Table 5. Heat content, apparent specific heat, and ice content of 11°Brix orange juice. Moisture content = 89%. Initial freezing temperature = 29.9°F.

Temperature (°F)	Heat content (BTU/lb.)	Apparent specific heat (BTU/lb. °F)	Ice content[z] (%)
−40.0	0.0	0.46	98
−30.0	4.6	0.51	97
−20.0	9.7	0.56	96
−15.0	12.5	0.60	95
−10.0	15.5	0.66	94
− 5.00	18.8	0.73	93
0.0	22.5	0.80	92
2.5	24.5	0.86	92
5.0	26.6	0.94	91
7.5	29.0	1.03	90
10.0	31.5	1.15	89
12.0	33.8	1.28	87
14.0	36.4	1.46	86
16.0	39.3	1.72	85
18.0	42.8	2.09	83
20.0	47.0	2.68	80
22.0	52.3	3.70	77
24.0	59.7	5.77	72
26.0	71.2	8.94	63
27.0	80.2	13.28	57
28.0	93.5	22.19	47
29.0	115.7	39.60	30
30.0	155.3	0.94	0
31.0	156.2	0.94	0
32.0	157.1	0.94	0
40.0	164.4	0.94	0
50.0	173.5	0.94	0
60.0	182.7	0.94	0
70.0	191.8	0.94	0
80.0	201.0	0.94	0

[z]Percent of total water.

Table 6. Heat content, apparent specific heat, and ice content of 42°Brix orange juice concentrate. Moisture content = 58%. Initial freezing temperature = 17.8°F.

Temperature (°F)	Heat content (BTU/lb.)	Apparent specific heat (BTU/lb. °F)	Ice content[z] (%)
−40.0	0.0	0.75	88
−30.0	7.5	0.89	83
−20.0	16.5	1.04	76
−15.0	21.7	1.17	72
−10.0	27.5	1.35	67
− 5.0	34.3	1.59	62
0.0	42.3	1.84	55
2.5	46.9	2.06	50
5.0	52.0	2.34	46
7.5	57.9	2.69	40
10.0	64.6	3.12	33
12.0	70.8	3.62	27
14.0	78.1	4.30	19
16.0	86.7	5.05	10
18.0	96.8	0.76	0
20.0	98.3	0.76	0
22.0	99.8	0.76	0
24.0	101.2	0.76	0
26.0	102.7	0.76	0
27.0	103.5	0.76	0
28.0	104.2	0.76	0
29.0	105.0	0.76	0
30.0	105.7	0.76	0
31.0	106.5	0.76	0
32.0	107.2	0.76	0
40.0	113.2	0.76	0
50.0	120.6	0.76	0
60.0	128.1	0.76	0
70.0	135.6	0.76	0
80.0	143.0	0.76	0

[z]Percent of total water.

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Proc. Fla. State Hort. Soc. 97:84-89. 1984.

THE SUITABILITY OF CITRUS TASTE EVAPORATORS FOR MUSCADINE GRAPE JUICE CONCENTRATE PRODUCTION

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Abstract. **Grape juice concentrates were prepared from 'Carlos,' 'Dixie,' and 'Noble' varieties using juice extraction and adjustment procedures specific for muscadines. Juices were concentrated from about 13 to 68° Brix in 227 kg/hr TASTE evaporators with and without essence recovery capabilities. Concentration produced little change in juice composition or quality. Addition of Muscadine or Concord grape essence to reconstituted juices did not enhance acceptability which was comparable to commercial canned juice and frozen concentrates. The process appears promising for muscadine concentrate production employing off-season citrus industry thermally accelerated, short time evaporation (TASTE) evaporators.**

The current rapid development of a grape industry in Florida has been accelerated by the establishment of 5 wineries in the last 3 yr and a dramatic expansion of grape plantings in state (6). Over the last decade grape plantings have increased from under 100 to over 600 bearing acres. While most of this production supports fresh market U-pick operations or the local wineries, the vineyards in the last several years have produced a modest grape surplus. It is estimated that between 15 and 25% of all grapes grown

Florida Agricultural Experiment Stations Journal Series No. 4984.

in Florida were not picked in 1983 and this surplus may increase as vines mature and new plantings are initiated. The surplus is not limited to Florida, since even more extensive plantings exist in other southern states, resulting in depressed grape prices on a regional, national and international scale.

