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Effect of pre-treatment and packing film for minimally processed carrots stored at low temperature

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ABSTRACT

Experiments were conducted to find out the suitable pre-treatment and package for extending shelf of the minimally processed carrot with microbiological safety. Of the pre-treatments used, 1 % citric acid, 1 % ascorbic acid and combination of 5 % citric acid and 0.5 % ascorbic acid, 1 % citric acid showed the minimum level of coliform counts at 7 days of storage. Size of package affected the growth of coliform during storage at 7±2 °C having a minimum counts in 15 x15 cm^2, 100 gauge, low density polyethylene (LDPE) bags. Percentage weight loss, browning, whitening, softening and visual quality rating of minimally processed carrot do not significantly affected by the pre-treatments and size of the package used. Although 1 % citric acid increased the total plate counts of minimally processed carrot, coliform counts were maintained at minimum level for 7 days.

Key words : Carrot, Citric acid, Low density polyethylene, Microbial counts, Minimal processing, Modified atmosphere.

INTRODUCTION

Washed, peeled and sliced vegetables can make available as ready-to-eat or ready-to-cook or salad form. This processing technology is termed minimal processing provides nutritionally sound, healthy and convenient food with a higher demand.

However, minimal processing accelerates deterioration of the product. Peeling, coring, shredding and slicing cause cell disruption with subsequent decompartmentalization of enzymes and substrates, resulting accelerated physiological reactions (Piga *et al.*,2000). These stress conditions lead to increase respiration rate by two or three folds over that of intact and cause unacceptable surface whitening and discoloration due to lignin synthesis (Kahl and Laties, 1989; Priepke *et al.*, 1976)

Both lignin synthesis (Both and Huxoll, 1991) and dehydration (Cisneros-Zevallos *et al.*, 1995) have been attributed to the surface whitening of cut carrot tissues. The extent of the injury to the product caused by slicing may depend on factors such as final size of the pieces, sharpness of slicing action and mechanical properties of the product (Tatsumi *et al.*, 1991; Zhou *et al.*, 1992; Abe *et al.*, 1993; and Bolin *et al.*,1997). Since peeling removes the natural protection provided by the skin, the commodity is highly susceptible for spoilage (Maxy,1982). Slicing accelerates the microbial spoilage of vegetables (Izumi *et al.*, 1996).Moreover, shredding facilitates contamination by epithelial micro flora and leaked nutrients provide rich substracts for their growth (Carline *et al.*, 1989).

Minimally processed foods are fresh and tend to lose their texture and appearance during storage. Specially, browning occurs on the cut surface making noticeable changes during the storage (Rolle and Chism, 1987). This enzymatic browning and other deteriorations reduce the visual quality of minimally processed products (Maria *et al*., 1998)

In order to retain the fresh colour, flavour, texture and extended shelf life of minimally processed vegetables, low temperature storage, control atmosphere storage and dip in divalent ion solutions have been recommended (King and Bolin, 1989). These techniques help to minimize the primary spoilage mechanisms of the tissue and the microbial growth. Refrigerated storage and suitable modified atmosphere packaging may minimize stress reactions. Passive modified atmosphere generated in sealed low density polyethylene bags able to retard the respiration rate in the minimally processed packed product (Kadar,1980). Modified atmospheric packed fresh products require that narrow range gas concentration to be maintained in a package, typically 3 % to 10 % O_2 and 3 % to 10 % CO_2. This is achieved by dynamic interaction between the respiring produce, the gas permeability of the packaging film and environmental conditions such as storage temperature (Barry- Ryan *et al*.,2000). Generally, films with a $CO_2 : O_2$ ratio 3:1 is the most suitable. Chemically inert, odour free and heat sealability are characteristic features of Low Density Polythylene (LDPE). Moreover, it is a good moisture barrier but a poor gas barrier. All these properties make LDPE a good choice of packaging material for minimally processed fruit and vegetable (Smith and Ramaswamy, 1996).

