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COLOR AND CLOUD STABILITY IMPROVEMENT OF CARROT JUICE

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Abstract. **A large percentage of the carrots harvested in Florida each year are unsuitable for the fresh market, but are otherwise sound and could be processed into a valuable juice due to the high β-carotene content. A study was conducted to improve the color and cloud stability of carrot juice since these problems can limit quality. Carrot juice discolored and clarified quickly unless the carrots were heated (90-95°C) prior to juice extraction. Heating whole carrots was more effective than heating milled carrots for improving color, but juice from carrots heated whole tended to clarify quickly if citric acid was not added. The addition of citric acid prior to juice extraction (acidification from pH 6 to 5 or 4) significantly improved color and cloud stability. A commercial pectinase/hemicellulase preparation added before extraction also improved juice color. The overall extraction of β-carotene into the juice was low (ca. 20%).**

A significant portion of the total carrot crop harvested in Florida each year never reaches the fresh market due to various defects such as size and shape (Bates and Koburger, 1974). These reject carrots are otherwise sound and could be utilized in various ways, but are usually either discarded or severely under-utilized as animal feed. Carrots have a high β-carotene content (Senti and Rizek, 1975), and the potential for carrot juice as a natural source of β-carotene and coloring agent appears to be good, especially since natural carotenes reportedly have a demand which exceeds supply.

Carrot juice is currently being produced by a company in Florida, but poor color and cloud stability often limit the quality (Stephens et al., 1971; Bates and Koburger, 1974). Blanching carrots, especially in acid, has been reported to improve color and cloud of heat processed (canned) juice (Stephens et al., 1971; Bates and Koburger, 1974; Kim and Kim, 1983), but timing and extent of acidification need further investigation. Carrots are known to have pectinesterase (PE) activity (Lee et al., 1979), which could lead to the precipitation of pectin in carrot juice with subsequent loss of cloud. Poor color is probably due to low β-carotene extraction, co-precipitation of β-carotene during cloud loss, or enzymatic and oxidative discoloration.

Research has also indicated that various commercial enzymes such as pectinases and/or cellulases increase extraction of juice from carrots (Sreenath et al., 1986; Foda et al., 1985; Anastaskis et al., 1987), but the impact of enzyme treatment on color extraction and cloud stability remains unclear. The most valuable component of carrot juice is probably β-carotene, but the amount of β-carotene extracted during pressing has not been reported and would probably be rather low (Imeri and Knorr, 1988). The objectives of this research were to evaluate the effects of acidification, heat, and enzyme treatments on the color and cloud stability of carrot juice, and to determine the extent of β-carotene extraction in carrot juice.

Materials and Methods

Study 1—Effects of Heat and Acidification

Carrots were obtained from a local market, lye-peeled in 10% sodium hydroxide at 60°C for 2 min, and thoroughly washed. A portion was heated in a steam tunnel to an internal temperature of 93°C, cooled in water, and milled in a hammer mill (1/8" screen). These conditions were sufficient to inactivate pectinesterase (data not shown). The milled carrots were then either acidified to pH 5 or pH 4 with a 50% citric acid solution or left non-acidified (control). The other portion of carrots was milled before heating and either acidified to pH 5 or 4 with a 50% citric acid solution or left non-acidified (control). The milled carrots were then heated to 93°C in a small stainless steel steam-kettle and cooled. The milled carrots were then extracted by placing in a press cloth and pressing in a small hydraulic press. The experiments were replicated 3 times.

Color of the juice was measured using a HunterLab Color Difference Meter (model D25-2). The turbidity or cloud of the juice was determined by measuring the absorbance at 660 nm (A_{660}) using a spectrophotometer. A portion of the juice was placed at 2°C for 2-3 days and the absorbance at 660 nm again determined to measure the extent of clarification or cloud loss. All data were subjected to analysis of variance using SAS, and least significant difference (0.05 level) was used to separate means.

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Study 2—Effects of Acidification Treatments

In the first part of this study, carrots purchased at a local market were lye-peeled and milled as described in Study 1, and subjected to one of 4 different treatments described below (a 50% citric acid solution was used for acidification, and juice was extracted as described above): 1) heat to 93°C, acidify to pH 5, extract juice; 2) heat to 93°C, extract juice, acidify to pH 5; 3) heat to 93°C, extract juice, no acidification; 4) acidify to pH 5, heat to 93°C, extract juice.

