness and taste using a 5 point scale. Scores of 3 or above were considered acceptable. Overall product acceptability was scored on a 9 point hedonic scale where 9 corresponded to excellent and 1 corresponded to unacceptable.

For carrot: Color was rated using 5 = bright orange, 3 = acceptable and 1 = whitish orange. Firmness was rated using 5 = brittle and juicy, 3 = medium and 1 = soft. Taste was rated using 5 = characteristic taste, 3 = acceptable taste and 1 = no characteristic taste. Overall product acceptability was rated using 9 = excellent or having a freshly harvested appearance, 5 = average and 1 = unacceptable.

### 2.7. Data Analysis

Statistical analyses were performed with the Statistical Analysis System (SAS) (Version 8.02; SAS Inst. Inc., Cary, NC, USA) using analysis of variance ANOVA. Duncan's multiple range (DMR) test was applied to calculate the significant difference between different treatments. Results were expressed as the average ± standard deviation. Data were also analysed to determine the effects of application, storage time and their interactions on the physical, chemical and sensory quality parameters.

## 3. RESULTS AND DISCUSSION

### 3.1. Headspace Gas Composition

During storage of minimally processed carrot discs, oxygen levels significantly ($P \leq 0.05$) decreased (Figure **1A**) and carbon dioxide levels significantly ($P \leq 0.05$) increased (Figure **1B**) in all packs. The initial oxygen concentration dropped from 21% to below 6% within 7 days and stayed stable for the rest of the storage time. This decrease could be attributed to the use of oxygen by chemical reactions or microbial growth. Package weight affected oxygen concentration, where 150 g (W1) packages had higher oxygen content than 200 g (W2) packages. The beginning $CO_2$ level started with 0%, but it increased to 4.5-5.5% in 7 days and stayed stable for the rest of the storage time. W2 packages had higher $CO_2$ concentration than W1 packages indicating package weight affected respiration rate. Similarly, Clife-Byrnes *et al.* [19] and Kenny and O'Beirne [20] reported lower oxygen and higher carbon dioxide levels in MA packaged carrot discs suggesting that severity of processing method resulted in increased respiration rate. Calcium-alginate coating loaded with silver-montmorillonite nanoparticles reduced respiration activity of minimally processed carrots compared to the uncoated samples [21]. The equilibrium gas composition (oxygen and carbon dioxide) and required time to reach this equilibrium in the package depend on both the packed product (respiration rate, transpiration rate, weight) and the permeability of the packaging material under passive MAP. Both LDPE films provided aerobic gas equilibrium inside the packages after 7 days of storage.

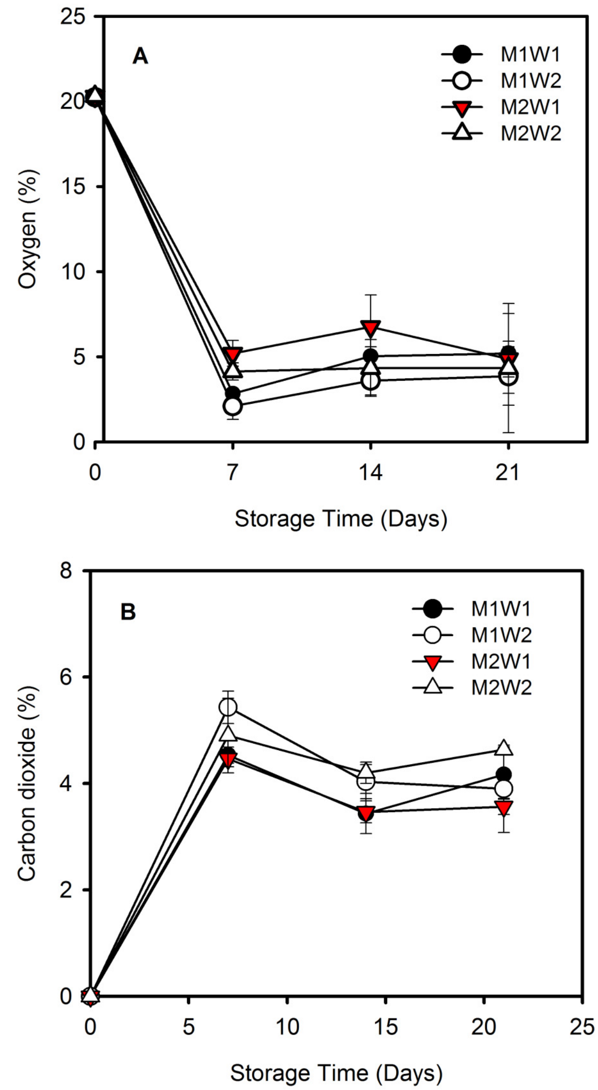


**Figure 1: A** Headspace oxygen (percent), **B** carbon dioxide (percent) during storage. M1 low density polyethylene film, M2 low density polyethylene film with aluminium silicate, W1 150 g, W2 200 g. Values are given as mean±SD.

