moving phenolic contaminants from packinghouse effluents (Table 1), which contained as much as 1080 ppm equivalent SOPP, removing more than 99% of its phenolic content.

Of the 418.7 g SOPP passed through the filtration unit, 203.99 g was retained on activated carbon (Table 2). Overall retention by 1362 g activated carbon was 51% of SOPP contained in 1100 gal 100 ppm soln. Removal percentage declined gradually as the volume introduced was increased. Removal efficiency gradually declined from an initial high of 81.5% to 27.5% after 1100 gal had passed through the purification system.

These results indicate that purification systems packed with granular carbon could be used for reducing SOPP content of citrus packinghouse effluents. Filtration and purification units with rated capacities of 1000 to 2000 gal per hr are commercially available. Use of such equipment would aid in reducing the load of SOPP in citrus packinghouses, thus making it less likely to violate regulations of the Florida Department of Pollution Control (2) which limits the level of phenolic type compounds in public water bodies (lakes, streams, etc.) receiving contaminated effluent to 0.001 mg/liter (0.001 ppm). An added benefit which might arise from use of filtration-purification systems is the recycling of rinse water for rinsing of additional fruit. This may result in considerable saving to packinghouses which use municipal water. It is estimated that a packinghouse may use up to 10 gal of water for packing a standard field box of fruit (personal communication).

Currently, research is under way evaluating a commercial filtration-purification system with 1000 gal/hr capacity.

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HIGH-TEMPERATURE—SHORT-TIME PROCESSING OF CARROT JUICE

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Abstract. **A simple prototype HTST process system was developed and found suitable for the production of sterile canned carrot juice. Sound, whole, packinghouse reject carrots were used. The juice was pressed from lye peeled, acid blanched, chopped carrots, homogenized at 5,000 psi, heated to 143°C, held 15 seconds, cooled to 40°C and filled aseptically into sterile glass jars. Carrot juice so prepared was sterile (F_0 = 15 min) and retained typical carrot color and fair flavor for at least 8 months at 25°C with only minor settling of suspended solids. While taste panel data was not encouraging, it is believed that this product would appeal to certain groups interested in improving their vegetable nutrient intake.**

The Florida fresh carrot industry generates a substantial quantity of sound, whole carrots which are rejected at the packinghouse due to variations in size and shape or superficial harvest-induced damage. Use of sound culls which possess good color and flavor as raw material for carrot juice would produce an acceptable product and at the same time aleviate the disposal problem.

The major problem in processing carrot juice is the low acidity of the juice. Carrots with a pH range of 6.1 to 5.3 and a high spore load from the soil require a relatively severe thermal process (3). Acidification to a pH below 4.5 can reduce the process requirements drastically, but carrot juice so treated acquires an atypical tart taste. In addition, thermal processing results in a highly pig-

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mented coagulum which rapidly settles out of processed juice. Stephens et al. (4) have reviewed carrot juice processing quite comprehensively and contributed a process improvement based upon heating raw, whole carrots in 0.05 N acetic acid prior to juice extraction and canning. The resulting juice had superior color retention and minimum coagulation. Luh et al. (2) evaluated carrot purees prepared by the HTST process and found superior color and flavor compared with the retorted pack. In addition, the HTST samples held up much better than conventionally packed puree during storage for 300 days at 86°F.

The HTST process seemed a promising approach for improving carrot juice quality; however, even the smallest lab-scale HTST unit was prohibitively expensive. We therefore sought to develop from equipment on hand a simple approximation of the HTST system. Reported here are our efforts to determine the feasibility of producing a stable, attractive, palatable carrot juice from packinghouse rejects, using a simple approximation of the HTST process.

Materials and Methods

Carrots of the "High Color 9" variety were obtained from packinghouses in Belle Glade and Zellwood, Florida, as typical 50 lb packs in plastic bags or directly from the reject belts. Collection was on the day of harvest for the culls and after 3 weeks storage at 6°C for the packed carrots. Samples were stored at 2°C and used within 2 weeks.