Historicaly, the 2 grape species of commercial interest—*Vitis vinifera* L. (wine and table grapes) and *Vitis labrusca* L. (juice and condiments) do very poorly in Florida due to Pierce's disease, a virulent insect-borne bacterium affecting these species (1, 4). Consequently, breeding efforts have emphasized resistant species such as *Euvitis* (bunch grapes) and *Vitis rotundifolia Michx.* (muscadines). The majority of current plantings in Florida (about 80%) are muscadines due to the potential cultivation and harvest advantages of the species and fresh eating popularity of certain muscadine cultivars.

However, the morphological, compositional and sensory characteristics of muscadines are markedly different from other *Vitis* species. Investigators in the Southeast have studied the composition and processing of muscadines for wine and juice (7, 8). A study comparing single-strength canned muscadine juices with commercial juices found white muscadine juices and red commercial juices to be slightly superior to commercial whites and muscadine red juices (3).

Since grape production areas overlap with or are adjacent to the Citrus Belt (Fig. 1), possessing one of the largest concentrations of citrus processing facilities in the world (14), the idea of grape juice concentration is intriguing. In addition, muscadines ripen in the late summer and early fall (August to October, depending on cultivar and location) when citrus processing facilities are idle or in minimum use. Thus, the opportunity exists to effectively integrate the processing needs of the fledgling grape industry with the excess citrus capacity at minimum capital commitment.

The purpose of this study was to explore the feasibility of utilizing a pilot scale TASTE evaporator, typical of existing commercial units, to produce muscadine grape concentrate and essence and to evaluate the quality of the resulting products.

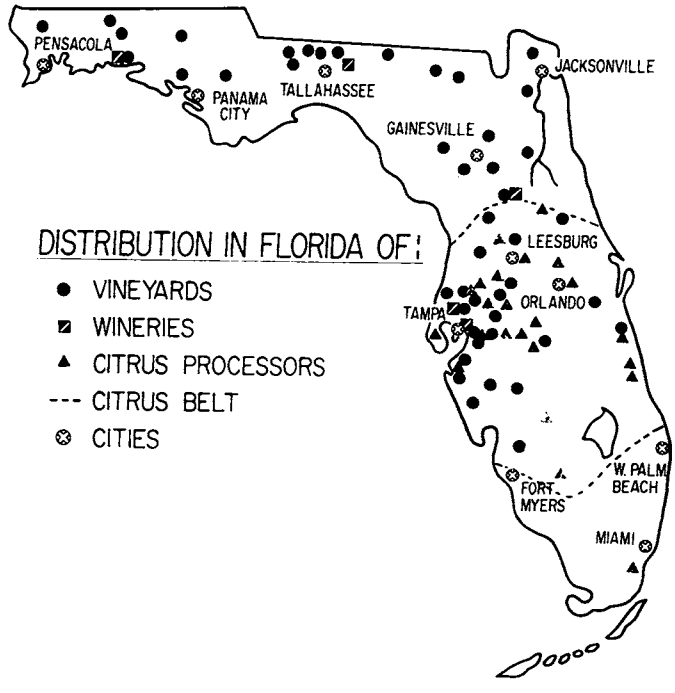

Fig. 1. Location of vineyards, wineries and citrus processors in Florida.

Methodology

Raw material. Bronze ('Carlos' and 'Dixie') and black ('Noble') muscadine grapes were hand harvested from 3 different commercial vineyards and handled as indicated in Table 1.

Table 1. Muscadine grapes, origin and treatment.