Aluminium silicate minerals (zeolites) have been incorporated into the packaging films to absorb ethylene [7] and to increase gas permeability by their selective permeability of gases resulting from their crystalline porous three-dimensional framework structure [22, 23].

### 3.2. Physical Quality

#### *3.2.1. Color*

The color attributes of the carrot discs packaged with different packaging materials and weight during cold storage are presented by Table **2**. The effects of experimental factors and their interactions on the color attributes (L*, a*, b* and WI) are presented by Table **3**. There were significant effects of storage time (main effect) and packaging material×storage time and packaging material×weight×storage time interactions on the brightness values (L*) of the carrot discs (P≤0.05). While there were no differences between applications at day 0, differences were observed on day 14 for brightness. L* values increased significantly (P≤0.05) at the end of the storage (Table **2**).

There were significant effects of packaging material and storage time main effects on the a* values of the carrot discs (P≤0.05). The initial a* value (red/green) was 25.68 and decreased in all applications during storage and ranged between 22.08-23.11 at the end of the storage period (Table **2**). Decrease in red color value was possibly caused by the oxidation and degradation of β-carotene, the major pigment in orange carrot. There was a significant effect of storage time on the b* and WI values of carrot discs (P≤0.05), While b* values (yellow/blue) increased during first 7 days of storage and then decreased afterwards, WI values decreased during first 7 days of storage and then increased afterwards. Color is one of the most important quality attributes of carrot. Surface whitening is the main external quality problem affecting the marketability of minimally processed carrots. A polymeric packaging film that can maintain a high relative humidity and act as a good moisture barrier could be used for control of surface whitening (white blush formation) [24]. Surface whitening was significantly controlled by the chitosan coating and the overall visual quality of coated carrot sticks was found higher than that of uncoated carrot sticks independent of the MAP [14]. Clife-Byrnes *et al.* [19] and Kenny and O'Beirne [20] reported that severity of processing method of carrots resulted in a greater loss of color with increased surface whitening.

**Table 2: The Effects of Packaging Material, Package Weight and Storage Time on Color Attributes of Carrot Discs during Cold Storage**

| Packaging Material | Mass | Day 0 | Day 7 | Day 14 | Day 21 |
|---|---|---|---|---|---|
| | | | L* | | |
| M1 | W1 | 52.48±2.76Ab | 52.50±2.78Ab | 54.44±2.96Aab | 54.65±3.43Aa |
| | W2 | 52.48±2.76Aab | 52.55±2.88Aab | 52.13±3.62Bb | 54.44±2.82Aa |
| M2 | W1 | 52.48±2.76Ab | 50.62±2.99Ab | 52.19±3.10Bb | 56.41±3.19Aa |
| | W2 | 52.48±2.76Abc | 51.09±3.03Ac | 54.18±2.75ABab | 55.47±3.03Aa |
| | | | a* | | |
| M1 | W1 | 25.68±2.35Aa | 24.83±2.12Aa | 25.07±1.87Aa | 23.28±2.09Ab |
| | W2 | 25.68±2.35Aa | 24.69±1.83Aab | 24.22±1.92Ab | 23.31±2.15Ab |
| M2 | W1 | 25.68±2.35Aa | 24.86±3.11Aa | 24.05±2.36Aa | 22.08±2.60Ab |
| | W2 | 25.68±2.35Aa | 24.53±2.71Aa | 23.93±3.46Aab | 22.17±3.04Ab |
| | | | b* | | |
| M1 | W1 | 34.50±4.37Abc | 36.83±3.20Aa | 36.48±2.95Aab | 32.22±2.97Ac |
| | W2 | 34.50±4.37Aab | 35.92±2.59Aa | 35.03±2.70ABa | 32.81±3.16Ab |
| M2 | W1 | 34.50±4.37Aab | 36.92±4.10Aa | 34.20±3.84Bb | 33.05±3.42Ab |
| | W2 | 34.50±4.37Aab | 36.01±2.96Aa | 35.06±3.46ABa | 32.41±3.38Ab |
| | | | WI | | |
| M1 | W1 | 35.71±2.50Ab | 34.84±2.30Ab | 36.36±2.38Ab | 39.58±3.20Aa |
| | W2 | 35.71±2.50Ab | 35.46±1.90Ab | 35.80±2.74Ab | 39.11±3.12Aa |
| M2 | W1 | 35.71±2.50Ab | 33.30±2.12Bc | 36.29±1.99Ab | 40.86±3.27Aa |
| | W2 | 35.71±2.50Abc | 34.35±2.31ABc | 37.41±3.77Ab | 40.52±4.13Aa |

Mean values with similar capital letters in the same column for a given storage day are not statistically significant (P > 0.05). Mean values with similar small letters in the same row for a given application are not statistically significant (P > 0.05). M1: LDPE, M2: LDPE with aluminium silicate. W1:150 g; W2: 200 g.