For the second part of this study, whole carrots were heated to an internal temperature of 93°C in a steam tunnel, cooled in water, milled, and subjected to one of 3 treatments: 1) acidify to pH 5, extract juice; 2) extract juice, acidify; and 3) extract juice, no acidification. All treatments consisted of 3 replicates, and analyses were the same as described in Study 1.

Study 3—Effects of A Commercial Enzyme

The enzyme preparation used was Rohament K by Rohm Tech, Inc. (Malden, MA), which is recommended for vegetable juice production and is reportedly a mixture of pectinases and hemicellulases. Carrots were lye peeled as described above, milled, heated to 93°C, and cooled to 50°C. The carrots were acidified to pH 5 with a 50% citric acid solution and the enzyme preparation was added at a rate of 0.45 mL/Kg (the recommended rate of 400 mL/ton) and mixed thoroughly. The temperature was maintained at 50°C in a large water bath, and portions were pressed after 30 min, 1 hr and 2 hr. A temperature of 50°C is recommended by the manufacturer for the enzyme treatment of carrots. The control was pressed after 2 hr. All treatments consisted of 3 replicates, and all analyses were the same as described in Study 1.

Study 4—Extent of β-Carotene Extraction

Carrots were lye-peeled, milled, acidified to pH 5, heated to 93°C, cooled, and pressed. The levels of β-carotene in the raw carrots, heated carrots, juice and press residue were determined using a HPLC procedure according to Bushway and Wilson (1982). For all the carrot fractions, 10 g (wet weight) were placed in a small stainless steel blender and blended for 5 min with 20 g anhydrous Na_2SO_4, 1 mg $MgCO_3$ and 100 mL tetrahydrofuran. The extract was vacuum filtered through filter paper (Whatman #43). The filter cake was rinsed with tetrahydrofuran to remove all carotenoids. The extract was then concentrated to ca 50 mL using a rotary evaporator at 40°C, then brought to a final volume of 100 mL with tetrahydrofuran. All samples were extracted in duplicate. A 100 μL sample was injected into the HPLC.

The HPLC system used consisted of an Aldex pump, a Rheodyne model 7125 injector with a 100 μL injection loop, a C-18 column (Perkin Elmer HS5 C18 column, 150 mm x 0.46 mm), a Spectra Physics UV-VIS detector, and a Hewlett Packard 3392A integrator. Detection was at 470 nm. The solvent system used was acetonitrile:tetrahydrofuran:water (85:12.5:2.5), and flow rate was 1.0 mL/min. A standard curves of β-carotene was used to quantify results. All samples were injected at least 3 times.

Results and Discussion

Study 1

It was obvious from preliminary trials that carrots must be heated or blanched prior to juice extraction to prevent juice clarification and poor color. Unheated juice had pectinesterase (PE) activity (data not shown), which could have led to the rapid precipitation of pectin and subsequent clarification. The carotenoids also seemed to co-precipitate with the particulates, leaving a rather colorless or brownish juice. Heating to 93°C either before milling or after milling was sufficient to inactivate PE (data not shown).

Blanching carrots to 93°C before milling improved juice color (higher CDM a and b values, or more redness and yellowness, respectively) compared to heating carrots after milling (Table 1). The heated, whole carrots had softened to some extent, which made juice expression by pressing through a press cloth more difficult. However, any discoloration due to enzyme activity during milling was prevented, and carotene release and extraction may have been increased. Delays between milling and heating during this experiment due to weighing and acidification could have led to the poorer juice color with this method.

Acidification significantly improved juice color (higher CDM a and b), especially when the carrots were milled before heating; acidification to pH 4 was more effective than pH 5 (Table 1). Acidification likely improved the extraction and/or retention of carotenes. Acidification had little effect on the initial turbidity or cloud of the juice (as measured by A_{660}). The juice produced by milling before heating did not clarify to any extent during 48 hr at 2°C, and acidification had little effect on clarification. Juices produced by heating whole carrots clarified to a large extent (large decrease in A_{660}) if not acidified. Since PE was not active in these juices, the loss of cloud was probably due to precipitation of pectin and other cell wall components. Although acidification improved juice color and stability, the taste was noticeably altered (distinct increase in acidity) in informal sensory evaluations and this would have to be considered for some applications of the juice.

Table 1. Effects of heating method (93°C) and acidification to pH 5 and 4 with citric acid on the color and cloud of carrot juice (Study 1).

