Carrot Juice Color, Carotenoids, and Nonstarchy Polysaccharides as Affected by Processing Conditions

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ABSTRACT

Effects of processing variables on color, α- and β-carotenes, and nonstarchy polysaccharides (NSP) of carrot juice products were investigated. Unblanched carrots produced the highest amounts of juice and lowest amounts of pulp. Compared to color of fresh juice, canned juice from acetic acid-blanched carrots retained redness best, and juice from unblanched carrots retained the least. Juice products from unblanched carrots retained highest total carotenes. Retorting, concentrating, and freeze-drying partly reduced juice product carotenes. In most cases, the reduced amounts from various processing methods were greater for β-carotene than for α-carotene. NSP contents of juice products ranged from 1.1 to 1.5%.

Key Words: carrot juice, carotenes, polysaccharides

INTRODUCTION

ALPHA- AND BETA-CAROTENES are precursors of vitamin A. Carrots (*Daucus carota* L.) have the highest carotene content among human foods and are consumed in large quantities (Khan et al., 1975). Much of the vitamin A in the human diet comes from vegetables, such as carrots, and fruits that contain considerable amounts of carotenes (Simpson, 1983). In the U.S., carrots are a principal vegetable crop, contributing 14% of the total vitamin A consumption (Senti and Rizek, 1975; Simon and Wolff, 1987). Beta-carotene accounts for more than half the total vitamin A contribution (Umiel and Gabelman, 1971).

Large quantities of carrots are discarded yearly because they do not meet physical standards for fresh markets. Such carrots are of good nutritional quality and could be used to make carrot beverage products and fiber products, which could be supplied year-round. Products such as carrot juice are popular (Lombrana and Dias, 1985). Therefore, developing carrot juice and pulp products to meet market standards and to preserve nutrients is important.

Canned carrot juice is a low-acid food requiring high-temperature heat processes to kill bacterial spores. Although high temperature could cause a coagulum to form in the juice, Stephens et al. (1971, 1976) found that juice extracted from carrots blanched in 0.05N acetic acid did not form a coagulum and maintained good color and flavor. High temperatures, especially retorting temperatures could destroy carotenoids in carrots (Khan et al., 1975; Kim and Gerber, 1988). Canned carrot juice contains significantly lower carotene than homemade or frozen juice (Jun, 1987).

Processing effects on total carotenoids in carrots have been reported (Khan et al., 1975; Kim and Gerber, 1988; Park, 1987; Jun, 1987). However, the effect on α- and β-carotenes has not been reported. Most studies used spectrophotometric methods to determine total carotenes. The nonstarchy polysaccharides in the juice have not been reported. Our objective was to investigate effects of blanching, juicing, and canning on juice color, α- and β-carotenes, and nonstarchy polysaccharides in carrot juice products.

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MATERIALS & METHODS

Production of carrot products

Raw carrots (Emperador cultivar, Dole brand, Dole Fresh Vegetables, Inc., Salinas, CA) were used. Juice was extracted according to the method of Stephens et al. (1976). Duplicate 11.5 kg quantities of washed and trimmed carrots were heated for 5 min in 30L of boiling distilled water or boiling 0.05N acetic acid solution, thoroughly drained, and ground through a Champion juicer (Plastaket Manufacturing Co., Lodi, CA) equipped with a stainless steel screen with alternating round openings (0.5 mm diameter). The juice was further filtered through a hand-held screen to remove precipitated residues. The pH of juice from acetic acid-treated carrots was adjusted with 10N NaOH to that of juice from water-blanched carrots. The boiling water-blanched juice was adjusted with table salt to contain 0.33% NaCl.

Juices from boiling water and acetic acid-blanched carrots were heated to 82°C, transferred immediately into 303 × 406 metal cans, and sealed. Juice from unblanched carrots was used as control. After juicing unblanched carrots, salt was added to obtain 0.33% NaCl and heated to 82°C for 5 min; cans were filled immediately and sealed. All sealed cans of juice were retorted at 115.6°C or 121.1°C for 25 min or 10 min, respectively. Both retorting conditions gave a sterilization value (F_o) of 3.

