Flora-Dade, and UF A2050 to be significantly lower than the other samples and reference. Overall acceptability means showed samples UF A2049, UF 71050-1, Flora-Dade, and UF 71050-2 to be significantly higher than Walter and UF A2050.

Table 5. Sensory panel evaluation of juice from selected tomato cultivars.[z,y]

Cultivar	Flavor	Consistency	Overall
UF A2049	4.0a	4.77a	4.23a
UF 71050-2	3.14a	4.67a	3.60a
Walter	2.27b	3.60b	2.57b
Flora-Dade	3.74a	3.77b	3.77a
UF 71050-1	4.0a	4.84a	4.07a
UF A2050	2.8a	4.10b	2.87b
Reference	4.9a	4.9a	5.1a

[z]Mean separation by Duncan's multiple range test at 5% level of significance.
[y]Means within vertical groups followed by the same letter are not different at the 5% level of significance.

Of the samples evaluated, panelists preferred the higher viscosity samples and described the lower ones as "watery" and "diluted." Flavor from the juice obtained for the entries was scored consistently lower than the reference, however, only the Walter variety was statistically different. Comments on flavor included "tangy", "sour", "green", "rubbery", "bitter", and "chalky". Overall, panelists gave higher scores based on the consistency attributes of a particular sample than for its flavor.

In conclusion, the consistency of juice from these entries grown in Florida compared favorably with commercial juice brands, however, the soluble solids of the cultivars were significantly lower than the commercial juice and the flavor scores of the juices were lower.

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POTENTIAL WATER POLLUTION FROM CITRUS UNIT PROCESSING OPERATIONS, A REVIEW[1]

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Abstract. **During the 1978-79 season, the Florida citrus industry processed more than 8.5 million tons of citrus. Several estimates on the amount of water pollution generated during a processing season are reviewed. One estimate of the lost products is equivalent to 40 million pounds of biochemical oxygen demand (BOD) and an estimated loss of 26 to 56 million pounds of juice solids. Then pilot plant studies were conducted to check these estimates under carefully controlled conditions. Four tests were conducted. Volume and pollution measurements were kept on the waste loads generated from the unit processing operations.**

For the pilot plant studies, approximately 1,660 lb. of water was required to wash a ton of oranges and the water contained 0.04 lb. of BOD. Clean-up required approximately 1,580 lb. of water and generated 1.28 lb. of BOD per ton of fruit processed. The oil mill operation used 1,022 lb. of water per ton of fruit and had a potential oxygen demand of 28.6 lb/ton. The oxygen demand, for products which potentially reach the waste stream, ranged from 102 lb. of BOD per ton of grapefruit juice lost to more than 1,100 lb. of BOD for dry grapefruit peel. The pilot plant data support the generalized calculations on the potential water pollution loads.

How close are Florida's citrus processors to totally utilizing all of the fruit that is taken into their plants? The easiest way to answer this question is to estimate how much waste is generated per ton of fruit processed. For example, during the 1978-79 season, Florida processed 8.5 million tons of citrus (3). During the same season, Federal and State water pollution guidelines stipulated that no more than 0.8 lb. of biochemical oxygen demand (BOD) (as a maximum 30-day average) could be discharged per ton of fruit processed (4, 6). Calculating from the tons of citrus processed, the BOD discharged would amount to a maximum of 6.8 million lb. for a whole season. After July 1, 1983, the wastewater guidelines will become 6 times more restrictive, limiting the discharge to 0.14 lb. of BOD per ton of fruit processed or 1.2 million pounds for the season. The average of these 2 levels, 4 million lb., can be used to estimate the amount of discharge because processing plants are at varying stages of compliance (9).

This 4 million pounds of BOD is NOT the amount of waste load leaving citrus processing plants but rather it is an estimate of the waste load discharged from their waste treatment facilities. The efficiency of most waste treatment is approximately 90% as shown in a 3-year study where un-

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treated samples were measured with a level of 2,000 ppm chemical oxygen demand (COD) and 710 ppm BOD compared to treated levels of 130 COD and 110 BOD for a 94% COD and 85% BOD waste treatment efficiency (11). Multiplying the 4 million lb. of BOD by 10 (90% efficiency of the waste treatment plant) gives an estimated 40 million pounds of BOD lost from citrus processing plants during one season.