The processing scheme is shown in Figure 1. Carrots were inspected and damaged or decayed roots discarded. Lots, of 10 kg each, were submerged 25 seconds in a 10% sodium hydroxide solution maintained at 95 to 100°C, drained 10 seconds and rinsed with a tap water spray in a revolving drum to remove most of the outer peel. The lot was then placed in a boiling 0.05 N acetic acid solution for 5 minutes, followed by a 2 minute tap water spray. The peeled, blanched carrots were butted, chopped in a Hobart food cutter, placed in a rack and cloth press and pressed at 200 psi for 15 minutes. The expressed juice was strained through an 80-mesh screen and processed within 2 hours of collection.

The HTST process system (Figure 2) consisted of a single stage Manton-Gaulin Laboratory Homogenizer, serving as both homogenizer and feed pump. The discharge line connected to a Votator Scraped Surface Heat Exchanger (0.7 ft²) operating on 60 psi steam. The Votator outlet fed a 12 ft length of jacketed 3/8 inch ID hydraulic hose, which served as the holding tube and connected to a manually operated back-pressure valve at the inlet to a water-cooled 3/8 inch ID tube-in-shell heat

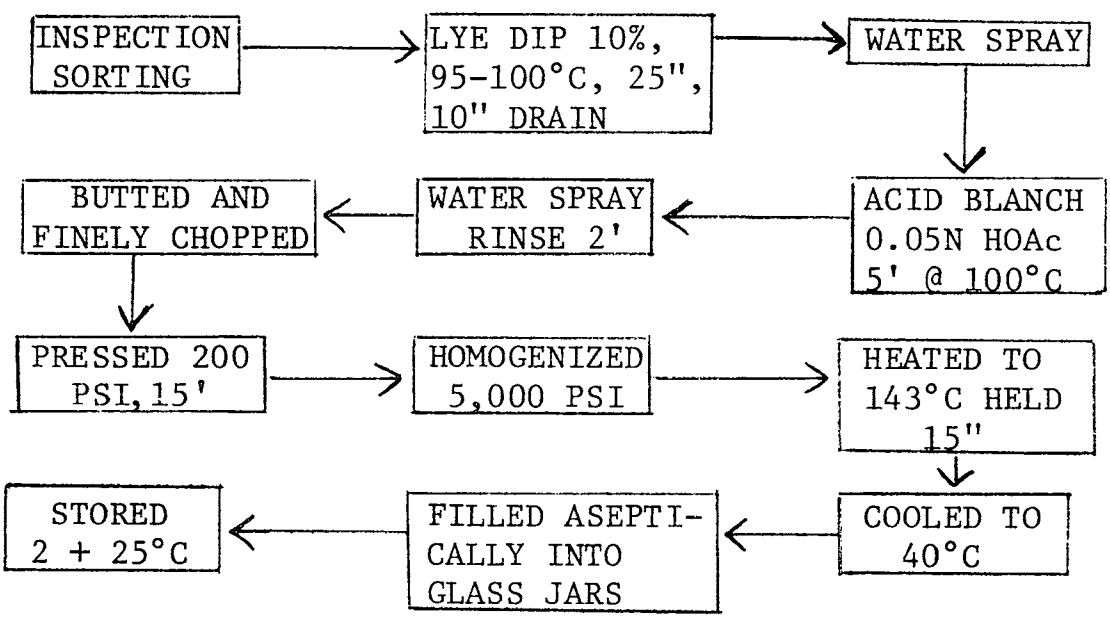

Fig. 1. Carrot juice processing flow scheme.