Concentrated juice was made from the fresh juice by rotary evaporation at 40 to 50°C until the weight of concentrated juice was one-third the weight of original fresh juice. Freeze-dried juice was produced from concentrated juice by freeze-drying until juice moisture was below 10%. All samples were analyzed in duplicate.

Physical and chemical analysis

Moisture and solid contents of carrot products (carrot, juice and pulp) were measured using a vacuum oven method (AOAC, 1990. Method 930.06). Surface color was measured with a Gardner Model XL23 Tristimulus Colorimeter equipped with a reflection optical system. The colorimeter was standardized, using a white tile ($L = 91.94$, $a_L = -1.03$, $b_L = 1.14$). Alpha- and beta-carotene contents of carrot juice products were analyzed, using high performance liquid chromatography (HPLC) (Bushway, 1985; Bao and Chang, 1994). Retention of carotenes in carrot juice products was calculated as percent carotenes in the original fresh carrots. Nonstarchy polysaccharides (NSP) of carrot juice products were analyzed using the method of Englyst and Cummings (1988).

Analysis of variance and means among the samples prepared by various methods were performed, using the SAS program (SAS/STAT User's Guide, 1990). Duncan's multiple range test was used to determine significant differences ($p < 0.05$).

RESULTS & DISCUSSION

Effect of blanching on fresh carrot juice yield

Effects of blanching on carrot juice yield and pulp were compared with yields from unblanched carrots (Table 1). Fresh juice yield from unblanched carrots was 67.8%, higher than the yield from those blanched in water or 0.05 N acetic acid, (48.1% and 51.7%, respectively, $p < 0.05$). Juice from unblanched carrots also contained more dry matter than that from carrot samples; juiced after blanching. Texture of whole carrots became soft after blanching, making juice extraction through the stainless steel screen more difficult. This was also reported by Sims et al. (1993).

Table 1—Effect of blanching on yield (%) of fresh carrot juice[a-c]

	Unblanched[d]	Water-blanched[e]	Acetic acid-blanched[f]
Wet weight basis			
Juice	67.8 (0.2)[a]	48.1 (1.2)[b]	51.7 (3.8)[b]
Pulp	28.7 (0.7)[b]	43.7 (0.6)[a]	40.1 (4.5)[a]
Loss	3.5 (0.6)[b]	8.2 (0.6)[a]	8.2 (0.7)[a]
Dry weight basis			
Juice	56.3 (0.7)[a]	40.9 (0)[c]	44.8 (0.2)[b]
Pulp	43.7 (0.5)[c]	57.3 (0.5)[a]	49.6 (2.3)[b]
Loss	0[b]	1.8 (0.9)[b]	5.6 (0.5)[a]

[a-c] Means (± standard deviation) in each row followed by a different letter were not the same ($p < 0.05$).
[d] from unblanched carrots.
[e] from water-blanched carrots.
[f] from acetic acid-blanched carrots.

Table 2—Effect of blanching and canning on pH of carrot juice products[a-c]

	Unblanched[d]	Water-blanched[e]	Acetic acid-blanched[f]
Canned juice (115.6 °C/25 min)			
Before canning	6.22 (0.02)[a(a)]	6.18 (0.01)[a(b)]	5.90 (0.01)[a(b)]
After canning	5.93 (0.02)[b(a)]	5.62 (0.04)[b(b)]	5.54 (0.01)[b(c)]
Canned juice (121.1 °C/10 min)			
Before canning	6.22 (0.02)[a(a)]	6.18 (0.01)[a(b)]	5.90 (0.01)[a(b)]
After canning	5.95 (0.01)[b(a)]	5.47 (0.04)[b(b)]	5.55 (0.01)[b(b)]
Concentrated juice			
Before canning	6.04 (0.04)[b(a)]	5.81 (0.01)[a(c)]	5.94 (9.01)[a(b)]
After canning	6.24 (0.01)[a(a)]	5.81 (0.01)[a(c)]	6.03 (0.09)[a(b)]

[a-c] Means (± standard deviation) within each product group in each column followed by a different letter were not the same ($p < 0.05$). Means in each row followed by a different letter in parentheses were not the same ($p < 0.05$).
[d] from unblanched carrots.
[e] from water-blanched carrots.
[f] from acetic acid-blanched carrots.