Black, Crow and Eidsness, 1970 (1) have stated in a study performed for the EPA that "In general, citrus processing wastewater may be considered as dilute solutions of citrus juice." Citrus juice has been found to have a BOD of approximately 94,000 ppm (2). This oxygen demand can be expressed as 0.78 lb. of oxygen per gallon of citrus juice of approximately 12.5° Brix and 1.1 lb. of soluble solids per gallon.

The estimated 40 million pounds of BOD discharged from citrus processing plants would be equivalent to the oxygen demand of 56 million pounds of solids or 51 million gallons of citrus juice. This is based on estimating the maximum amount of solids as juice. The *minimum* amount of juice solids would be one-half of this amount because approximately half the solids brought into a plant is in the juice and the other half is in the peel. So minimally, half of the 56 million pounds of solids could be valued as juice and half as cattle feed. (Juice, 28 million x $0.90/lb. = $25 million; 28 million ÷ 2,000 lb/ton x $115/ton = $1.6 million. Total value = $26.6 million).

This assumes that the majority of all the waste produced by a citrus processing plant came originally from the citrus fruit that was weighed as it came into the plant. The weight of this fruit is corrected for the amount of culls and trash.

These estimates can be compared to actual citrus industry studies. In the 1969-70 season, one plant processed 305,325 tons of fruit and discharged 3.26 lb. of BOD per ton to a city treatment plant (1). This was the strongest waste and represented only about 5% of the total wastewater discharged. Similarly Ratcliff (13) reported that approximately 8,454 gal of water per ton were needed in citrus processing. This water is normally segregated on a relative waste load basis. Approximately 10% of this water had the strongest waste load of 590 mg/liter of BOD. This is equivalent to 4.2 lb. of BOD per ton of fruit processed, based on ONLY the 10% strongest waste. The estimated waste load from these 2 studies is quite similar to that previously calculated.

Woodroof and Luh (16) estimated that processing 7.8 million tons of citrus used 23 billion gal of water, 3,000 gal/ton. The total load would be 31 million pounds of BOD or 4 lb. of BOD per ton of fruit processed. The Environmental Protection Agency (EPA) reports in one publication (5) an estimate of 4,300 gal of wastewater is generated per ton of fruit processed, and this waste had a load of 16 lb. of BOD per ton processed. In another publication, EPA estimated 3,000 gal/ton with 9.6 lb. of BOD/ton (6).

In an effort to validate these estimates, pilot plant studies were conducted under carefully controlled conditions in order to collect basic information on the various waste streams produced during citrus processing.

Experimental Methods

Materials. Three samples each of 'Marsh' grapefruit and 'Valencia' oranges, each weighing approximately 1,102 lb., were processed on 2 separate dates. Samples were taken during each of the following processing operations: Prewash rinsing of the fruit (PWR), after wash rinsing to remove the soap and dirt (AWR), and clean-up water from the floor and extractor. Composite samples were taken of the finished juice, oil emulsion, juice sacs, press liquor and dry peel. Samples of whole fruit were ground and analyzed. An additional analysis was carried out on oil mill effluent from a citrus processing plant. Details on the way the fruit was processed are described by Kesterson and Braddock (10).

Method. Samples were analyzed for total solids by drying in an oven at 176°F for 18 hr and the water pollution measurements, COD and BOD, were measured according to the Standard Methods for the Examination of Water and Wastewater (12).

Results and Discussion

Approximately 1,586 lb. (190 gal) of water were used in the combined prewash and after wash rinse per ton of grapefruit (Table 1). Although this is a large volume of water, it has a small pollution load; a combined BOD = 0.04 lb/ton of fruit washed. This shows that the contribution to the waste load by sand, leaves, sooty mold, etc., is relatively small. Similar results have been found in plant scale tests where the cleaning of fruit may require as much as 37% of the total water demand but contain only 1% of the BOD load (9). In another study, commercial brush washers were found to use 500 lb. of water per minute and generate a BOD of 1,000 ppm or 3,300 ppm COD (13). Fruit washing was also reported to consume 982 lb. of water per ton of fruit washed. With the large consumption of water and low waste load, there have been numerous studies on potential recycling of this water (7, 8, 9) which will have the affect of decreasing the consumption of water but increasing its waste load.