Acidification treatment	Color[z]		A_{660}[y]	
	CDM a	CDM b	Initial	After 48 hr
Milled before heating				
None	4.5b[x]	13.7b	1.66b	1.64a
pH 5	9.2ab	17.2a	1.99ab	1.71a
pH 4	11.5a	18.4a	2.24a	1.93a
Milled after heating				
None	18.9b	25.9c	2.99a	0.83b
pH 5	20.5a	26.8b	3.17a	2.88a
pH 4	21.3a	27.7a	3.26a	3.22a

[z]Higher CDM a and b values indicate more redness and yellowness, which indicates better color in carrot juice.
[y]A_{660} indicates turbidity, with a higher value indicating a more turbid juice.
[x]Means within a column and heating method followed by the same letter are not signifiantly different (lsd, 5%).

Study 2

When carrots were milled prior to heating, there were no significant differences in juice color between acidification before or after heating, as long as the carrots were acidified before extraction (Table 2). Acidification after extraction did not improve juice color compared to the non-acidified control. This indicates that the effect of acidification is probably more efficient extraction of carotenoids during pressing. Juice produced by milling before heating did not clarify to any extent, and the acidification treatments had only minor effects on turbidity.

The effects of acidification treatments on juice color were less pronounced when carrots were heated prior to milling (Table 2). There was no significant difference in juice color between acidification before or after pressing, and the non-acidified control had just slightly poorer color than the acidification treatments, which suggests that carotenoid extraction is not enhanced by acidification if the carrots are heated before milling. As in the previous study, juice extracted following heating of whole carrots had superior color compared to juice extracted from carrots that were milled before heating.

The acidification treatments had a major effect on the clarification of juice from carrots that were heated before milling (Table 2). The only treatment that prevented juice clarification was acidification before extraction; acidification after extraction did not prevent juice clarification. Acidification before extraction could have altered the pectin and other cell wall constituents extracted, which could influence precipitation of these compounds.

Study 3

The enzyme preparation significantly improved juice color as shown by the higher CDM a and b values, which indicates greater extraction of carotenoids during pressing (Table 3). There were some statistically significant differences in turbidity (A_{660}) between the treatments, but overall, the turbidity of the juice was not greatly affected by the enzyme preparation, and none of the juices clarified to any extent, even though the enzyme preparation remained in the juice and was not inactivated.

Table 2. Effects of heating method (93°C) and timing of acidification (to pH 5 with citric acid) on the color and cloud of carrot juice (Study 2).

Acidification treatment	Color[z] CDM a	Color[z] CDM b	A_{660}[y] Initial	A_{660}[y] After 48 hr
Milled before heating				
Heat acidify	16.5a[x]	17.8a	2.66a	2.45a
Heat, extract, acidify	14.2b	15.9b	2.42a	1.75b
Heat, no acidification	13.6b	15.6b	2.55a	1.78b
Acidify, heat	16.5a	18.4a	2.50a	2.12ab
Milled after heating				
Acidify, extract	20.6a	24.5a	2.88a	2.59a
Extract, acidify	20.0a	23.8ab	2.84a	0.61b
No acidification	18.2a	22.4b	2.79a	0.42b

[z]Higher CDM a and b values indicate more redness and yellowness, which indicates better color in carrot juice.
[y]A_{660} indicates turbidity, with a higher value indicating a more turbid juice.
[x]Means within a column and heating method followed by the same letter are not signifiantly different (lsd, 5%).

Table 3. Effects of enzyme treatment (Rohament K, 400 mL/ton, 50°C) on the color and cloud of carrot juice (Study 3).

Enzyme treatment time	Color[z] CDM a	Color[z] CDM b	A_{660}[y] Initial	A_{660}[y] After 48 hr
None	21.6c[x]	22.1c	2.75c	1.94b
30 min	23.5b	22.9b	2.93b	2.84a
60 min	23.8b	22.9b	2.90b	2.75a
120 min	25.6a	23.5a	3.08a	2.93a

[z]Higher CDM a and b values indicate more redness and yellowness, which indicates better color in carrot juice.
[y]A_{660} indicates turbidity, with a higher value indicating a more turbid juice.
[x]Means within a column followed by the same letter are not signifiantly different (lsd, 5%).