Table 3—Effect of processing on color of carrot juice products[a-c]

	L value	a_L value	b_L value
Fresh juice			
Unblanched[d]	43.8 (0.3)[c]	34.7 (0.4)[b]	26.7 (0.1)[c]
Blanched (water)[e]	45.2 (0)[b]	38.4 (0.1)[a]	27.9 (0)[b]
Blanched (HOAc)[f]	46.7 (0.1)[a]	38.5 (0.1)[a]	29.2 (0.1)[a]
Canned juice (115.6 C/25 min)			
Unblanched[d]	38.1 (0.2)[c]	33.1 (0.2)[c]	24.3 (0.1)[c]
Blanched (water)[c]	42.2 (0.1)[b]	36.5 (0.1)[b]	26.7 (0.1)[b]
Blanched (HOAc)[f]	44.8 (0)[a]	37.4 (0.1)[a]	27.9 (0)[a]
Canned juice (121.1 C/10 min)			
Unblanched[d]	36.8 (0.3)[c]	28.6 (0.3)[b]	23.1 (0.1)[c]
Blanched (water)[e]	43.3 (0.1)[b]	35.8 (0.1)[a]	26.3 (0.1)[b]
Blanched (HOAc)[f]	44.6 (0)[a]	36.2 (0.2)[a]	27.7 (0.1)[a]
Concentrated juice			
Unblanched[d]	37.7 (0.1)[b]	32.5 (0.1)[c]	23.3 (0.1)[b]
Blanched (water)[e]	44.6 (0)[a]	36.1 (0.5)[a]	26.4 (0.2)[a]
Blanched (HOAc)[f]	43.7 (0.8)[a]	34.8 (0.3)[b]	26.1 (0.4)[a]

[a-c] Means (± standard deviation) within each product group in each column followed by a different letter were not the same ($p < 0.05$).
[d] from unblanched carrots.
[e] from water-blanched carrots.
[f] from acetic acid-blanched carrots.

Acetic acid-blanched carrots produced a similar amount of juice to that of the water-blanched carrots. However, juice from acetic acid-blanched carrots retained more ($p < 0.05$) dry matter than that from water-blanched carrots (Table 1). Stephens et al. (1971) reported an increase of 3.3% yield in fresh juice from carrots heated in acetic acid compared to juice from carrots heated in water.

Effects of blanching and canning on pH

Carrot juice is a low-acid vegetable juice with pH ≈6.1. High-temperature heating processes are required to achieve commercial sterility in low-acid canned foods. Thermal processing required for canned carrots has been reported to result in undesirable changes in color, texture, and flavor (Kim and Gerber, 1988). The effects of blanching and canning on pH of carrot juice products were compared (Table 2).

All pH values of juice products from blanched carrots were lower than those of juice products from unblanched carrots ($p < 0.05$). Because acetic acid was used to blanch experimental carrots, we investigated the effect of acetic acid treatment on juice pH. The pH values of canned carrot juice from blanched carrots decreased more than that of the juice from unblanched carrots after canning, 0.3 to 0.5 vs 0.2 (the difference between pH values of juice before and after canning), regardless of retorting temperature.

The pH value of concentrated juice from unblanched carrots increased 0.2 unit after canning. However, pH values of concentrated juice from blanched carrots remained unchanged. Bates and Koburger (1974) reported that juice from carrots blanched at 100°C for 5 min were pH 6.2, similar to our results. The decrease in pH among canned carrot juices of three treatments was probably due to heat decomposition of pectic substances to pectic acid and the absorption of acetic acid by carrots which decreases juice products (Stephens et al., 1971). The small decrease in pH was not enough to protect against microbial growth. Foods with pH 4.5 or higher are categorized as low-acid foods and require adequate heat treatment to achieve commercial sterility.