The amount of water used to clean-up a processing plant can be almost as much as that used in fruit washing. For oranges, 1,580 lb. of clean-up water used per ton of

Table 1. Chemical oxygen demand (COD) and biochemical oxygen demand (BOD) values of 4 citrus processing operations (based on processing 1 ton of fruit).

Processing operation		Lb. of waste per ton	COD ppm	Lb. COD per ton of fruit	BOD ppm	Lb. BOD per ton of fruit
Prewash rinse	GF[z]	804	68.2	0.05	14.8	0.01
	O	932	83.3	0.08	18.3	0.02
Afterwash rinse	GF	782	263	0.21	43.5	0.03
	O	744	335	0.25	73.2	0.05
Clean-up water	GF	866	1,640	1.42	929	0.81
	O	1,580	1,470	2.33	807	1.28
Oil emulsion	GF	622	28,700	17.9	16,400	10.2
	O	1,022	27,900	28.6	10,800	11.1

[z]GF = 'Marsh' grapefruit; O = 'Valencia' oranges.

fruit processed (Table 1). Unlike fruit washing water, the clean-up water contained appreciable amounts of peel, juice and other solids causing a BOD of 1.28 lb/ton. In an actual in-plant study 1,390 lb. of clean-up water were used per ton of fruit processed (7), and another report states that as much as 35% of the waste treatment load may be generated during clean-up operations (9). However, a plant running a few hours at a little more than half its capacity will probably require almost as much water to clean-up as a plant running all day at full capacity. There are a number of suggestions for minimizing the waste load during clean-up operations (7, 9).

The oil mill operation used 1,022 lb. of water per ton for oranges, with a COD of approximately 28,000 ppm with a potential of 28.6 lb. of COD per ton of fruit. In an in-plant study, the oil mill aqueous discharge from 'early-mid-season' oranges had a COD of 35,100 ppm and 'Valencia' aqueous discharge had a COD of 23,175 ppm. This commercial study went on to state that there was a COD demand of 23 lb/ton for 'early-midseason' and 22.8 lb/ton for 'Valencia' (15). In a separate study, it was determined that 40% of the total BOD and only 12% of the water flow could come from the oil mill (9).

In a separate experiment, samples of industrial oil mill effluent were analyzed. The aqueous discharge from the desludging centrifuge had a COD of 55,300 ppm, 0.45% oil by volume and 4% total solids (% TS). The sludge from this centrifuge had a COD of 497,000 ppm, 15.6% oil by volume and 6.4% TS. The sludge from the polisher had a COD of 1,120,000 ppm, 55.2% oil and 50% TS.

The loss of 1 ton of orange juice down a drain represents the loss of 196 lb. of solids and a COD demand of 212 lb/ton of juice (Table 2). The BOD, COD and % TS give an indication of the oxygen demand for each product. The huge COD and BOD for ground peel indicate the importance of keeping it out of the clean-up water. The press liquor from grapefruit peel has a BOD load of 59,000 ppm (Table 2). This value is lower than another study where press liquor was found to have BOD ranging from 100,000 to 185,000 ppm (9). This range of values is probably due to differences in manufacturing practices.

Dry peel has the highest solids of these 6 products and it also has the greatest oxygen demand when it gets into a waste stream. The dry orange peel had a COD demand of 2,360 lb. per 2,000 lb. of peel.

Two other products, not shown in Table 2, which have large oxygen demand are d-limonene and cold pressed oil. We found pure cold pressed oil to have a COD value of 1.2 million and a BOD value of 1 million. This is equivalent to a BOD demand of 2,000 lb. per ton for the pure cold pressed oil.

The oxygen demand of whole oranges and grapefruit is shown in Table 2. For every ton of fruit taken into a processing plant that is not made into a salable product, an oxygen demand load of approximately 300 lb. of COD and 200 lb. of BOD per ton of fruit occurs. This emphasizes the importance of the loss of even a ton of raw material.