**Table 3: P Values for Main Factors and their Interactions of Color (L*, a*, b*, WI)**

| Source of Variation | L* | a* | b* | WI |
|---|---|---|---|---|
| Packaging material | 0.7287 | 0.0355 | 0.5271 | 0.4345 |
| Weight | 0.6603 | 0.4614 | 0.3456 | 0.4842 |
| Storage time | <.0001 | <.0001 | <.0001 | <.0001 |
| Packaging material×Weight | 0.0687 | 0.7429 | 0.6833 | 0.2658 |
| Packaging material×Storage time | 0.0014 | 0.2155 | 0.4372 | 0.0015 |
| Weight×Storage time | 0.7434 | 0.8157 | 0.7346 | 0.3630 |
| Packaging material×Weight×Storage time | 0.0055 | 0.8965 | 0.2763 | 0.6344 |

**Table 4: The Effects of Packaging Material, Package Weight and Storage Time on Textural and Chemical Attributes (pH, TTA, β-carotene) of Carrot Discs during Cold Storage**

| Packaging Material | Mass | Day 0 | Day 7 | Day 14 | Day 21 |
|---|---|---|---|---|---|
| | | | Texture (N) | | |
| M1 | W1 | 65.25±3.86Aab | 65.02±3.31Ab | 66.04±3.54Cab | 69.08±5.02Aa |
| | W2 | 65.25±3.86Ac | 64.87±3.56Ac | 74.26±3.08Aa | 69.53±4.85Ab |
| M2 | W1 | 65.25±3.86Ab | 66.03±2.95Aab | 68.60±4.42BCab | 69.71±4.76Aa |
| | W2 | 65.25±3.86Ab | 65.78±3.69Ab | 70.66±2.79Ba | 70.41±6.31Aa |
| | | | pH | | |
| M1 | W1 | 6.37±0.18Aa | 6.19±0.03Ab | 6.18±0.12Bb | 6.40±0.13Aa |
| | W2 | 6.37±0.18Aa | 6.01±0.02Bc | 6.16±0.12Bb | 6.18±0.07Cb |
| M2 | W1 | 6.37±0.18Aa | 5.89±0.11Cb | 6.36±0.12Aa | 6.35±0.21ABa |
| | W2 | 6.37±0.18Aa | 6.04±0.06Bc | 6.21±0.06Bb | 6.23±0.07BCb |
| | | | Total titratable acidity (malic acid g $l^{-1}$) | | |
| M1 | W1 | 1.76±0.14Ab | 2.10±0.20Ca | 2.20±0.11Aa | 2.08±0.09Aa |
| | W2 | 1.76±0.14Ac | 2.32±0.13Ba | 2.19±0.13Aa | 2.12±0.05Ab |
| M2 | W1 | 1.76±0.14Ac | 2.62±0.17Aa | 2.02±0.06Bb | 2.09±0.26Ab |
| | W2 | 1.76±0.14Ac | 2.33±0.12Ba | 2.10±0.08ABb | 2.27±0.15Aa |
| | | | β-carotene (g $kg^{-1}$ fresh tissue) | | |
| M1 | W1 | 5.89±1.19Aa | 5.02±0.92Ab | 5.16±0.36Ab | 4.63±0.59Ab |
| | W2 | 5.89±1.19Aa | 3.45±0.72Bc | 4.44±0.69BCb | 3.57±0.55Bc |
| M2 | W1 | 5.89±1.19Aa | 4.79±0.78Ab | 4.03±0.82Cc | 4.32±0.52Abc |
| | W2 | 5.89±1.19Aa | 3.87±0.30Bc | 4.76±0.61ABb | 4.29±0.53Abc |

Mean values with similar capital letters in the same column for a given storage day are not statistically significant (P > 0.05). Mean values with similar small letters in the same row for a given application are not statistically significant (P > 0.05). M1: LDPE, M2: LDPE with aluminium silicate. W1:150 g; W2: 200 g.