Sample and cultivar	Origin (Date picked)	Extraction treatment	Juice quantity (gal)
A. Carlos	Tallahassee (9/8/82)	Fresh grapes Screw press 150 ppm SO_2	64
B. Dixie	Archer (9/20/82)	Frozen grapes Screw press 250 ppm SO_2	61
C. Noble	Tallahassee (8/28/82)	Fresh grapes Rack & cloth Hot press 200 ppm SO_2	103
D. Noble	Orange Lake (9/12/82)	Frozen grapes Rack & cloth Hot press 200 ppm SO_2	108
E. Noble	Hollister	Frozen grapes Rack & cloth Hot press No SO_2	64

The bronze muscadine cultivars, Dixie and Carlos, find widespread use in U-pick operations and as wine grapes in the Southeast. The black cultivar Noble is most popular for red muscadine wine. In Florida roughly 10, 7 and 17% of the total bearing/planted acreage are in these 3 varieties, respectively. Due to limited facilities, equipment and time, 3 of the 5 pickings (Table 1) had to be frozen and juiced after the harvest season which runs from mid-August through September in North Central Florida and the Panhandle.

Juice preparation. Juice was prepared from fresh or frozen grapes as outlined in Fig. 2. Thawing of frozen grapes or juices (in preparation for concentration) was conducted at 10 or 20°C. Bronze muscadines were crushed, potassium metabisulfite added at the crusher at about 200 ppm and passed through a 1½ ton/hr twin screw press. The juice was refrigerated at 2°C within 2 hr of pressing. Black muscadines were given a hot press. Samples were crushed with and without the addition of SO_2, pectic enzyme (Klerzyme 200) was added at 10 oz/1000 gal, and the crush was heated and held for 30 min at 50°C with stirring. Rice hulls at 2% crush weight were added and the crush was pressed for 15 min at about 200 psi in a rack and cloth press. The resulting juices were held at 2°C in 50-gal plastic barrels for 7 to 10 days, decanted from the sediment and tartrate crystals and passed first through a Westfalia SAOH 205 continuous centrifuge and then through an Ertel M-60 filter pad using "Hyflo Supercel" filter aid. The juices were then either frozen and stored at −18°C or held at 2°C up to 3 days.

Concentration. Chilled juices were transported to 1 of 2 concentrate facilities and concentrated to about 68° Brix in a 4-stage, 3-effect TASTE evaporator (Fig. 3) (15) (Gulf Machinery Corporation). These pilot units each had an evaporation capacity of about 500 lb water/hr. The Lake

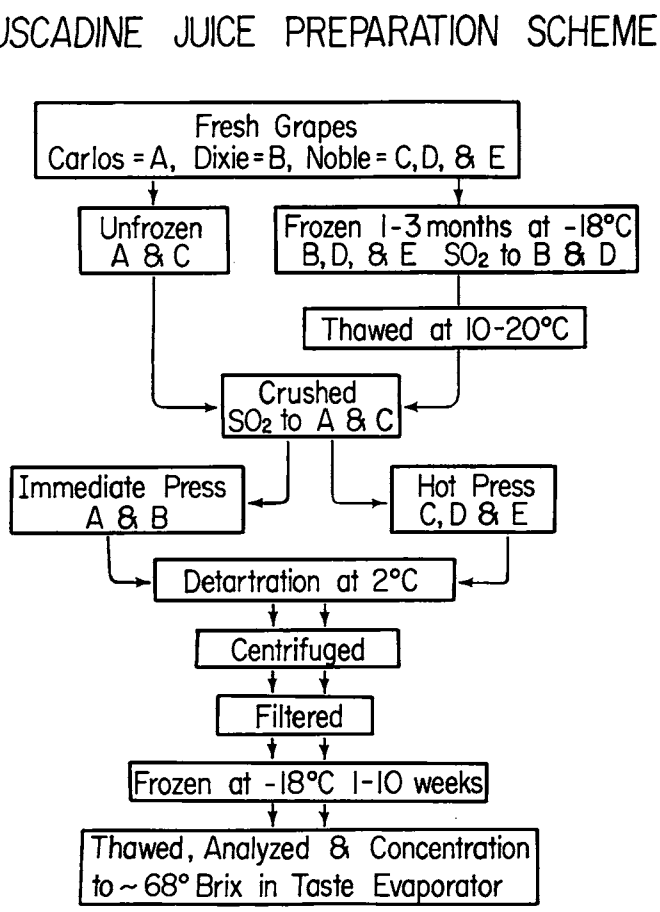

Fig. 2. Muscadine grape juice preparation scheme.