Moreover, reducing temperature increases the lag time leading to slow rate of reproduction of the microorganisms (Elliott and Michener, 1965).Further, reduced temperature lowers the respiration rate of the produce resulting slowing of physiological activities through supply of low energy (Kadar,1980). However, refrigerated conditions allow growing some pathogenic microorganisms resulting a health risk (Alzamora *et al*., 2000).

Experiments were therefore conducted to find out a suitable pre-treatment ,type and size of the package to be used for extending the shelf life of minimally processed carrot at 7±2 °C.

MATERIALS AND METHODS

Experiment 1 : Effect of pre-treatment on extending shelf life of the sliced carrot

Carrot was harvested from a commercial vegetable garden at Nuwara Eliya and transported to the laboratory on the same day. During transportation and harvesting, precautions were taken to minimize the physical damages and to avoid possible stress conditions. On the following day, carrots were washed three times using chlorinated tap water. Top and bottom part of each carrot roots was trimmed off and peeled using a sharp stainless steel peeler. Peèled carrot roots were dipped in 100 ppm chlorine solution for 5 minutes. The temperature of the chlorine solution was maintained at 8-15°C. After draining off of excess chlorine water , carrots were divided in to four equal groups. Each group of carrot was pre-treated with 1% citric acid solution, 1% ascorbic acid solution, and combination of 0.5 % citric acid and 0.5% ascorbic acid solution respectively. The treatment duration was 0.5min and temperature of the solution was maintained at 10-15°C. The remaining group was dipped in clean tap water(10-15°C) for the same duration and used as the control treatment. Each treated carrot group was allowed to drain off separately and cut into strips using a sharp stainless steal knife. Each strip was 3 cm in length,0.5 cm in width and 0.5 cm in height. Two hundred grams of sliced carrots from each treatment was packed in 100 guage, 15 cm x 15 cm, low density polyethylene (LDPE) bags and sealed using an electric impulse sealer. Excess gas in the bag was removed by gently pressing the bag with hand, before sealing. Sealed bags were immediately transferred into a refrigerator operated at 7±2 °C.

Fifteen such sealed packs of carrot were prepared from each pre-treatment. Five sealed bags from each treatment were randomly taken out for observations on 3rd ,5th and 7th day of the storage. At each sampling time, browning ,visual quality rating, % weight loss, softening index, total plate count and coliform count were recorded. Browning index was recorded using an index 1-4 where 1=<10 % browning and 4=>30 % browning (Sarananda *et al.*, 2003). Visual quality rating was recorded using an index;1=poor and 9=excellent (Kader *et al.*, 1973). The softening index used was 1=Hard, 2=Slightly soft, 3= Moderately soft and 4= Very soft. Total plate count was taken using pour plate method (SLSI 1991)and the coliform counts were taken by recording the number of colonies formed in MacConkey broth agar incubated at 35 °C for 7 days (SLSI 1991).

The statistical design used was completely randomized design with five replicates. Microbial counts were subjected to ANOVA and the F test was used to select the significant difference at 5 %. The rest of the parameters were analyzed using Kruskal-Wallis test in Minitab package. Sensory evaluation was conducted using ten trained taste panelists, for off adour development, flavour and overall acceptability using hedonic scale.

Experiment 2: Effect of the size of the package and citric acid pre-treatment on extending shelf life of minimally processed carrots

Freshly harvested carrots were brought to the laboratory, washed, trimmed, peeled and dipped in 100 ppm chlorine solution, as described in the experiment 1.Carrots were then treated with 1 % citric acid solution and sliced similar to that of experiment 1. Sliced carrots were packed in 15 cm x 12 cm, 15 cm x15 cm, 15 cm x 20 cm 100 gauge low density polyethylene (LDPE) bags, as each bag contained 200g of carrots and stored in a refrigerator (7±2 °C).