Effect of blanching on carrot product color

With carrots, carotenes contribute to product color and are partly converted into vitamin A during human digestion. Enzymatic discoloration through phenolases or lipoxygenase, and nonenzymatic browning reactions during processing also affected color of the products.

Effects of blanching and concentration on the color of carrot juice products (Table 3) showed all products produced from blanched carrots had greater redness (a_L) and yellowness (b_L) than those from unblanched carrots. Blanching inactivates enzymes, such as pectinesterase, which may decrease methoxyl content (degree of esterification) of pectin molecules to make them more sensitive to crosslinking with calcium ions. Sims et al. (1993) reported pectin with low esterification would co-precipitate with carotenes to affect color quality of carrot juice. They also reported that Hunter redness and yellowness color values of carrot juice were increased by blanching.

After retorting carrot juices at 115.6°C, juice from acetic acid-blanched carrots had a higher a_L value than that from water-blanched carrots. However, the red color values of both blanched juice products retorted at 121.1C were not significantly different ($p > 0.05$).

Effects of processing on carotene retention

Within each product group, blanching reduced retention of carotenes (Table 4). Fresh carrot juice from unblanched carrots had highest carotene retention. Fresh juice from water- and acetic acid-blanched carrots had lower carotene retention. This was partly because unblanched juice had the highest yields (Table 1).

When the sum of retentions of carotenes in fresh juice and in pulp (Bao and Chang, 1994) was subtracted from total carotenes in fresh carrots, we found the juicing resulted in a loss of 23.5% of the total carotenes in the unblanched carrot samples. Since carrots were juiced after blanching, losses for water-blanched and acid-blanched carrots due to juicing were not known. However, water-blanching seemed to provide protection against loss of carotenes, since only 15.7% of carotenes were lost in the combination process of blanching and juicing. However, acid-blanching did not protect against loss of carotenes during juicing since 26% of carotenes were lost.

Table 4—Effect of Processing on Carotene Retention in Carrot Juice Products[a-c]