Alfred unit was fitted with an essence recovery system. When desired, about 20% of the first stage vapor (at ~86°C) supplied as heating media to the second stage evaporator is ducted to an essence condensor and reflux column linked to the No. 2 stage tube nest (Fig. 4). Evaporator operation and data collection were automatic (9, 13). The concentrate and recovered essence were returned to Gainesville and frozen at −18°C within 4 hr after concentration.

Analyses. The crush grapes, refined juice and reconstituted concentrate were analyzed for °Brix (temperature corrected refractometer), pH (glass electrode), titratable acidity (pH 8.2 endpoint), free and total SO_2 (2), and color (absorbance at 420 nm for white juice, ratio of absorbance at 520/420 nm for red juice).

Sensory evaluations, conducted after 4 to 6 months of storage at −18°C, consisted of reconstituting the concentrates to 16° Brix and adjusting the Brix/Acid ratio (B/A) with citric acid to 25 for white juices (Carlos and Dixie) and 20 for red (Noble). In preliminary trials essence derived from the concentration runs or commercial 'Concord' grape or citrus essences were added to the reconstituted muscadine juices.

In formal evaluations, juices chilled to about 10°C were presented in sets of 5 to 12 judges obtained from the department staff, who were asked to rate the juices on a 9 point hedonic scale for color, flavor and overall acceptance. Unmarked samples of 1 brand of canned white single strength unconcentrated grape juice was presented with the experimental white juices, since no white juice concentrate was available commercially. Three commercial brands of sweetened, frozen red concentrate, reconstituted according to manufacturer's instructions were presented randomly with the muscadine red juices. White and red juices were tested separately and all evaluations were replicated twice. Data were subjected to analysis of variance and multiple range tests (12).

Results and Discussion

All grapes except sample B were comparatively low in Brix due to early maturity. Acid levels are lower in cold pressed juice and strongly influenced by pressing regime (5). Sample D was somewhat unusual, since the picked grapes had been exposed to ambient temperatures (~32°C) for up to 48 hr prior to freezing. Fermentation had commenced and the juice possessed a volatile acidity of 0.3%—clearly unsuitable for wine or juice, but useful in checking out the concentration and essence recovery system.

Holding the freshly expressed juices at 2°C for 7 days produced complete detartration of the white and substantial detartration of the red juices. The subsequent freezing and slow thawing effectively cold stabilized all juices. Generally, detartration reduces titratable acidity of white and red muscadine juices by about 0.1 and 0.15%, respectively.

Considering the major difficulties in scaling up from batch preparation of 1.3 to 5.3 gal samples to >50 gal quantities, the concentration step was the easiest. In fact, the 60 gal/hr evaporation rate of the TASTE evaporator was too great for muscadine juice prior to 1980, since there was inadequate surplus production from any single vineyard to even feed this pilot unit. Concentration runs of 1 to 2 hr achieved steady state evaporation operation within 15 min of the switchover from water to juice. The automatic display of data such as temperature, °Brix, juice and steam feed rates and evaporator control afforded by the Department of Citrus evaporator (9) simplified the concentration operation considerably compared to runs on a similar but manually controlled evaporator without such capabilities. The fact that all grape juices were detartrated and filtered and similar to pulp-free citrus juices in °Brix and consistency simplified achievement of the desired 68° Brix set point.

The juices were subjected to a maximum temperature of 96°C for <10 sec at a vacuum of 1.6 to 2.4 inches Hg during the preheating and first effect evaporation, and to correspondingly lower temperatures in subsequent effects (Fig. 3). During this stage the flashed vapor, representing about 30% of the total water removed during concentration was partitioned between the second stage evaporator and the essence recovery system with about 20% being used for essence reflux (Fig. 4).

There was no evidence of thermal degradation due to the concentration process. Table 2 compares juice composition before and after concentration. White juices showed no change in absorbance at 420 nm and red concentrates had a slightly diminished absorbance ratio, due primarily to an increased 420 nm absorbance. Most importantly, there was no indication of a processed or "canned juice" flavor in these products, attesting to the mild concentration procedure.

The greatest change attributed to concentration was observed in Sample D—from partially fermented grapes which produced low °Brix and high acid juice. The single strength juice had 0.3% volatile acidity, about the level of reduction affected in total acidity by concentration (reconstituted basis). This concentrate possessed no acetic acid and was sound, although the recovered essence had 0.6% volatile acidity. Of course, such poor quality, mishandled raw material should never be produced nor considered for concentration.