Fifteen such sealed bags from each packaging size were used for the experiment. The experimental design was completely randomized designing with five replications. Five packages from each treatment were randomly taken out for observations at 3rd ,5th and 7th day of storage. Percentage weight loss, browning, visual quality rating, softening index, total plate counts, Coliform counts and sensory evaluation were recorded as described in the previous experiment. Data analysis was also done similar to the experiment 1.

Experiment 3 : Measurement of modified atmosphere composition during storage of minimally processed carrots packed in LDPE.

Freshly harvested carrots were cleaned and washed with Clorox, and allowed to drain as described in the experiment 1. One half of the carrots were immersed in 1 % citric acid while the remaining half served as control. Citric acid treated carrots were sliced as described in the experiment 1 and 200 g was packed in LDPE (100 gauge) bags. Size of the package used was 15x 15cm. The remaining carrots were sliced and similarly packed in LDPE (100 Gauge). Twelve packages were sealed and stored in a refrigerator maintained at 7±2 °C. For gas analysis GC 9A Shimadzu Gas Chromatograph (Japan) was used. Using an air tight syringe, 0.3 ml of air was withdrawn from a pack and injected to the Poropack Q column having injector temperature 110 °C, oven at 90 °C ,flow rate 30 ml/min and thermal conductivity detector at 200 °C for CO_2 analysis. Molecular sieve column similar to above conditions was used to measure oxygen concentration during storage. These packages were used to measure gas concentration at each sampling time. Gas composition was recorded every 2 days interval starting from the first day of storage.

The statistical design used was completely randomized design and the mean separation was done using LSD 5 %.

RESULTS AND DISCUSSION

Experiment 1:Effect of pre-treatment on extending shelf life of the sliced carrot

No significant differences were recorded in percentage weight loss, browning index, softening index , visual quality rating of treated carrots and control samples during 7 days of storage (Figure 1, Table 1,2 and 3)

All the sensory parameters tested on minimally processed carrots were not significantly different among treatments at 5 % significant level. Significantly higher total plate counts were observed in 1 % citric acid and 1 %

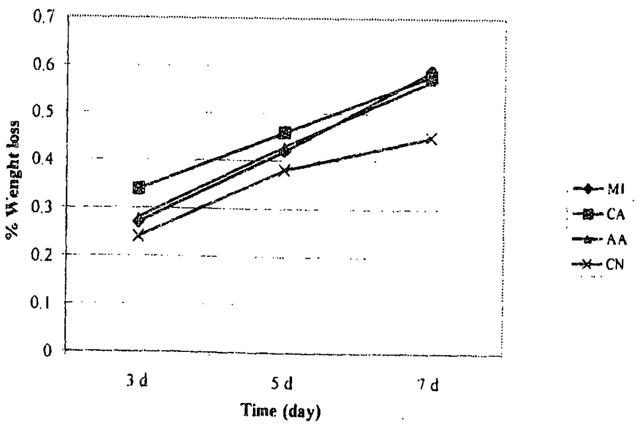

Figure 1:Percentage weight loss of minimally processed carrots during storage at 7 ±2 °C for 7 days

MI-0.5% Citric acid+0.5% Ascorbic acid
CA-1%Citric acid
AA-1%Ascorbic acid
CN-Control

Table 1:Mean browning index of carrot as affected by pre-treatment during the storage at 7±2 °C for 7 days

Treatment	3 day	5 day	7 day
0.5% Citric acid + 0.5% Ascorbic acid	1.0	1.0	1.0
1% Citric acid	1.0	1.0	1.0
1% Ascorbic acid	1.0	1.0	1.0
Control	1.0	1.0	1.0
P<0.05	NS	NS	NS

Browning Index: 1=1-10 % browning, 2=11-20 % browning,3=21-30 % browning, 4=31 % < browning

Table 2: Mean softening index of carrot as affected by pre-treatment during storage at 7±2 °C for 7 days.

