COMPOSITION AND WASTE LOAD OF UNIT EFFLUENTS FROM A COMMERCIAL LEAFY GREENS CANNING OPERATION

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ABSTRACT

Analysis of data on composite waste loads from canning of collard, turnip, mustard, spinach, and kale greens revealed no significant differences among the five types of greens. For unit effluents from the dunker washers, reel washers, and blancher, significant differences were found for solids load and total acidity. The most concentrated effluent was from the tumbler fillers. It contained 16% of the composite COD load and 1.3% of the total flow. Segregation and separate treatment of this effluent was recommened. Washing and blanching operations accounted for 77% of the composite COD load and 90% of the flow. The average composite waste load for all leafy greens was 20.2 ± 5.7 lb./ton COD, 8.5 ± 2.8 lb./ton BOD, 2.8 ± 1.2 lb./ton suspended solids, and 2,666 ± 427 gal/ton waste water. These values are less than one-half of those previously reported for wastes from spinach greens. These results suggest possible improvement for in-plant control of waste from leafy greens, and may also be relevant to the setting of effluent standards for the fruit and vegetable industry.

A description of the composition and waste load of individual effluents produced from unit processes in the canning of leafy green vegetables is not currently available in the scientific literature. A complete report on the first phase of the survey conducted for the Environmental Protection Agency (EPA) by SCS Engineers of Long Beach, California on the Canned and Preserved Fruits and Vegetables Industry *(13)* has not yet been released. A second phase study of the fruits and vegetables industry which is being conducted for EPA by the Ben Holt Company of Pasadena, California is intended to develop the data needed to make a verifiable determination of effluent guidelines. The National Canners Association (NCA) and American Frozen Food Institute are conducting a Food Processing Industry Survey in parallel to the EPA study which, when published, will include data on spinach greens.

It appears that most published data on wastes from leafy green vegetables are based on surveys and estimates by the National Canners Association *(5, 8, 10, 12)* of composite waste effluents. The reported volumes of waste water from spinach processing ranged from 8.4 to 9.0×10^3 gal/ton. The total waste loads of biochemical oxygen demand (BOD) and suspended solids were reported as 25-28 lb./ton and 10-18 lb./ton, respectively *(8, 12)*. The concentration of suspended solids in screened spinach effluents was reported to range from 90 to 580 mg/liter *(8)*. Gilde *(4)*, citing a report by Sanborn of the NCA Research Laboratories, gave the range of concentrations of suspended solids and BOD as 90-580 and 280-730 mg/liter. All of the above data apply to the final composite effluent from processing of spinach and not to any unit operation.

Some analytical data were reported by Streebin et al. *(14)* on unit effluents from the canning of leafy greens. The COD concentrations of blanching effluents ranged from 187 to 610 mg/liter, and those of packing effluents from 298 to 410 mg/liter. Estimates on waste generation in percentages from unit spinach processing operations were given by NCA *(8)* with the qualification given that the values were "estimated by experienced persons in the industry and are not carefully measured values." Cleaning and blanching operations generated the majority of the processing wastes.

The number of cases, basis 24 No. 303 cans, of leafy greens and spinach packed in 1971 in the United States was reported to be 4,443,000 and 7,675-000, respectively *(6)*. Assuming a conversion factor of 85 cases/raw ton, the pack of leafy greens and spinach in 1971 was 52,270 and 90,082 tons, respectively.

This study was conducted to characterize the waste components in unit effluents and determine the contribution of each unit processing operation to the composite waste load from the commercial canning of leafy green vegetables.

EXPERIMENTAL

A flow diagram of a typical processing operation in the commercial canning of leafy greens is shown in Fig. 1. The effluents sampled, designated by letters A-F, and flow rates of each are shown The leafy greens, packed in ice, were trucked into the receiving shed, unloaded by a Durrand greens rake, and conveyed through a dry reel washer to partially remove ice and small debris. The greens passed over a grading table, through one of two dunker washers, and sequentially through two reel washers before entering the blancher. There was a continuous flow of fresh water into the dunker washers; a certain amount was removed with the product; and spent wash water was released intermittently