### *3.2.2. Firmness*

The firmness of carrot discs with different packaging materials and weights during cold storage is presented by Table **4**. The effects of experimental factors and their interactions on the textural attributes are presented by Table **5.** The firmness of carrot discs increased significantly (P≤0.05) for all applications at the end of storage. The initial firmness value was 65.25 N and it increased to 69.08-70.41 N on the 21st day. There were significant effects of weight and storage time main effects and weight×storage time interaction on the firmness values of the carrot discs (P≤0.05). Ayhan *et al.* [13], on the other hand, reported that the texture values of minimally processed carrots declined after 14 of storage in MAP applications tested.

### *3.2.3. Mass Loss (%)*

Packaging materials significantly reduced the mass loss of the carrot discs. LDPE (M1) and LDPE with aluminium silicate (M2) provided a good barrier to water permeation. Mass loss of packaged samples was less than 0.3 % at 21 d of storage (data not shown). Esturk *et al.* [7] reported that mass loss was less than 1% for broccoli samples packaged in LDPE.

## 3.3. Chemical Quality

### *3.3.1. Moisture Content, pH and Total Titratable Acidity (TTA)*

The initial moisture content of 95.56% did not change much during storage and measured as 95.36% at the end of the storage (data not shown). The pH of the sliced products under all applications during storage is given by Table **4.** The effects of experimental factors and their interactions on chemical attributes (pH, TTA and β-carotene content) of the product are presented by Table **5.** The initial pH of the product was determined as 6.37, slightly decreased during 7 days of storage then showed a slight increase in all applications ranging between 6.18-6.40 at the end of the storage period. There were significant effects of product weight and storage time main effects and packaging material×storage time, weight×storage time and packaging material×weight×storage time interactions on the pH of carrot ($P \leq 0.05$). The initial TTA of the products was measured as 1.76 g malic acid $l^{-1}$ and ranged between 2.08-2.27 g malic acid $l^{-1}$ at the end of the storage.

### *3.3.2 β-Carotene Content*

Major carotenoids in carrot are β-carotene, α-carotene and lycopene. The initial β-carotene content of fresh carrot was 5.89 g $kg^{-1}$ fresh tissue. β-carotene content of carrot discs decreased significantly ($P \leq 0.05$) for all applications ranged from 3.57 to 4.63 g $kg^{-1}$ fresh tissue at the end of the storage (Table **4**). Except packaging material, all main effects and their interactions were found significant on the β-carotene content of carrots (Table **5**). Alasalvar *et al.* [25] reported that total carotenoid content decreased gradually in orange carrots during storage under all treatment conditions, and this was particularly significant in the 95% $O_2$ +5% $CO_2$ treatment.

## 3.4. Sensory Evaluation

The effect of packaging material and weight on the sensory quality of minimally processed carrot discs during storage is shown in Table **6.** While the color scores of carrot discs were found acceptable (above 3) for 14 d, texture scores were above 3 for all packaged applications throughout the storage. Minimally processed carrot discs were acceptable in term of taste for all treatments during the 21 days of storage except M1W2, which was acceptable for 14 days. Similar to taste results, all treatments had scores above 5 for overall product acceptance throughout the storage except M1W2, which was acceptable for 14 days. Considering all sensory attributes tested and overall product acceptance, the shelf-life of minimally carrot discs was considered 14 d for all treatments. Most of the sensory attributes were found unacceptable after 7 d for the minimally processed carrots packaged with passive (in air) and active modified atmospheres at low (5% $O_2$, 10% $CO_2$, 85% $N_2$) and high oxygen concentrations (80% $O_2$, 10% $CO_2$, 10% $N_2$) [13]. Alasalvar *et al.* [25] reported that sensory evaluation of the shredded orange carrot samples packaged in air (control), or in MAP (90% $N_2$ +5% $O_2$ +5% $CO_2$ and 95% $O_2$ +5% $CO_2$) were acceptable for 10 days and slight off smell/odor were only evident on day 13. On the other hand, Amanatidou *et al.* [26] indicated that the use of MAP (50% $O_2$, 30% $CO_2$ and 20% $N_2$)

**Table 5: P Values for Main Factors and their Interactions of Texture, pH, TTA and β-Carotene**

| Source of Variation | Texture | pH | TTA | β-carotene |
|---|---|---|---|---|
| Packaging material | 0.5717 | 0.8271 | 0.029 | 0.7486 |
| Weight | 0.0094 | 0.002 | 0.321 | <.0001 |
| Storage time | <.0001 | <.0001 | <.0001 | <.0001 |
| Packaging material×Weight | 0.1552 | 0.1101 | 0.146 | <.0001 |
| Packaging material×Storage time | 0.7377 | 0.0009 | <.0001 | 0.0383 |
| Weight×Storage time | 0.0008 | 0.0206 | 0.174 | <.0001 |
| Packaging material×Weight×Storage time | 0.092 | 0.0025 | <.0001 | 0.0096 |