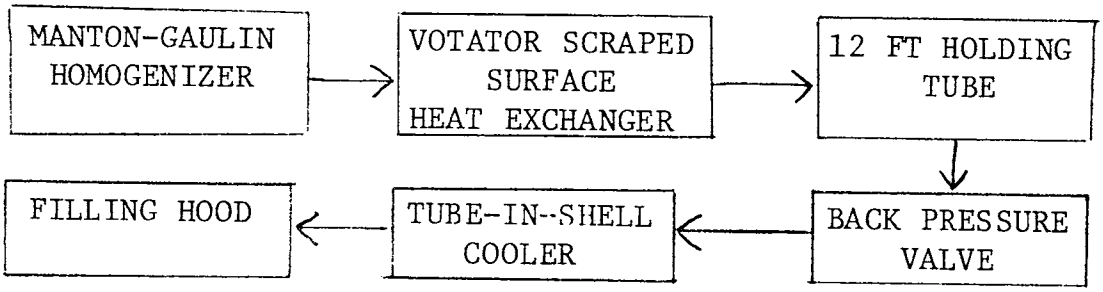

Fig. 2. HTST protoype system.

exchanger. From this a 10 ft length of Tygon tubing lead to a manual filling nozzle under a UV lamp in an enclosed bacteriological hood.

Prior to processing, the thoroughly cleaned system was sterilized by pumping water through it with the back pressure valve set at 70 psi without the cooling water being on. This condition was maintained for 20 minutes after steam issued from the filling nozzle. About 2 L of a 200 ppm chlorine solution was then added to the homogenizer feed tank and pumped through, followed by about 4 L of tap water. During this period the holding tube reached 145°C and the filling line 100°C.

To commence processing, the cooling water was turned on, well mixed carrot juice was added to the homogenizer hopper just as the water was pumped out and homogenizer pressure was adjusted to 5,000 psi. After about 3 minutes, sterile, undiluted carrot juice flowed from the filler at 40°C. Presterilized jars were opened, filled as aseptically as possible by an operator with sanitized, gloved arms inserted through holes in the hood window. Samples were prepared for analyses or stored at 2 and 25°C.

Analyses conducted on raw or processed juice were: pH, titratable acidity (reported as citric, pH 8.2 end point) soluble solids by refractometer and color using a Gardner Automatic Color Difference Meter, Model AC-1 and standard Hunterlab Color Plate D33C-423 ($L_L = 47.9$, $a_L = +19.7$, $b_L = +24.0$). Juice acceptability was evaluated in duplicate by an untrained 10-member panel served samples of freshly prepared raw and HTST processed juice at 5°C. Panelists were asked to rate samples on a 9-point hedonic scale for color, flavor and overall acceptance.

Both freshly processed and stored samples were analyzed by standard procedures (1). Aseptically obtained samples were plated using Plate Count Agar. At least three samples from each lot and storage condition were analyzed. Four sets of plates were prepared from each sample with incubation at 20 and 45°C under both aerobic and anaerobic (BBL, GasPak) conditions. Generally from each half-pint jar 3-10 ml, 3-1 ml and 3-0.1 ml portions of undiluted juice were analyzed. Plates were incubated at 20°C for 5 days and at 45°C for 2 days. When colonies developed on any of the plates, gram stains were prepared for morphological identification of the organisms.

Results and Discussion

It was found necessary to both peel and blanch the carrots prior to juicing; otherwise the juice was an unsightly muddy orange color due either to peel extract or enzymic browning (Table 1). The acid blanch treatment of Stephens et al. (4) seemed to improve color slightly relative to water blanching and decreased sedimentation of the processed juice. Juice yields ranged from 60 to 70% based on chopped carrots or 45 to 55% based on whole carrots. There was no obvious difference in raw juice quality between wholesale packed and well sorted cull carrots.

The homogenizer delivered a steady pulsed flow of about 820 ml/min to the Votator. This flow rate was fixed, as was the steam-pressure in the Votator (60 psi). Thus the only means of varying the process time-temperature conditions was by varying the holding time by changing the holding tube length, or the temperature by adjusting the back pressure valve below 60 psi. The maximum temperature which could be achieved in the system with the back pressure valve at 70 psi was 145°C with water and 143°C with carrot juice. Minimum residence time in the holding tube, as calculated by injecting acid into the flow stream and monitoring pH at various points, was 15 seconds. This represents an F_o of about 15 minutes and was demonstrated to be adequate on the basis of microbial analyses of both stored and freshly prepared

