review with 1960, knowing that most of you are familiar with publications in the more recent years. The literature in the Proceedings for these early years was extremely interesting. Papers I have discussed in no way are the only important developments reported in the Proceedings during this period; they are only some of the important developments. I apologize to the many authors and papers which I did not have the time to cite. The Florida State Horticultural Society Processing Section in 1960 became the Florida State Horticultural Society Handling and Processing Section.

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STABILITY OF PREPARED CARROT STICKS IN STORAGE

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Abstract. **The market for prepared carrot sticks and other deli items would be greatly expanded if quality retention could be extended in storage. The limitation to extended shelf life for carrot sticks includes microbial deterioration and the consequences of slicing and exposure of the cut surface to air. Accelerated senescence is a major consequence of slicing which results in loss of flavor, discoloration, and loss of turgidity. Antimicrobials, antioxidants and cellular constituents were vacuum infused into carrot sticks, shrink packed in oxygen transmissible bags and stored at 2°C. Ascorbic and citric acids combined and calcium chloride singly, adversely affected flavor but not color or microbial population after 2 weeks storage. Glucose, pyruvate, and lecithin treated carrot sticks stored as well as untreated stored and freshly prepared carrots in terms of flavor, but glucose treated samples had higher microbial count and distinguishable color from freshly prepared control carrot sticks. All treatments increased resistance to sheer. The results suggest that vacuum infusion has promise as a technology for intimately contacting carrot tissue with agents to preserve quality in storage.**

Fresh immature or partially mature carrots (*Daucus carota* L.) can be stored for 4 to 6 weeks at 0°C and retain fresh flavor and appearance (4). However, after processed into carrot sticks, storage in vacuum shrink bags is limited to 2 weeks for acceptable flavor and appearance (Kent Shoemaker, personal communication). The major markets for prepared carrot sticks are restaurants with salad bars, and delicatessens; but if quality retention in carrot sticks can be extended in storage, supermarkets and other produce outlets will greatly increase the demand. The limitations to extended shelf life for carrot sticks include microbial deterioration and the consequences of slicing and exposure of the cut surface to air. Accelerated senescence is a major consequence of slicing to prepare carrot sticks, which results in loss of flavor, discoloration, and change in texture. Retarding microbial development and senescence would extend the shelf life of carrot sticks and open up new markets for the product.

Compounds were examined for their effectiveness in extending shelf life of carrot sticks. Citric and ascorbic acids are effective antimicrobial and antioxidant agents in foods (3) and calcium chloride slows down senescence in fruits and vegetables (9, 13). Lecithin is an important constituent of cell membranes (10) and glucose and pyruvate are normal metabolites in the carrot. The effect of these materials on taste, color, texture and microbial population of carrot sticks in storage was determined.

Materials and Methods

Carrots were commercial Emperato type obtained in 50-lb bags from Zellwin Farms, Zellwood, FL. They were stored at 2°C until processed, but not longer than 2 weeks. The carrots were placed in cold 1% solution of sodium hypochlorite for 30 minutes before they were peeled by hand. Carrot sticks (3/8" X 2") were prepared with a Hobart (Model PD 70) power unit with dicer attachment. Carrot sticks were infused with solutes in sterile solutions by evacuating air from the sticks submerged in the solutions in vacuum oven at 50 mnm Hg. The vacuum was held for 5 minutes before being slowly released. Approximately 10% of the weight of the carrot sticks was infused with the solutions. About 300g of carrot sticks were packaged in each Cryovac E bag (20 X 40 cm, 2 mil thick; O_2 transmission: 4000 cc per m^2 at 20°C, 1 atm and 24 hrs). The bags were evacuated with a Model 750 B Piab vacuum pump and sealed with a Model 12A Sentinel heat sealer. The packaged carrots were stored at 2°C and 90% RH.

Taste preference. A panel of twenty tasters were submitted three samples of carrot juice to be ranked for preference, using scores of 1 for best liked, 2 for next best, and 3 for least liked. The juice was prepared from carrot sticks by blending with equal weight of deionized water which was served to the panel at room temperature. Ranked sums were used to determine significance of difference between samples (7). In the first experiment carrot sticks infused with three levels of solutes were evaluated by the panel. The following solutes in solution were infused: 0.05, 0.01 and 0.002% citric and ascorbic acids, 0.01, 0.002, and 0.0004% calcium chloride, 0.005, 0.001, and 0.0002% sodium pyruvate, 0.1, 0.02 and 0.004% lecithin and 2, 0.7 and 0.2% glucose. In the second experiment carrot sticks stored after infusion with one level of solute were taste tested with an untreated stored package of carrot sticks and freshly prepared carrot sticks.