**Table 6: The Effects of Packaging Material, Package Weight and Storage Time on Sensory Attributes of Carrot Discs during Cold Storage**

| Packaging Material | Mass | Day 0 | Day 7 | Day 14 | Day 21 |
|---|---|---|---|---|---|
| | | | Color | | |
| M1 | W1 | 4.4±0.70Aa | 3.4±0.70Aab | 3.3±1.25Aab | 2.9±1.29Ab |
| | W2 | 4.4±0.70Aa | 3.0±1.25Ab | 3.2±1.35Aab | 2.6±0.97Ab |
| M2 | W1 | 4.4±0.70Aa | 3.2±1.03Ab | 3.1±1.45Ab | 2.8±1.23Ab |
| | W2 | 4.4±0.70Aa | 3.0±0.82Ab | 3.0±1.14Ab | 2.8±0.92Ab |
| Texture | | | | | |
| M1 | W1 | 4.7±0.48Aa | 3.7±0.82Ab | 3.9±0.74Aab | 3.7±1.06Ab |
| | W2 | 4.7±0.48Aa | 3.6±1.17Ab | 4.1±1.10Aab | 3.4±0.70Ab |
| M2 | W1 | 4.7±0.48Aa | 4.1±0.57Aab | 3.8±0.92Ab | 3.5±0.53Ab |
| | W2 | 4.7±0.48Aa | 3.6±1.07Aa | 3.8±1.23Aa | 3.8±1.14Aa |
| Taste | | | | | |
| M1 | W1 | 3.8±0.92Aa | 3.6±1.07Aa | 3.1±1.29Aa | 3.3±1.34Aa |
| | W2 | 3.8±0.92Aa | 3.2±0.92Aab | 3.9±0.74Aa | 2.5±0.71Ab |
| M2 | W1 | 3.8±0.92Aa | 3.3±1.06Aa | 3.5±1.35Aa | 3.5±0.97Aa |
| | W2 | 3.8±0.92Aa | 3.2±0.92Aa | 3.5±0.71Aa | 3.1±0.88Aa |
| Overall product acceptance | | | | | |
| M1 | W1 | 7.8±1.14Aa | 6.5±1.65Aa | 5.9±2.13Aa | 5.7±2.11Aa |
| | W2 | 7.8±1.14Aa | 5.7±1.95Abc | 6.8±1.75Aab | 4.5±1.72Ac |
| M2 | W1 | 7.8±1.14Aa | 5.7±2.36Aa | 5.6±2.41Aa | 6±1.83Aa |
| | W2 | 7.8±1.14Aa | 5.2±1.81Ab | 5.8±1.48Ab | 6.4±0.84Aab |

Mean values with similar capital letters in the same column for a given storage day are not statistically significant (P > 0.05). Mean values with similar small letters in the same row for a given application are not statistically significant (P > 0.05). M1: LDPE, M2: LDPE with aluminium silicate. W1:150 g; W2: 200 g.

**Table 7: P Values for Main Factors and their Interactions of Sensory Properties**

| Source of Variation | Color | Texture | Taste | Overall Product Acceptance |
|---|---|---|---|---|
| Packaging material | 0.2003 | 0.8539 | 0.6921 | 0.8548 |
| Weight | 0.8207 | 0.7127 | 0.4762 | 0.6473 |
| Storage time | <.0001 | <.0001 | 0.0168 | <.0001 |
| Packaging material×Weight | 0.7057 | 1.0000 | 0.9369 | 0.5831 |
| Packaging material×Storage time | 0.4790 | 0.7554 | 0.6419 | 0.0806 |
| Weight×Storage time | 0.9526 | 0.7473 | 0.1524 | 0.4319 |
| Packaging material×Weight×Storage time | 0.7402 | 0.5935 | 0.5268 | 0.5075 |

prolonged the shelf-life of sliced carrots by 3 days as compared to samples stored under air.

## 4. CONCLUSIONS

In conclusion, the MAP treatment can be used to maintain the quality of minimally processed carrots discs since it preserved the physicochemical characteristics and sensory quality of the carrot discs for up to 14 d of storage. MAP also quite effectively reduced the mass losses of minimally processed carrot discs for 21 d of storage. Storage time had more pronounced effect on physicochemical and sensory properties of carrot discs than packaging material and package weight. Incorporation of aluminium silicate minerals (zeolite) did not change the level of headspace oxygen and carbon dioxide significantly.

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