In the concentrate industry, volatile aroma, inevitably lost in water evaporation is usually replaced in some manner in order to enhance the flavor quality of the product. This

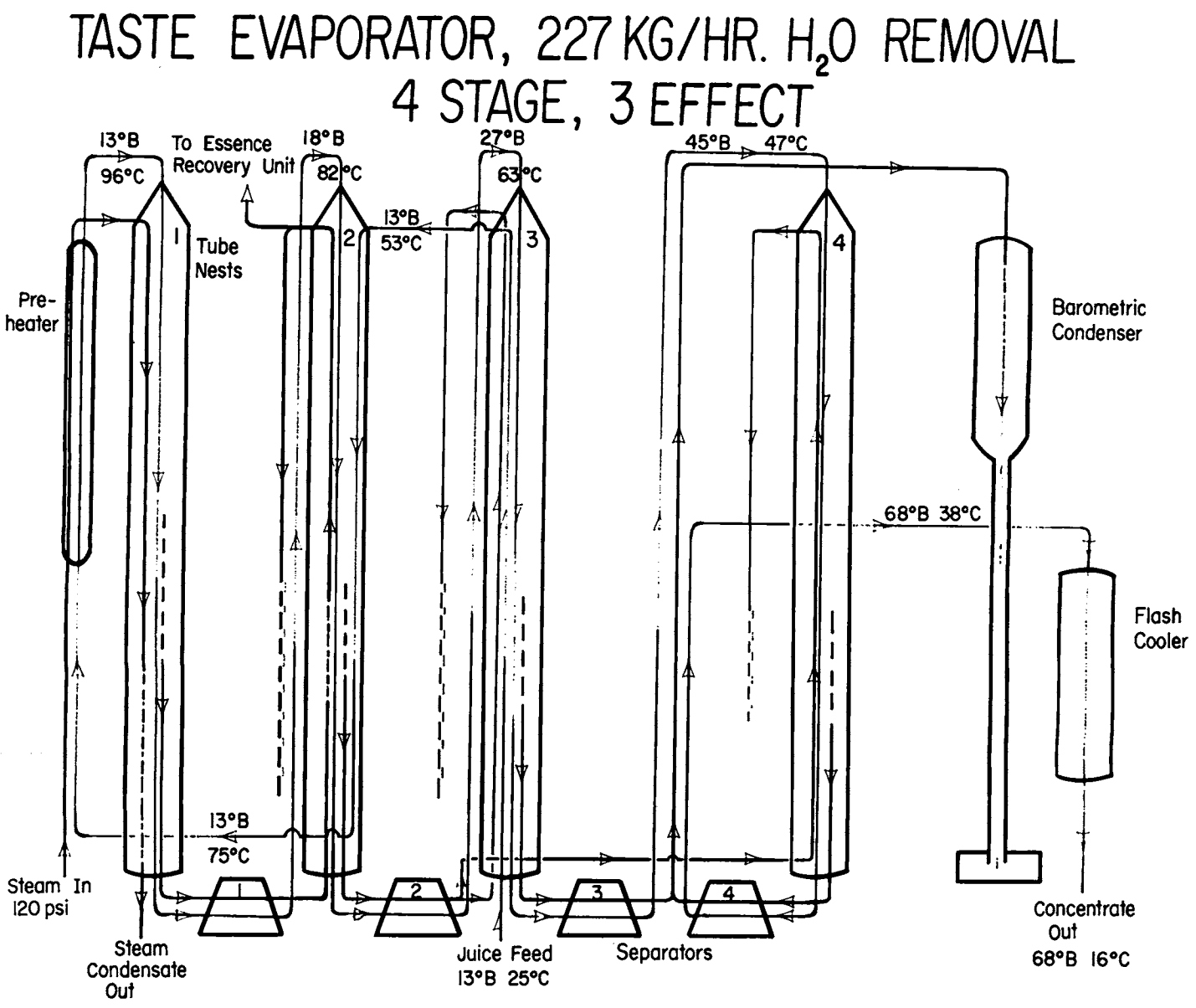

Fig. 3. Florida Department of Citrus TASTE evaporator, Lake Alfred Agricultural Research and Education Center.

is accomplished in citrus either by cut-back (where the juice is overconcentrated and cut back with some pasteurized or unpasteurized single strength juice with its volatile aroma reasonably intact) or essence recovery and return. Over the last decade essence recovery from the initial evaporate (first stage vapor) by fractional distillation has gained in importance (10).