Carrot product	Alpha-carotene		Beta-carotene		Alpha- + Beta-carotenes	
	Mg/100 g (dry wt)	Retention[d] (%)	mg/100 g (dry wt)	Retention[d] (%)	mg/100 g (dry wt)	Retention[d] (%)
Fresh carrot	43.3 (1.1)		133.4 (3.7)		176.7 (4.5)	
Fresh juice						
Unblanched[e]	43.9 (2.6)[ab]	57.0 (2.6)[a]	140.1 (2.5)[b]	59.0 (1.1)[a]	184.0 (4.8)[b]	58.5 (1.5)[a]
Blanched (water)[f]	47.1 (0.6)[a]	45.4 (0.6)[b]	160.3 (1.2)[a]	50.1 (0.4)[b]	207.4 (1.5)[a]	48.9 (0.5)[b]
Blanched (HOAc)[g]	41.8 (2.4)[b]	41.1 (1.0)[c]	131.9 (1.0)[c]	42.1 (0.4)[c]	173.6 (1.4)[c]	41.9 (0.4)[c]
Canned juice (115.6 °C/25 min)						
Unbleached[e]	31.7 (1.9)[b]	47.5 (1.7)[a]	108.5 (2.8)[a]	52.7 (1.4)[a]	140.2 (4.2)[a]	51.3 (1.8)[a]
Blanched (water)[f]	32.4 (0.7)[a]	33.4 (0.7)[b]	87.2 (0.9)[b]	29.1 (0.3)[c]	119.7 (1.5)[b]	30.2 (0.4)[c]
Blanched (HOAc)[g]	30.2 (0.3)[c]	33.4 (0.3)[b]	87.8 (2.3)[b]	31.8 (0.8)[b]	118.0 (2.2)[b]	32.2 (0.6)[b]
Canned juice (121.1 °C/10 min)						
Unblanched[e]	24.4 (1.1)[c]	36.5 (1.6)[a]	85.4 (5.3)[b]	41.4 (0.7)[a]	109.8 (5.9)[c]	40.1 (2.3)[a]
Blanched (water)[f]	31.6 (0.6)[a]	34.3 (0.7)[b]	86.6 (2.3)[a]	30.4 (0.8)[b]	118.3 (2.90)[a]	31.4 (0.8)[b]
Blanched (HOAc)[g]	29.9 90.2)[b]	33.6 (0.3)[b]	82.0 (0.9)[c]	30.1 (0.3)[b]	111.9 (1.1)[b]	31.0 (0.3)[b]
Concentrated juice						
Unblanched[e]	40.4 (0.8)[b]	56.6 (1.1)[a]	108.7 (1.3)[a]	49.4 (0.6)[a]	149.1 (1.3)[b]	51.2 (0.4)[a]
Blanched (water)[f]	44.7 (0.5)[a]	44.4 (0.5)[b]	106.5 (1.0)[b]	34.3 (0.3)[b]	151.2 (0.9)[a]	36.7 (0.2)[b]
Blanched (HOAc)[g]	35.9 (0.4)[c]	37.1 (0.4)[c]	87.9 (0.6)[c]	29.4 (0.2)[c]	123.8 (0.9)[c]	31.2 (0)[c]
Freeze-dried juice						
Unblanched[e]	40.9 (2.8)[a]	56.3 (2.1)[a]	102.1 (1.3)[a]	45.6 (0.6)[a]	143.0 (3.8)[a]	48.2 (0.9)[a]
Blanched (water)[f]	41.9 (1.4)[a]	40.7 (1.4)[b]	95.5 (2.6)[b]	30.1 (0.8)[b]	137.4 (1.6)[a]	32.7 (0.4)[b]
Blanched (HOAc)[g]	35.6 (3.1)[b]	36.1 (3.1)[c]	78.9 (4.3)[c]	26.0 (1.4)[c]	114.5 (1.3)[b]	28.5 (1.8)[c]

[a-c] Means (± standard deviation) within each product group in each column followed by a different letter were not the same ($p < 0.05$).
[d] Percent retention of carotene was calculated based on the amount in the fresh carrot using the equation:

$$\% \text{ Retention} = \frac{\% \text{ Yield (carrot product)} \times \% \text{ Solid (carrot product)} \times \text{Carotene content (carrot product)}}{\% \text{ Solid (fresh carrot)} \times \text{Carotene content (fresh carrot)}} \times 100\%$$

[e] from unblanched carrots.
[f] from water-blanched carrots.
[g] from acetic acid-blanched carrots.

Juice from unblanched carrots canned at 115.6°C retained the highest percent (≈50%) of the total α- and β-carotenes among all canned juices. Canning at 121°C for 10 min did not improve retention of carotenes compared to the 115.6°C/25 min process.

The canning process decreased α- and β-carotene levels in fresh juice (Table 5). Among all canned juice samples, juice from water-blanched carrots lost the highest percentage (38.29%, a decrease from 48.9 to 30.1% of the total carotene retention) of the total carotenes in fresh juice (Table 5). Canning had a more detrimental effect on β-carotene than on α-carotene in both blanched products. However, canning seemed to degrade more α-carotene in unblanched juice (Table 5).

Kim and Gerber (1988) investigated the effects of retorting on carotenes in commercially canned carrot juice. They reported fresh juice and canned juice contained 9.5 and 6.7 mg carotenoids/100 mL, respectively. The different reporting unit for carotenoid content made comparisons with our results difficult. Canned juice retained 70-77% of the carotenoids in freshly made juice in their study. The difference might be due to differences in processing methods and/or raw materials. In our study, the acetic-acid blanched juice canned at 115.6°C for 25 min lost 24.5% of β-carotene of the fresh juice. However, the canned juice from water-blanched carrots lost 41.8% of β-carotene (Table 5). The canned juice product from acetic acid-blanched carrots also resulted in less destruction of α-carotene than canned juice from water-blanched carrots (Table 5). Therefore, carotenes in canned carrot juice from acid-blanched carrots were more stable than those from water-blanched carrots. Acetic acid treatment tended to protect carotenes from destruction by the high-temperature canning process.