TABLE 1. WASTE EFFLUENTS FROM THE CANNING OF COLLARD GREENS

Effluent:	A	B	C	D	E	F	G
Processing operation:	Dunker Washers	Reel washers	Blancher	Chopper	Tumbler fillers	Receiving shed	Composite
Total solids, mg/1	895 ± 353[1]	735 ± 312	1,474 ± 684	4,725 ± 929	19,474 ± 2,264	866 ± 810	1,218 ± 457
Fixed solids, mg/1	260 ± 166	155 ± 65	527 ± 230	1,656 ± 475	6,949 ± 1,021	220 ± 189	362 ± 243
Volatile solids, mg/1	563 ± 359	456 ± 298	808 ± 374	3,070 ± 491	12,526 ± 1,817	654 ± 642	761 ± 238
Suspended solids, mg/1	261 ± 116	62 ± 22	64 ± 36	255 ± 35	1,214 ± 248	144 ± 93	91 ± 47
Dissolved solids, mg/1	634 ± 326	513 ± 151	1,203 ± 770	4,471 ± 897	18,162 ± 2,428	722 ± 749	1,127 ± 415
Settleable solids, ml/1	1.2 ± 0.7	0.1 ± 0.1	5.8 ± 12	4.0 ± 2.0	23 ± 12	1.7 ± 2.9	3.2 ± 5.8
pH	6.7 ± 0.2	7.0 ± 0.7	6.8 ± 0.8	6.1 ± 0.4	5.9 ± 0.3	6.9 ± 0.3	7.8 ± 1.5
Total acidity, mg/1[2]	20 ± 8	14 ± 5	48 ± 22	199 ± 32	793 ± 92	19 ± 11	24 ± 8
COD, mg/1	633 ± 268	325 ± 125	1,006 ± 404	3,148 ± 541	14,073 ± 3,292	346 ± 310	755 ± 275
BOD_5, mg/1	223 ± 115	122 ± 51	425 ± 141	1,542 ± 283	6,588 ± 1,334	111 ± 53	320 ± 76

[1]Standard deviation
[2]Expressed as mg/1 $CaCO_3$

TABLE 2. CHARACTERIZATION OF WASTES EFFLUENTS FROM THE CANNING OF TURNIP GREENS

Effluent:	A	B	C	D	E	F	G
Processing operation:	Dunker Washers	Reel washers	Blancher	Chopper	Tumbler fillers	Receiving shed	Composite
Total solids, mg/1	1,400 ± 186[1]	749 ± 123	1,729 ± 158	5,873 ± 371	12,421 ± 640	623 ± 286	1,364 ± 335
Fixed solids, mg/1	434 ± 86	228 ± 67	644 ± 89	2,091 ± 214	4,438 ± 604	208 ± 95	489 ± 183
Volatile solids, mg/1	966 ± 140	521 ± 74	1,085 ± 140	3,783 ± 152	7,982 ± 583	415 ± 219	875 ± 172
Suspended solids, mg/1	365 ± 128	118 ± 44	74 ± 39	272 ± 127	836 ± 425	61 ± 30	131 ± 68
Dissolved solids, mg/1	1,035 ± 125	631 ± 90	1,655 ± 164	5,605 ± 459	11,585 ± 656	562 ± 264	1,233 ± 289
Settleable solids, ml/1	5.3 ± 3.0	0.8 ± 0.8	0.8 ± 0.4	6.8 ± 4.2	29 ± 18	0.1 ± 0.1	2.0 ± 1.4
pH	6.7 ± 0.2	7.0 ± 0.1	6.7 ± 0.9	6.0 ± 0.1	5.7 ± 0.4	6.8 ± 0.2	6.6 ± 0.4
Total acidity, mg/1[2]	31 ± 5	20 ± 7	47 ± 8	256 ± 40	560 ± 80	29 ± 18	42 ± 16
COD, mg/1	1,080 ± 68	554 ± 80	1,059 ± 160	3,244 ± 340	6,912 ± 680	430 ± 781	855 ± 227
BOD_5, mg/1	336 ± 56	186 ± 43	470 ± 54	1,825 ± 279	4,406 ± 914	120 ± 86	365 ± 109