Runs A and C (Table 2 and Fig. 2) were conducted in a pilot TASTE evaporator without essence recovery. In runs B and D the recovered essences had such a substantial SO_2 content that grape character was masked when this essence was added at approximately 10 times its initial juice level. Only run E, in which no SO_2 was used in the juice preparation step, yielded an essence with a recognizable muscadine character. However, this aroma contribution was so weak, even at 10 times the occurring level, that no positive effect was obtained by muscadine essence add-back. Since the initial 'Noble' grapes were slightly immature (possessing a °Brix near 13 instead of desired 16, indicative of full maturity) and were subjected to 50°C for 30 min with stirring during the hot press pretreatment, less volatile production and retention might be expected.

To gain some insight into flavor enhancement of muscadine concentrate, samples of commercial 'Concord' grape essence and experimental orange essence were used. Preliminary tests of 100-fold essences at twice their natural level (2%, single strength basis) proved too over-powering and citrus essence was deemed incongruous in grape juice. Thus, 1% 'Concord' essence was used in formal evaluations. Sensory data are shown in Table 3. There were no significant differences between reconstituted 'Dixie' and 'Carlos' concentrates compared to a commercial bottled single strength juice (no frozen white concentrate was available for comparison). The addition of 'Concord' essence had no detectable influence upon hedonic ratings. All white juices obtained evaluations of between "like slightly" and "moderately" for color, flavor and overall acceptance.

Use of 'Concord' essence also did not affect sensory scores of the 3 brands of commercial red grape concentrate or the 3 'Noble' concentrates. However, there were significant differences in color and overall acceptance scores. Two of the 3 commercial samples rated lower in color and one of the experimental muscadines (derived from vinegary grapes) rated lower in overall acceptance.

Although essence did not seem to be as important a quality factor as initially hypothesized, the adjustment of

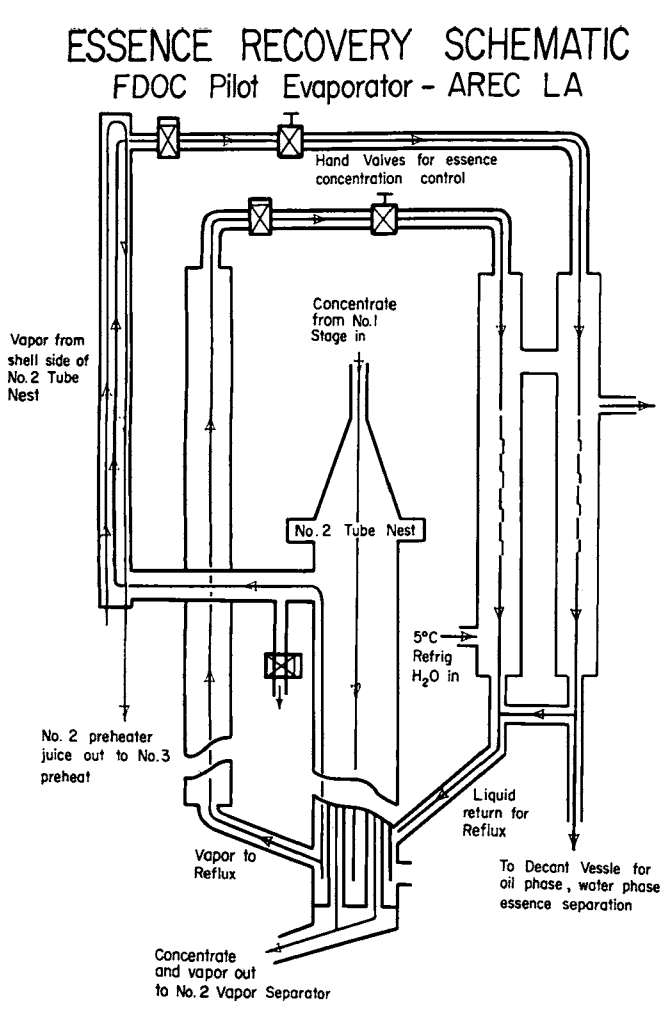

Fig. 4. TASTE evaporator essence recovery system.