Study 4

Although the carrot juice produced by milling, heating, acidifying, then pressing had good overall color acceptability, the extraction of β-carotene was poor. The juice contained only 20% of the potential β-carotene in the milled carrots, with the remainder left in the press residue (Table 4). Further research is needed to improve the extraction of carotenes from carrots for juice. Different enzyme treatments or extraction methods may improve the extraction. β-carotene was higher in the heated carrots than in the raw, which may have been due to the release of bound forms of β-carotene, thus improving extraction.

Conclusions

Heating carrots to 93°C was necessary to inactivate PE and prevent clarification and poor juice color, but heating whole carrots prior to milling produced better juice color than heating milled carrots. Acidification of milled carrots to pH 5 or 4 improved juice color, and prevented juice clarification when carrots were heated prior to milling. Acidification was not effective if delayed until after extraction. Juice color was also improved by a commercial pectinase/hemicellulase preparation. The best juice color and stability was achieved by heating whole carrots, milling, acidifying to pH 5 or 4, enzyme treatment, and pressing.

Table 4. Carotene levels (wet weight basis) in carrot juice and various fractions (Study 4).

Product[z]	β-carotene (μg/100g)	β-carotene (% of heated carrots)
Raw carrots	6,960 ± 614[y]	
Heated carrots	9,567 ± 1,085	100
Juice	3,128 ± 441	20.5 ± 2.5
Press residue	18,800 ± 5,233	80.0 ± 12.3

[z]Carrots were lye-peeled, milled, acidified to pH 5, heated to 93°C and pressed.
[y]Means of 4 observations ± standard deviation.

Overall extraction of β-carotene from the carrots was very low, with only 20% of the potential β-carotene being extracted from milled carrots. Further research is needed to improve the extraction of carotenoids from carrots.

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EVALUATION OF SIZER TECHNOLOGIES FOR FLORIDA CITRUS

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Abstract. **Traditional mechanical-based dimensional sizers are being replaced by optical, ultrasonic, or load cell sensors to provide more refined sizing, advanced operator control, and fruit information via computer interfacing. Data were collected utilizing multiple sensor inputs of density and size for fruit separation. A volumetric compensation factor was developed to enhance the density estimation. Handling impacts, as measured with an Instrumented Sphere, have been reduced in the newer sizers compared to those encountered in master belt-and-roller units.**

Sizing of most fresh fruits and vegetables is required to provide uniformity for packaging and consumer acceptance. Size is also well-established as a criteria on which to base economic value of fresh produce. Traditionally, the sizing unit operation has been accomplished by mechanical techniques. A review of such sizers, e.g. perforated belt, belt-and-roller, diverging grommet, is detailed by Peleg (1985). More recently for citrus, electronic sizing has been implemented based on either dimensional measurements by solid-state cameras, ultrasonic transducers, or load cells for weight sensing. Such systems require different materials handling equipment as the fruit is singulated for sensing and distribution to the proper packing stations.

Secondary benefits may be derived from these advanced sizing technologies. For example, Miller et al. (1988) have proposed coupling weight and dimensional measurements to perform on-line density sorting. Such density sorting is important to identify fruit that is freeze-damaged, immature (off-bloom), or has undergone natural internal desiccation. For other commodities such as apples, color sorting has been added to these sizers to separate both on size and overall product color. Fruit labeling equipment has been integrated to facilitate selective labeling of certain sizes. These advanced sizer systems, which typically have a personal computer operator interface, also provide more detailed records, such as fruit size distribution on individual grower lots, and the ability to make sizer adjustments real-time.

In this study, data will be reported on the accuracy in sizing utilizing these electronic sensor-based systems. Also, an attempt was made to assess the potential for fruit damage associated with various sizers. Previous research (Miller and Wagner, 1991) has identified initial fruit dumping from pallet bins and mechanical sizing as major impact areas in Florida citrus packinghouses. However, comparisons were not made of the cup transfer and distribution type sizers at that time. Tests were conducted with an Instrumented Sphere (IS) to ascertain impact levels for various sizing units.

Specific objectives of this research reported herein were to:

1. Establish baseline data on sizing accuracy and estimate accuracy needs with respect to density sorting.
2. Measure impact damage levels associated with mechanical belt-and-roll sizers and electronic-based cup or roller transfer units.

Materials and Methods

Artificial grapefruit, filled with various ratios of alcohol and water, were utilized to give density ranges of 0.80 to 1.00 g/cm³. Manual diameter and mass measurements were

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