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Pyruvate decarboxylase. Extracts of carrots were prepared using a modification of the procedure of Roe et al. (11). Peeled sliced carrots (20 g) were homogenized in 20 ml 0.05 M Tris, pH 7.2 at 4°C. The homogenate was strained through two layers of cheesecloth and centrifuged at 10,000X g for 15 min. The supernatant was saturated with solid $(NH_4)_2SO_4$' equilibrated for 2 hrs at 4°C and centrifuged at 15,000X g for 15 min. The pellet was dialyzed against H_2O at 4°C overnight. The resulting suspension was centrifuged at 15,000X g for 15 min. The clear supernatant was assayed for pyruvate decarboxlyase activity by modification of the procedure of Holzer et al. (5).

Color. The color (tristimulus value) of the carrot juice served to the panel of tasters was measured in a Hunter Lab Color-Difference Meter (Model D 45D2). The values for X, Y, and Z of the various treatments were compared to the values for fresh cut carrot sticks to obtain the NBS unit standard of color difference, Δ E, for each treatment (6).

Texture. Texture of the carrot sticks was determined as resistance to stress using the Allo-Kramer Shear-Compression-Cell and the Instron Universal Testing Instrument, Model 1101 as described by Bourne (2). Individual carrot sticks were placed in the cell. Results are presented as the average of six replications and are expressed as lb force per 1" thick sample.

Microbial analysis. Carrot stick samples for analysis were blended with 0.1% peptone asceptically to give a 10^{-1} dilution. Further decimal dilutions were prepared also using 0.1% peptone. The microbial population was assessed by the Pour Plate method (12) with standard methods agar (Tryptone-glucose-yeast extract). After 5 days incubation at 25°C the plates were examined and the number of colonies counted.

Table 1. Preference scores for stored carrot sticks.

Treatment	Ranked sums after storage for[z] 5 d	10 d	14 d	28 d
Citric plus ascorbic acids				
0.05% each	—	—	40	43
0.01% each	—	—	42	34
0.002% each	—	—	38	43
Calcium chloride				
0.01%	—	—	45	39
0.002%	—	—	39	43
0.004%	—	—	36	38
Glucose				
2.0%	39 33	36 34	36 44	—
0.7%	45 49	40 44	42 40	—
0.2%	36 38	44 42	42 36	—
Sodium pyruvate				
0.005%	41 31	36 47	44	—
0.001%	32 45	45 36	39	—
0.0002%	47 34	39 37	37	—
Lecithin				
0.1%	43	—	41	—
0.02%	38	—	34	—
0.004%	39	—	45	—

[z]Panel of 20 tasters ranked 3 samples: 1 (best liked), 2 (next best), and 3 (least liked). Significant differences between ranked sums ($P < 0.01$): 50 or higher, 30 or lower (ref. 7).

Results and Discussion

Taste preference. The taste panel showed no preference for a specific level of solute in carrot sticks stored up to 14 days (Table 1). No preference was indicated for a specific level when carrot sticks were infused with three levels of citric plus ascorbic acids or three levels of calcium chloride and stored for 28 days. Results of these taste tests indicate that the levels of solute selected for these experiments would not adversely affect the preference test.

The taste panel preferred fresh unstored carrot sticks over carrot sticks infused with 0.01% citric acid plus 0.01% ascorbic acid when stored for 3, 10 or 14 days (Table 2). They also preferred fresh to stored carrot sticks infused with 0.02% $CaCl_2$. In both cases the difference was highly significant ($P < 0.01$).

Citric-ascorbic acids in solution have been used as dips of fruits and vegetables to protect them from browning during storage (3). However, infiltration into the carrot changed the flavor and resulted in a lower preference value in these experiments. Calcium salt solutions are used commercially as dips and infusates for protecting apples from flavor and textural deterioration in storage (8). In our experiments calcium chloride infusion detracted from the flavor and lowered their preference compared to untreated stored control and freshly cut carrot sticks.

Infusion of 0.7% glucose, 0.001% sodium pyruvate or 0.02% lecithin into carrot sticks and then stored up to 14 days did not affect preference when ranked with fresh and untreated stored carrot sticks (Table 2).

Glucose was expected to sweeten the carrot sticks and influence taste preference. However, no significant difference between glucose treated and untreated carrot sticks was detected by the taste panel.

Pyruvate decarboxylase activity was assayed in fresh carrot. Activity was found to be equivalent to the formation of 50 ng of acetaldehyde per minute per gram of carrot at saturation levels of sodium pyruvate. Since acetaldehyde contributes to the flavor of fresh fruit and vegetables it was expected that infusion of pyruvate would improve the flavor of stored carrot sticks. However, no significant dif-

Table 2. Preference scores for stored carrot sticks.