Table 2. Juice composition—single strength (SS) and after concentration and reconstitution (C&R).

Sample and cultivar	°Brix		pH		Acidity (%)		Color[z]	
	SS	C&R	SS	C&R	SS	C&R	SS	C&R
A. Carlos	12.8	12.9	3.2	3.3	0.50	0.47	0.172	0.170
B. Dixie	17.1	17.1	3.6	3.6	0.37	0.37	0.135	0.140
C. Noble	13.4	13.1	3.3	3.3	0.50	0.45	5.6	4.9
D. Noble	11.8	11.8	3.0	3.0	0.92	0.65	4.6	4.0
E. Noble	13.2	13.3	3.2	3.3	0.67	0.49	5.0	4.6

[z]A & B absorbance at 420 nm; C, D, E ratio absorbance 520/420 nm.

°Brix/acid ratio (B/A) was critical, since unadjusted muscadine juices were overly sweet and bland as determined in other studies (3, 11). B/A's of up to about 60 are common with detartrated muscadine juices. Adjustment of B/A's to between 20 and 25 had a markedly beneficial effect on juice flavor, whereas ratios of <20 produced overly tart juices.

It will be useful to investigate the muscadine essence recovery features of the TASTE evaporator and add-back techniques as a strategy for perhaps further enhancing the quality of muscadine concentrates. Investigations are only now beginning to characterize muscadine volatiles (16).

The TASTE evaporation system is well suited to the production of muscadine grape juice concentrate from bronze and black varieties, provided that juices are clarified and detartrated prior to concentration. Brix/acid ratio adjustment is more critical in enhancing juice quality than essence add-back—a feature which will require more study. Experimental concentrates prepared from sound grapes achieved acceptability ratings similar to commercial grape concentrates. Citrus industry off-season capacity could be used for grape concentrate with minor changes in juice handling procedures.

Table 3. Sensory data for experimental and commercial frozen concentrates.

Sample and cultivar	Treatment[z]	Color[y,x]	Flavor[x]	Overall acceptance[x]
White juices				
A. Carlos	As is	6.8[ab]	6.6	6.7[a]
Carlos	+ Essence[w]	6.8[ab]	6.8	6.7[a]
B. Dixie	As is	7.0[ab]	6.5	6.9[a]
Dixie	+ Essence	6.8[ab]	6.5	6.9[a]
Commercial	As purchased	6.7[ab]	6.0	6.3[ab]
Commercial	+ Essence	6.5[b]	6.5	6.2[ab]
Red juices				
C. Noble	As is	7.1[ab]	6.6	6.6[ab]
Noble	+ Essence	6.7[ab]	6.6	6.5[ab]
D. Noble	As is	7.0[ab]	5.7	5.1[b]
Noble	+ Essence	7.0[ab]	5.5	5.2[b]
E. Noble	As is	7.5[a]	6.1	6.4[ab]
Noble	+ Essence	7.5[a]	6.0	6.4[ab]
I. Commercial	As purchased	6.9[ab]	6.6	6.7[a]
Commercial	+ Essence	6.8[ab]	6.1	6.1[ab]
II. Commercial	As purchased	6.3[b]	6.3	6.4[ab]
Commercial	+ Essence	6.4[b]	6.8	6.7[a]
III. Commercial	As purchased	6.4[b]	6.8	6.7[a]
Commercial	+ Essence	6.1[b]	6.4	6.7[a]
IV. Bulk	As obtained	6.5[b]	5.9	5.5[ab]

[z]Experimental samples reconstituted to 16° Brix, adjusted to a Brix/acid ratio of 25 (white), 20 (reds).
[y]Column means followed by the same letter or by no letter are not significantly different, $P \leq 0.05$.
[x]Hedonic ratings: 1 = dislike extremely, 9 = like extremely.
[w]1% Commercial 100-fold 'Concord' essence added.