Concentrated juice from unblanched carrots retained the highest total carotenes among the three concentrates (Table 4). Concentrated juice from water-blanched carrots retained more total α- and β-carotenes than did acetic acid-blanched carrots. Concentrated juice from unblanched carrots lost only 12.5% of total carotenes during concentration (Table 5).

Freeze-dried juice produced from unblanched carrots also retained the highest total carotenes. Losses were only 5.8% of total α- and β-carotenes in freeze-dried juice from unblanched carrots due to freeze-drying (Table 5). Freeze-dried juice from water-blanched carrots retained more total carotenes than did that from acetic acid-blanched carrots. Park (1987) investigated the effect of freezing and cooking on carotene retention in carrots. Fresh carrots were cooked at 100°C for 20 min or freeze-dried at −40°C for 24 hr. Cooked carrot retained 97.8% of the carotenes, whereas freeze-dried carrots retained 41.6% of the carotenes of fresh carrots after freeze-drying.

Concentration and freeze-drying processes therefore decreased the amounts of carotenes in juice products. The losses of carotenes in juice products from blanched carrots were greater than those from unblanched carrots. Acetic acid blanching did not protect against loss of carotenes during concentrating and freeze-drying of fresh juices. Diminishing effects of juice con-

Table 5—Loss (%) of carrot juice products carotenes due to processsing [a-c]

	Alpha-carotene	Beta-carotene	Alpha- + Beta-
Canned juice (115.6 °C/25 min)[d]			
Unblanched[d]	16.7 (2.1)[b]	10.3 (0.8)[c]	12.3 (1.3)[c]
Blanched (water)[e]	26.4 (1.8)[a]	41.8 (1.0)[a]	38.3 (1.2)[a]
Blanched (HOAc)[f]	18.8 (1.7)[b]	24.6 (2.2)[b]	23.0 (1.9)[b]
Canned juice (121.1 °C/10 min)[d]			
Unblanched[f]	36.1 (1.0)[a]	29.9 (2.4)[b]	31.4 (2.5)[b]
Blanched (water)[g]	24.5 (1.4)[b]	39.3 (1.9)[a]	35.9 (2.1)[a]
Blanched (HOAc)[h]	18.4 (2.4)[c]	28.5 (1.3)[b]	25.9 (1.2)[c]
Concentrated juice[d]			
Unblanched[f]	0.7 (0.1)[c]	16.2 (0.9)[c]	12.5 (1.8)[b]
Blanched (water)[g]	2.3 (0.8)[b]	31.6 (0.1)[a]	24.9 (0.3)[a]
Blanched (HOAc)[h]	9.9 (1.3)[a]	30.1 (0.6)[b]	25.5 (0.7)[a]
Freeze-dried juice[e]			
Unblanched[f]	0.5 (0.4)[c]	7.7 (0.5)[b]	5.8 (1.0)[b]
Blanched (water)[g]	8.2 (1.9)[a]	12.1 (1.7)[a]	10.9 (0.6)[a]
Blanched (HOAc)[h]	2.5 (0.2)[b]	11.8 (0.7)[a]	8.7 (0.9)[a]

[a-c] Means (± standard deviation) within each product group in each column followed by a different letter were not the same ($p < 0.05$).
[d] % loss compared to fresh juice.
[e] % loss compared to concentrated juice.
[f] from unblanched carrots.
[g] from water-blanched carrots.
[h] from acetic acid-blanched carrots.