[1]Standard deviation
[2]Expressed as mg/1 $CaCO_3$

TABLE 3. CHARACTERIZATION OF WASTE EFFLUENTS FROM THE CANNING OF MUSTARD GREENS

Effluent:	A	B	C	D	E	F	G
Processing operation:	Dunker Washers	Reel washers	Blancher	Chopper	Tumbler fillers	Receiving shed	Composite
Total solids, mg/1	1,191 ± 215[1]	619 ± 198	1,834 ± 349	5,942 ± 912	14,278 ± 3,768	960 ± 399	1,305 ± 270
Fixed solids, mg/1	302 ± 96	135 ± 143	508 ± 143	1,705 ± 502	3,746 ± 1,118	300 ± 138	369 ± 174
Volatile solids, mg/1	883 ± 129	484 ± 140	1,346 ± 266	4,238 ± 596	10,532 ± 3,146	661 ± 259	936 ± 93
Suspended solids, mg/1	549 ± 136	123 ± 52	75 ± 28	341 ± 62	831 ± 104	127 ± 54	132 ± 50
Dissolved solids, mg/1	704 ± 200	496 ± 155	1,779 ± 356	5,696 ± 953	13,575 ± 3,535	480 ± 174	1,173 ± 248
Settleable solids, ml/1	4.2 ± 1.0	1.4 ± 1.2	0.6 ± 0.4	3.3 ± 0.5	8.8 ± 4.0	0.2 ± 0.1	2.0 ± 1.6
pH	6.4 ± 0.5	6.6 ± 0.5	6.5 ± 0.3	6.1 ± 0.1	5.8 ± 0.2	6.7 ± 0.1	6.3 ± 0.7
Total acidity, mg/1[2]	46 ± 26	22 ± 10	48 ± 6	186 ± 21	544 ± 210	28 ± 19	59 ± 36
COD, mg/1	1,143 ± 326	486 ± 198	1,533 ± 249	4,597 ± 733	11,650 ± 3,701	686 ± 375	903 ± 178
BOD_5, mg/1	329 ± 128	182 ± 75	654 ± 230	2,444 ± 290	6,881 ± 2,587	175 ± 75	421 ± 161

[1]Standard deviation
[2]Expressed as mg/1 $CaCO_3$

to be replaced by fresh water. Wash water from the reel washers ran in either of two directions to combine with the effluent from the dunker washers or the blancher. The blanched product passed over a grading table and through an Urshell chopper, 1/4 inch cut. The chopped greens were conveyed into Solbern tumbler fillers for 303 × 406 cans and 401 × 411 cans. Large 603 × 700 cans were filled with an FMC Hand-Pack filler. Cap-off water was added and the cans were then sealed and processed in a vertical retort. Cooling water from retorts and a large oval tank was discharged separately from processing wastes to a small creek.

A weir and flow meter were used to measure the flow rate of the composite effluent. The equipment design and floor gutters leading away from the reel washers were such that the flow rate had to be estimated by the valve size on the water supply pipe. Effluents from the receiving shed, dunker washers, blancher, chopper, and fillers were estimated by measuring the rate of fill of containers of known volume. The flow of cap-off water was estimated by the rate-of-fill method. No chemical analyses are reported on this effluent because it did not contribute significantly to the processing waste load.

Due to design of equipment and floor gutters it was impossible to collect continuous flow data on unit effluents. Another uncontrollable factor was shut-down time on the processing line. However, once restarted, the processing line was fully operative in approximately 1 min. Consideration of these factors suggested that several grab samples for each type of greens from each unit effluent would give reliable data on the maximum waste load. Thus, 5 or 6 replicate samples (collected on different days) of unit effluents A-G, passed through a 20-mesh screen, were collected for collard, turnip, mustard, spinach, and kale greens. A total of 28 samples including replicates of each unit effluent collected during the 1972 and 1973 seasons for greens, were analyzed in duplicate for total, fixed, volatile, suspended, and settleable solids; pH; total acidity; COD; and BOD. The same methods employed in a previous study of pimiento wastes were employed *(1)*.

Production data, raw tons/hour processed, were obtained from plant records to express generation of wastes as pounds of waste component/ton of raw greens. The daily waste load data on individual samples for each effluent, waste component and type of greens were subjected to an analysis of variance. Means were separated by Duncan's multiple range technique *(7)*.

RESULTS AND DISCUSSION

The concentrations of waste components in unit effluents from the canning of collard, turnip, mustard, spinach, and kale greens are shown in Tables 1-5. Each mean value and standard deviation shown was derived from 5-6 replicate samples. While no specific comparisons between data in these tables are made, it is important to note that the most concentrated effluents were produced by the blancher, chopper, and tumbler fillers. The action of blanching and chopping, as expected, produced an increase in the concentration of waste solids. There was also increased waste generation caused by the rotating action of the tumbler fillers because the rotating perforated drum exerted a shearing force on the chopped greens. As a result, this effluent was extremely high in waste components. The mean values for COD concentrations in the blancher effluents ranged from 1,006 to 1,800 mg/liter. This range of values is higher than the 187-610 mg/liter reported by Streebin et al. *(14)*.