Table 1. Carrot juice characteristics as influences by treatment

Carrot Preparation Treatment	pH	Brix	Titra. Acidity as (citric) %	Col. Dif. Meter L	a	b	Appearance
1. Unpeeled, unheated	6.4	8.2	0.20	23.8	3.8	11.3	muddy orange
2. Unpeeled, 5' water blanched	6.3	8.1	0.21	29.9	13.3	15.7	dark orange
3. Lye peeled, 5' water blanched	6.2	7.5	0.20	33.7	15.4	17.8	typical carrot orange
4. Lye peeled, 5' HOAc blanched	5.6	7.6	0.19	34.1	15.7	18.8	slightly brighter than 3
5. Lye peeled, 5 ' HOAc blanch HTST	5.6	7.2	0.16	34.5	9.1	20.5	slightly darker than 4
6. Lye peeled, acidified with citric acid	4.3	7.2	----	38.5	16.4	22.7	very bright orange
7. Lye peeled, stored 8 mo. @ 25°C	5.7	7.1	0.17	31.8	12.3	17.2	slightly darker than 5

samples. Some contamination in the form of yeasts and/or molds was observed in a few of the plates left open under the hood during juice filling operations and in an occasional agar-containing jar. Once the process was refined, less than 1% of the carrot juice samples were nonsterile and these solely due to post-process contamination.

HTST carrot juice was slightly darker than the unprocessed juice and had a mild cooked carrot flavor. After several days about 2 mm of a bright orange coagulum settled from the juice, but went into suspension readily if the jar was inverted a few times. Heating the juice to 100°C prior to homogenization or passing the juice through the HTST system twice reduced this settling to less than 1 mm, but produced a more pronounced cooked flavor. If the juice could be homogenized aseptically while at process temperature, a further reduction in settling might be accomplished. However, this step was not possible in the system used.

Results of the sensory evaluations are presented in Table 2. The unprocessed and HTST processed juice obtained an overall acceptability rating of like slightly and dislike slightly, respec-

Table 2. Hedonic rating[2] of fresh and HTST processed carrot juice.[1]

	Fresh	HTST
Color	6.9	6.4
Flavor	6.1	4.3
Overall acceptance	6.3	4.3

[1] 10 taster, average of duplicated tastings.

[2] 9-point scale, 6 = like slightly, 4 = dislike slightly.

tively. Samples of commercially canned carrot juice had been obtained for comparative purposes from several stores and bearing different codes. However, all were found to be thick, dark orange colored and possessed an extremely offensive aftertaste; they were deemed undrinkable and not presented to the panel. Thus, the HTST carrot juice, although not well received by the taste panel, is a considerable improvement over the commercial product and may serve a special nutrient need. HTST samples stored 8 months at 25°C appeared slightly darker than samples stored at 2°C, but similar in flavor and acceptable in color. Following storage at both 2 and 25°C, coagulum settling was about 4 mm and vigorous shaking was necessary to break up and resuspend this sedimentation.

Microbial quality of raw carrots, and raw and processed juice are shown in Table 3. The rapid increase in counts associated with juice preparation is due to the chopping and pressing steps. Modern, high speed pressing equipment would greatly reduce this source of contamination. Numerous checks of the HTST system indicated complete sterility at the filler. However, despite the described sanitary measures during filling, about 1% of the jars showed post-process contamination as manifested by gas and/or acid production. Organisms isolated from spoiled samples were yeast, micrococci, and a few molds. Of course, a commercial system can tolerate no contamination and this prototype system serves primarily to define the feasibility of HTST processing of carrot juice.

Table 3. Microbial quality of carrots and carrot juice. (numbers/ml)

	Aerobic		Anaerobic
	20°C	45°C	45°C
Raw carrots	1.5×10^6	7×10^3	400
Lye peeled carrots	1.1×10^4	600	140
Acid blanched carrots	110	75	5
Raw juice	3×10^5	1.5×10^5	8×10^3
HTST	0	0	0

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