Treatment	3 day	5 day	7day
0.5% Citric acid +0.5 % Ascorbic acid	1.00	1.33	1.50
1% Citric acid	1.00	1.50	1.67
1% Ascorbic acid	1.00	1.50	1.83
\Control	1.00	1.83	1.83
P<0.05	NS	NS	NS

Softening index: 1=Hard,2=Slightly soft, 3=Moderately soft, 4=Very soft

Table 3: Mean visual quality ratingcarrots as affected by pre-treatment during storage at 7+2 °C for 7 days.

Treatment	3 day	5 day	7 day
0.5% Citric acid +0.5% Ascorbic acid	9.0	8.6	7.3
1% Citric acid	9.0	8.7	7.2
1% Ascorbic acid	8.8	8.3	7.2
Control	9.0	8.2	7.2
P<0.05	NS	NS	NS

VQR: 1=not edible, 3= high defects can not be sold but edible, 5= moderate defect, 7= slight defect, 9= excellent (same as fresh)

Table 4 : Total plate counts and coliform counts of carrot as affected by pre-treatments during storage at 7 ± 2 °C for 7 days

Treatment	Total plate count Cfu/g	Coliform count cfu/g
0.5% Citric+0.5% Ascorbic	0.16×10^3 c	4.8×10^3 a
1% Citric acid	11.8×10^3 a	0.85×10^3 c
1% Ascorbic acid	3.0×10^3 b	1.7×10^3 b
Control	0.77×10^3 c	6.3×10^3 a

Treatment means in a column having a common letter(s) are not significantly different by DMRT 5%

ascorbic acid (Table 4). The minimum coliform counts were recorded in 1 % citric acid treated samples. The coliform counts of 1 % ascorbic acid and combined acid treatment were lower than that of control, but were higher than in 1 % citric acid.

Experiment 2:Effect of the size of the package and citric acid pre-treatment on extending shelf life of minimally processed carrots

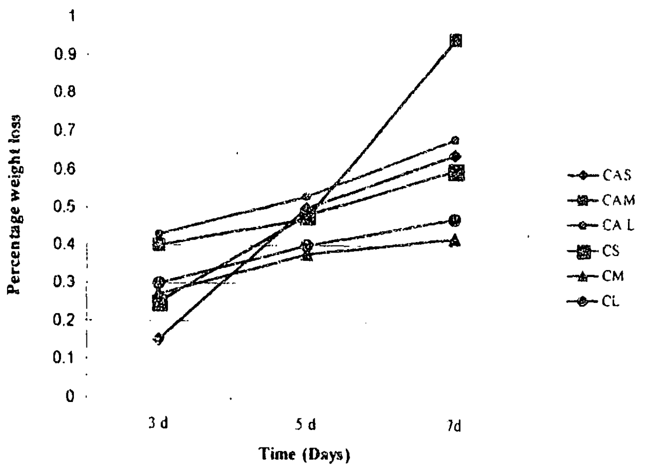

Figure 2: Variation of weight loss (%) as affected by package size

CAS-Citric acid treated small size (12x25cm2) packages, CAM-Citric acid treated medium size (15x15 cm^2) packages, CAL-Citric acid treated large size (15 x 20 cm^2) Packages, CS-Control small size (12x25cm^2) Packages,CM-Control medium size(15x15cm^2) Packages,CL-Control large size (15x20cm^2) packages

No significant difference in weight loss was observed with pre-treatments and size of the packaging used to create modified atmosphere (Figure 2).Very low percentage weight loss was observed in all treatments (less than 1% even at 7 days of storage.

No significant differences in browning among treatments were observed even at 7th day of storage (Table 5).Similarly no significant difference in VQR was observed at each sampling time.

No significant difference of softning index and whitening index were observed in minimally precessed carrot during storage at 7+2 °C for 7 days (Table 6).

Total plate counts of carrot packed in 15x20 cm^2 were significantly higher than rest of the treatments irrespective of pre-treatment (Table 7). The minimum levels of coliform counts were recorded in 12x15 cm^2 and 15x15 cm^2 packages, which were treated with 1 % citric acid.

Sensory evaluation also confirmed that, there was no significant difference among minimally processed carrots as affected by different packaging sizes, for observed sensory characteristics such as off odour, taste and overall acceptability (data not shown).