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Proc. Fla. State Hort. Soc. 97:89-91. 1984.

FREEZE EFFECTS ON JUICE YIELD AND OTHER CHARACTERISTICS OF 'VALENCIA' ORANGE AND 'MARSH' GRAPEFRUIT

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Additional index words. state test, commercial extraction, yield loss, prediction model, regression, peel thickness, peel weight, °Brix, ratio, drying, vesicles, segments.

Abstract. **'Valencia' oranges and 'Marsh' grapefruit were randomly harvested from adjacent tracts several times during 21 weeks following the December 1983 freeze. Fruit were analyzed for juice yield, composition and physiological characteristics. In 'Valencia' oranges severe drying and significant yield losses were found through the eighth week when some increase in yield began. In 'Marsh' grapefruit little drying and some early juice yield losses were noted, but the juice yield losses were almost offset by yield increases in 16 weeks.**

Freezing weather has caused significant economic losses to the Florida citrus industry. This is due not only to foliage and tree losses but also to juice loss by drying of the fruit on the tree. Since over 80% of the citrus crop is processed for juice (3), on tree drying can represent large losses. A mathematical model predicting juice losses following freezes would be useful in determining the best picking times for optimum returns.

The purpose of this paper is to report on analyses of juice quality and juice yield of oranges and grapefruit harvested at intervals following the December 1983 freeze and to compare this data with data from a similar experiment after another freeze (1).

Materials and Methods

Temperatures. No recordings were made in the experimental tracts during the freezing weather. However, careful estimates were made by averaging actual readings in an adjacent commercial grove and from the nearest National Weather Service thermographs.

Oranges. A limited harvest (40 lb.) of 'Valencia' oranges was made December 29, 1983 and after that larger harvests of approximately ten 90-lb. boxes (2.23 bu.) of 'Valencia' oranges were made from the same 40 trees on each harvest date during the 21-week experiment between January 17 and May 23, 1984. The mature trees were located in 3 north-south rows in Tract 4 of the Citrus Research and Education Center Davenport grove located at the intersection of I-4 and U. S. Highway 27.

Fruit were harvested by hand with special instructions to insure a representative sampling of all trees each harvest. Eight fruit were harvested from each quadrant of each tree each harvest, 4 fruit from the top of each quadrant including 1 inside fruit and 4 fruit from the bottom of each tree quadrant including 1 inside fruit. A total of 32 fruit were removed from each tree for each harvest and transported to the Citrus Research and Education Center, Lake Alfred (CREC-LA) packinghouse in 900 lb. pallet boxes where the fruit were washed and sized so that samples included fruit from 2 1/4 to 3 1/8 inches in diameter and a size distribution was determined.

At each harvest, three 100-fruit randomized samples, weighing approximately 40 lb., were extracted and analyzed using Toledo auto state test equipment (2, 7). Also at each harvest, one size-randomized sample weighing approximately 700 lb. was extracted using an FMC 291 extractor and FMC model 35 finisher with 0.020 inch screen modified for pneumatic pressure control and settings listed in Table 1. Preliminary extraction-finishing tests were made on each harvest to produce a desired finisher discharge pulp quick fiber value of 160 on each experiment extraction (4). Weights of the various components of the fruit were re-

Table 1. Extractor and finisher settings for 'Valencia' orange and 'Marsh' grapefruit.

	Orange		Grapefruit	
	State test FMC 091B extractor No fiinisher	FMC 291 extractor FMC 35 finisher	FMC 391 extractor	FMC 591 extractor
			FMC 35 finisher	
Cup size (inches)	3	3	4	5
Upper cutter type	Long	Long	Long	Long
Strainer tube holes, diam. (inches)	0.025	0.040	0.040	0.040
Orifice tube, diam. (inches)	0.850	0.438	0.625	0.625
Ring, type	Split	Split	Split	Split
Orifice type restricter (inches)	None	7/16 long	1/2 short	1/2 short
Beam set (inches)	1/8 down	3/4 down	3/4 down	3/4 down
Finisher screen opening (inches)	None	0.020	0.020	0.020
Finisher psi air range	None	46-62	47-54	
Quick fiber range	None	128-186	156-174	
Quick fiber mean		155	165	