A considerable amount of study has been conducted on the water pollution load and volume from juice and molasses evaporators (Table 3). Most previous studies examined evaporators without considering the barometric water used to pull the vacuum. A study showed that the amount of barometric water needed was approximately 10 times the amount of condensate (14). So when 871.3 lb. of condensate water was produced from evaporating the juice from 1 ton of fruit, then 8,713 lb. of barometric water was needed. Less than half the citrus plants recycle their barometric water (9). There was no information on the barometric water used in molasses evaporators.

The waste loads from evaporators have a large range of values (Table 3). Part of this variation is due to differences in the evaporator operation. Using an essence recovery and a vent condensing system has been found to reduce the pollution load (14). Recycling the barometric water builds up its waste load but the cooling towers remove some of the volatile components and reduce the waste load (8).

This paper presents findings from pilot plant data and published commercial scale information that significant amounts of waste are generated per ton of fruit processed. This indicates NOT all the fruit taken into a plant is actually used. Processing citrus will probably always generate some level of waste. Processors must develop their own figures by looking at water consumption, BOD loading and fruit receipts. Then they will know how much of the fruit delivered into a plant is actually used.

Table 2. Chemical oxygen demand (COD) and biochemical oxygen demand (BOD) values of 6 citrus products.

Sample		% total solids	COD, parts per thousand[z]	Lb. COD per ton of sample	BOD, parts per thousand[z]	Lb. BOD per ton of sample
Fresh juice	GF[y]	8.0[x]	77	154	51	102
	O	9.8[x]	106	212	69	138
Finisher pulp	GF	9.7	99	198	64	128
	O	14.9	171	342	89	178
Ground peel	GF	15.9	158	316	103	206
	O	17.9	204	408	101	202
Press liquor	GF	8.9[x]	152	304	59	118
	O	8.8[x]	96	192	63	126
Dry peel	GF	90.1	861	1,722	554	1,108
	O	90.1	1,180	2,360	440	880
Whole fruit	GF	12.4	130	260	89	178
	O	16.8	187	374	104	208

[z]Each value multiplied by 1,000 = ppm COD or BOD.
[y]GF = 'Marsh' grapefruit; O = 'Valencia' oranges.
[x]Expressed as °Brix.

Table 3. Water pollution generated during juice and molasses evaporation (based on processing 1 ton of fruit).

References	Juice evaporator		Molasses evaporator		
	Condensate	Barometric	'Clean' condensate	'Scrubber' condensate	Barometric
		Volume in lb/ton			
7[z]	788		278	278	
8	871.3		362.8	362.8	
14		8713			
		Load ppm			
8 COD	10,500		11,000	3,050	
BOD	3,930		8,334	1,224	
14 COD	500	60			
9 BOD (range of values)	35-3,930	20-150	495-1,220	614-1,224	150-200

[z]Refer to references in Literature Cited section.

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MODELING THE EFFECTIVENESS OF RELEASE®[1] AS A CITRUS HARVEST AID FOR 'VALENCIA' FRUITS[2]

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Additional index words. Citrus sinensis (L.) Osbeck, abscission, growth regulators, regreening, ethylene, uptake, absorption.

Abstract. **There is a significant interaction that occurs between temperature and uptake of Release®[1], between temperature and metabolism of Release and both differ with the physiological state of the fruit. Mature-green fruit have greater uptake and rates of metabolism of Release than orange-mature fruit. Release is an effective agent for stimulating peel tissue to produce ethylene and this production is very dependent on concentrations of Release in the peel. A critical level of Release per se in the peel tissue is required for ethylene production at a concentration and a duration to cause fruit loosening and abscission. Thus, the differential response between green-mature and orange-mature fruit is highly dependent on the rate of metabolism of Release and is a critical factor controlling ethylene production by the tissue. A model is presented to demonstrate the interrelations between environmental factors, particularly temperature; physiological state of the fruit; metabolism of Release; ethylene production and fruit abscission.**

[1]Release is a trademark registered by Abbott Laboratories.

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