Treatment	Ranked sums after storage for[z] 3 d	6 d	10 d	14 d
0.01% Citric acid plus 0.01% ascorbic acid	56	—	50	52
Untreated stored	36	—	40	38
Fresh	29	—	30	30
0.002% $CaCl_2$	—	56	—	53
Untreated stored	—	38	—	40
Fresh	—	26	—	27
0.7% Glucose	39	42	38 46	45 46
Untreated stored	34	46	41 35	40 42
Fresh	47	32	41 39	35 32
0.001% Sodium pyruvate	37	43	45	49 44
Untreated stored	40	40	37	35 40
Fresh	43	37	38	36 36
0.02% Lecithin	44	—	40	38
Untreated stored	41	—	45	35
Fresh	35	—	35	47

[z]Panel of 20 tasters ranked 3 samples: 1 (best liked) 2, and 3 (least liked). Significant difference between ranked sums: ($P < 0.01$) 50 or higher, 30 or lower (ref 7).

Table 3. Color change in carrot sticks in storage.

Treatment	Δ E[z]
1. Glucose	2.12 ± 0.18
2. Calcium chloride	0.87 ± 0.10
3. Pyruvate	0.78 ± 0.08
4. Citric & ascorbic acids	0.48 ± 0.07
5. None	0.45 ± 0.05
6. Lecithin	0.27 ± 0.04

[z]Δ E, NBS unit standard of color difference. Values, relative to color of whole carrots in storage, are means and standard deviations of four to eight samples.

ference between pyruvate treated and untreated carrot sticks was detected by the taste panel.

Lecithin is a major lipid in carrot and is lowered during extended storage (1). However, no significant difference between lecithin treated and untreated carrot sticks was detected by the taste panel.

Color. Differences in color between carrot sticks infused with protectants and freshly prepared from whole carrots in storage were not perceptible with the eye and slightly preceptible with the spectrophotometer. Only one Δ E value (Table 3) exceeded 1.0, the recognized limit of perception (6). Values in Table 3 for each treatment are means of readings for three concentrations and multiple storage periods. The values were combined because the variation between values for concentration and storage period was not regular to distinguish an effect from either on color.

Texture. Vacuum infusion of all the test substances increased the relative resistance to shear of the stored carrot sticks, compared to freshly prepared and untreated stored controls (Table 4). The higher value for the fresh control at 3 weeks may be explained by partial dehydration of the whole carrot in storage. The values for treated carrot sticks were consistently high over the storage period, suggesting that the texture of the sticks is not greatly affected by storage at 2°C.

Microbial population. Sodium hypochlorite at 1% was an effective sanitizing dip for carrots. Soaking carrots for 30 minutes in the solution reduced the microbial load on sticks prepared from them to about $1X10^3$ colony forming orgainisms per gram (Table 5). Composition of the infusate affected the microbial population in carrot sticks. Plate counts were recorded for three concentrations of each solute but differences were small so only the average is shown. Calcium chloride, sodium pyruvate, citric and ascorbic acids and lecithin infusion reduced the count compared to the untreated control carrot sticks, whereas glucose treatment increased the count compared to no treatment. No attempt was made to identify the microorganisms.

Table 4. Texture of stored carrot sticks.

Treatment	Relative shear force (lb/in) after storage[z]		
	1 week	2 weeks	3 weeks
Fresh control	370±50	365±51	517±62
Stored control	372±48	321±42	347±52
Calcium chloride (0.01%)	516±76	497±43	502±67
Citric & ascorbic acids (0.01%)	513±70	518±59	611±71
Sodium pyruvate (0.005%)	400±43	619±68	535±58
Lecithin (0.2%)	437±70	642±71	523±63
Glucose (2.0%)	402±41	427±63	367±39

[z]Mean values of 6 replications ± standard deviation.

Table 5. Microbial population on carrot sticks after 10 day storage at 2°C.

Infused solution	Plate count[z] 10^3 colonies/g carrot
Glucose	40 ± 5
Sodium pyruvate	6 ± 0.4
Citric & ascorbic acids	2 ± 0.2
Calcium chloride	0.3 ± 0.05
Glucose	4 ± 0.5
Sodium pyruvate	0.6 ± 0.04
Lecithin	0.07 ± 0.01
None	1 ± 0.2

[z]Average of 3 plates each of 3 samples.

Conclusion

Carrot sticks vacuum infused with sodium pyruvate, lecithin or glucose and stored two weeks at 2°C retained flavor as well as freshly prepared carrot sticks. The presence of lecithin and pyruvate had no adverse effect on color or microbial population of the carrot sticks in storage, but glucose slightly affected these quality parameters. Citric with ascorbic acid and calcium chloride treatments affected carrot flavor adversely after one to two week storage but color and microbial population were not afftected. The data suggest that vacuum infusion is a useful technique for intimately contacting carrot tissue with agents to preserve quality in storage. A combination of substances examined in this report should be tested for possible effect on extending shelf life of carrot sticks.

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