Table 6—Nonstarchy polysaccharide content of carrot juice products[a-c] (% Dry matter basis)

Carrot product	Rhamnose	Arabinose	Xylose	Mannose	Galactose	Glucose	Galacturonic acid	Total
Canned juice (115.6 °C/25 min)								
Unblanched[d]	0[b]	0.60 (0.19)[a]	0[b]	0[a]	0.49 (0.04)[a]	0.17 (0.02)[a]	0.24 (0.02)[b]	1.50 (0.30)[a]
Blanched (water)[e]	0.06 (0)[a]	0.57 (0.06)[ab]	0[b]	0[a]	0.40 (0.01)[b]	0.13 (0.01)[b]	0.36 (0.03)[a]	1.52 (0.09)[a]
Blanched (HOAc)[f]	0.01 (0.01)[b]	0.58 (0.14)[ab]	0.08 (0.01)[a]	0.01 (0)[a]	0.46 (0.04)[a]	0.17 (0.02)[a]	0.25 (0.01)[b]	1.56 (0.33)[a]
Canned juice (121.1 °C/10 min)								
Unblanched[d]	0[a]	0.37 (0.12)[a]	0.02 (0)[a]	0.01 (0.01)[a]	0.46 (0.03)[a]	0.17 (0.03)[a]	0.16 (0.01)[c]	1.19 (0.05)[b]
Blanched (water)[e]	0[a]	0.36 (0.13)[ab]	0.06 (0.03)[a]	0.03 (0)[a]	0.51 (0.04)[a]	0.18 (0.03)[a]	0.37 (0.03)[a]	1.51 (0.10)[a]
Blanched (HOAc)[f]	0.01 (0.01)[a]	0.31 (0.12)[ab]	0.04 (0.02)[a]	0.02 (0)[a]	0.48 (0.03)[a]	0.18 (0.03)[a]	0.24 (0.01)[b]	1.28 (0.13)[a]
Freeze-dried juice								
Unblanched[d]	0.01 (0)[a]	0.29 (0.02)[a]	0[b]	0[b]	0.41 (0.02)[b]	0.21 (0.05)[a]	0.18 (0.01)[c]	1.10 (0.01)[b]
Blanched (water)[e]	0.02 (0.01)[a]	0.33 (0.02)[a]	0.06 (0.02)[a]	0.05 (0.03)[a]	0.52 (0.03)[a]	0.25 (0.01)[a]	0.31 (0.01)[a]	1.54 (0.01)[a]
Blanched (HOAc)[f]	0.01 (0)[a]	0.25 (0.03)[b]	0.05 (0.02)[a]	0.01 (0.01)[b]	0.45 (0.02)[b]	0.14 (0.02)[a]	0.25 (0.03)[b]	1.16 (0.09)[b]

[a-c] Means (± standard deviation) within each product group in each column followed by a different letter were not the same ($p < 0.05$).
[d] from unblanched carrots.
[e] from water-blanched carrots.
[f] from acetic acid-blanched carrots.

centration and freeze-drying were greater on β-carotene than on α-carotene (Table 5).

Effect of Processing on Non-starch Polysaccharides

Carrots contain considerable nonstarchy polysaccharides (NSP). After juicing, most of the NSP in carrots was retained in the pulp (Table 6). Juice products from unblanched and blanched carrots contained low total NSP, ranging from 1.1% to 1.5%, which presumably was water-soluble NSP. Results also showed that arabinose and galactose were major sugars in the NSP and that glucose and galacturonic acid were minor sugars. Only trace amounts of xylose and mannose were found in the juice.

CONCLUSIONS

JUICE PRODUCTS from acetic acid-blanched carrots retained the least carotene. Juice from unblanched carrots canned at 115.6°C retained more total α- and β-carotenes than did the same juice canned at 121.1°C. Retorting, concentrating, and freeze-drying decreased carotene content of carrot juice products. Compared to water blanching, acetic acid blanching could protect against loss of carotenes during high-temperature canning. Arabinose and galactose were major sugars in the non-starchy polysaccharides of juice products.

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