Experiment 3: Measurement of modified atmospheric composition during storage of minimally processed carrots packed in LDPE

A rapid reduction of oxygen and increased level of carbon dioxide in all packages at 1 day after sealing was observed (Table 8). Significantly higher levels of O_2 and CO_2 were recorded in citric acid pre-treated samples at day 5 and 7, compared to those of controls.

Weight loss of carrot stored in sealed LDPE at 7+2 °C would have created a minimum vapour pressure deficit resulting in very low levels of moisture loss. Similar results observed in minimally processed Cactus confirm the observation of this experiment (Piga *et al.*,

Table 5: Mean browning index and visual quality ratings of minimally processed carrots as affected by the package size and citric acid pre-treatment

Treatment	Size	Browning index (BI)			Visual Quality Ratings		
Package		3rd day	5th day	7th day	3rd day	5th day	7th day
CA	12x25cm^2	1.00	1.00	1.00	8.67	7.16	6.17
	15x15cm^2	1.00	1.00	1.33	8.83	6.17	5.50
	15x20cm^2	1.00	1.00	1.33	8.33	7.16	5.50
Control	12x25cm^2	1.00	1.00	1.00	8.33	7.33	6.83
	15x15cm^2	1.00	1.00	1.00	8.67	8.17	7.33
	15x20cm^2	1.00	1.00	1.00	7.67	7.16	6.83
P<0.05		NS	NS	NS	NS	NS	NS

CA-citric acid
Browning Index: 1=1-10% browning, 2=11-20% browning, 3=21-30% browning, 4=31%<browning
VQR: 1=not edible, 3=high defect can not be sold but edible, 5=moderate defect, 7=slight defect, 9=excellent(same as fresh)

Table6: Mean softening index and Whitening index of minimally processed carrots during 7 days of storage at 7+2°C temperature as affected by the package size and the citric acid pre-treatment.

Treatment	Size	Softening index (SI)			Whitenening index (WI)		
Package		3rd day	5th day	7th day	3rd day	5th day	7th day
CA	12x25cm^2	1.17	1.83	2.50	1.00	1.33	1.33
	15x15cm^2	1.00	1.17	2.00	1.00	1.00	1.00
	15x20cm^2	1.17	1.67	2.33	1.00	1.33	1.66
Control	12x25cm^2	1.67	1.83	2.00	1.00	1.00	1.00
	15x15cm^2	1.00	1.17	1.83	1.00	1.00	1.00
	15x20cm^2	1.83	2.00	2.00	1.00	1.33	1.33
P<0.05		NS	NS	NS	NS	NS	NS

Softening index: 1=soft, 2=moderately soft, 3=slightly soft, 4=hard.
Whitening index: 1=1-10% whitening, 2=11-20% whitening, 3=21-30% whitening, 4=over 31% whitening

2000). Browning in carrot is probably related to oxidation of phenols (Chubey and Nylund, 1969). No browning observed in all treatments indicated that pre-treatments had no effect on browning of carrot. Generally, carrot shows lesser incidence of browning. That would have been further restricted due to low oxygen in all sealed bags.

Modified atmosphere (low oxygen and high carbon dioxide) developed in sealed packages would have retarded the rate of respiration of sliced carrot extending the shelf life for up to 7 days. Based on VQR and softening indexes no significant differences were recorded among treatments when LDPE was used. This shows the modified atmosphere generated in all bags together with low temperature would have extended the shelf life of minimally processed

Table 7: Microbial counts of minimally processed carrots as affected by the package size and citric acid pre-treatment.

Treatment	Package Size	Total plate count (Cfu/g)	Coliform count (Cfu/g)
CA	15 x 12m^2	2.6×10^4b	0.4×10^3c
	15 x 15cm^2	0.3×10^4c	0.3×10^3c
	15 x 20cm^2	4.6×10^4a	4.1×10^3a
Control	15 x 12cm^2	0.5×10^4c	4.9×10^3a
	15 x 15cm^2	0.2×10^4c	2.1×10^3b
	15 x 20cm^2	3.4×10^4a	4.8×10^3a

Treatment means in a column having a common letter(s) are not significantly different at DMRT 5%.

carrots.

Total plate count of a sample gives an indication of the cleanliness of the process used during preparation. Although citric acid showed the highest total plate count the values recorded were at very low levels. However, the minimum level of coliform count was observed in carrot pre-treated with 1% citric acid. Acidity together with low temperature would have created unfavorable environment for growth of coliform. Similar observations reported for minimally processed catus pear fruit confirm the results observed in this experiment (Piga *et al.*, 2000). On the other hand, the higher levels of total plate count of the same treatment may be due to favourable condition for the growth of aciduric bacteria. Nguyen and Colin (2000) recorded that; there was a comparatively high proportion of lactic acid bacteria and yeast found in some minimally processed products. It was also reported that, 10^6 Cfu/g for shredded carrots by Manzanno *et al.*, 1995 (Cited by Nguyen and Colin, 2000).

Size of the package used to create modified atmosphere did not affect the quality parameters tested during storage period for 7 days. However, both total plate count and coliform count showed minimum values with 15x15 cm^2. This may be due to unfavourable gas composition developed in that package compared to those developed in other two sizes. Since ,MA gas composition was measured only in 15x15 cm^2 a comparison is not possible.

No bloating observed in all packages together with gas composition analyzed in 15x15cm^2 bags showed no anaerobic respiration has taken place. In addition, citric acid pre-treated packages were vacuumed automatically at the latter part of the storage. The reasons for evacuation of gases inside the package are not known.

The results showed that use of citric acid, as a pre-treatment did not give benefical effect as far as the tested quality parameters are concerned. The similar results have been reported for lettuce where no addition shelf life

Table 8: Gas composition of minimally processed carrot during storage as affected by pre-treatment.

Treatment	Day 1		Day 3		Day 5		Day 7	
	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2
Cont/LDPE	6.1a	10.22a	1.67a	14.89b	4.55b	13.22b	4.58b	6.35b
CA/LDPE	4.00a	11.9a	1.71a	18.80a	15.2a	17.73a	12.9a	12.33a
CV%	12.1	16.2	18.3	12.6	9.6	17.3	15.6	17.6

Treatment means within a column having a common letter(s) are not significantly different at LSD 5%..

extension was obtained with the treatments of sulfite, chlorine and calcium phosphate (Bolin *et al.*,1977 and Priepke *et al.*, 1976). Microbial population of carrot was maintained at low levels during storage. Since carrot comes in contact with soil, if proper hygienic practices are not followed, excessive levels of microbial population would have been expected due to presence of natural flora. Sanitation of the product and all surfaces such as processing equipments and packaging materials will reduce the potential microbial growth (King and Bolin, 1989).

When Carrots are harvested at optimum stage of maturity and washed with water and again washed with chlorinated water, the surface microbial population can be reduced to a lower level, which do not allow the pathogens to multiply and build up at higher levels during the storage. In addition, sliced Carrots enclosing in sealed LDPE, 100 gauge bags create an ideal modified atmosphere to extend the shelf life of sliced carrots. If proper hygienic practices and proper package size are chosen and stored at 7^0 C, shelf life of the carrot can be extended up to seven days.

The first and second experiments were repeated 3 times and the same results were recorded. The same experiment was again repeated using carrot purchased from the local market, which have been handled and transported under local conditions. Although the source of supply was different, similar response for the technology was observed. The technology can therefore be adopted to produce minimally processed carrot commercially.

CONCLUSION

Washed ,peeled and repeated wash with 100ppm Chlorox, carrot can successfully be minimally processed when sliced pieces were sealed in 15x15 cm^2, 100 gauge LDPE, stored at 7±2°C. Freshness of carrot can be maintained up to 7 days having a minimum level of coliform providing a consumer safe product.

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