The ranges of mean concentrations of suspended solids and BOD in the composite effluents were 91-182 and 320-453 mg/liter, respectively. These values are similar to the ranges of 90-580 and 280-730 mg/liter reported by NCA *(4, 8)* for suspended solids and BOD, respectively.

The waste loads of total solids, volatile solids, suspended solids, total acidity, COD, and BOD for each processing effluent and type of greens are shown in Table 6. Analysis of variance was conducted in order to determine the significant differences of means for each type of greens on a particular effluent. Table 6 shows that the mean values obtained for effluents A-C contained significant differences, whereas the mean values for effluents D, E, and G were not significantly different at the 5% level. Comparison of the results obtained for effluents A-C revealed that the waste loads for spinach were consistantly high for those analyses showing significant differences in the mean values. This observation has important implications for processors of leafy greens, since the effluent standards for vegetable and fruit wastes to be set by the EPA will be based largely on the results of the Ben Holt Company study which has not been reported to include any greens other than spinach *(9)*. If the waste load from spinach is as great or greater than for other leafy greens, then an effluent standard for greens based upon spinach data would not discriminate against other leafy greens. Data reported here suggest that whatever pollution control technology is necessary to treat spinach waste would be adequate for waste from other leafy greens.

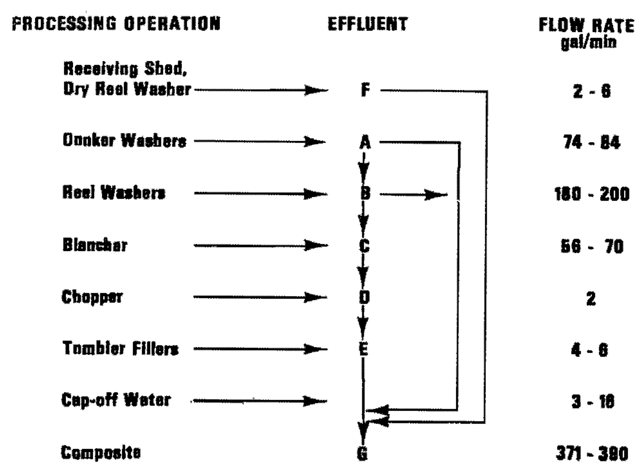

Figure 1. Flow diagram of unit processing operations, effluents, and flow rates in a commercial leafy greens canning operation.

TABLE 4. WASTE EFFLUENTS FROM THE CANNING OF SPINACH GREENS

Effluent:	A	B	C	D	E	G
Processing operation:	Dunker washers	Reel washers	Blancher	Chopper	Tumbler fillers	Composite
Total solids, mg/l	1,842 ± 490[1]	836 ± 221	3,103 ± 552	7,350 ± 755	17,574 ± 3,588	1,799 ± 352
Fixed solids, mg/l	452 ± 103	253 ± 92	1,369 ± 209	3,308 ± 144	7,290 ± 892	707 ± 115
Volatile solids, mg/l	1,391 ± 458	583 ± 166	1,933 ± 761	4,041 ± 758	10,283 ± 2,711	1,091 ± 282
Suspended solids, mg/l	973 ± 578	159 ± 28	171 ± 26	402 ± 60	1,023 ± 368	182 ± 63
Dissolved solids, mg/l	869 ± 132	677 ± 204	2,932 ± 538	6,948 ± 710	16,551 ± 3,354	1,617 ± 276
Settleable solids, ml/l	9.5 ± 2.8	1.1 ± 0.4	2.9 ± 1.5	12.4 ± 7.5	19.5 ± 11.8	2.1 ± 0.7
pH	6.5 ± 0.4	6.5 ± 0.2	6.6 ± 0.1	6.7 ± 0.1	6.5 ± 0.1	6.6 ± 0.2
Total acidity, mg/l[2]	36 ± 15	27 ± 7	60 ± 8	134 ± 17	325 ± 53	50 ± 19
COD, mg/l	1,322 ± 366	528 ± 155	1,600 ± 446	3,898 ± 810	10,138 ± 3,503	1,004 ± 218
BOD_5, mg/l	263 ± 37	185 ± 64	766 ± 249	1,815 ± 380	4,992 ± 1,926	415 ± 77

[1]Standard deviation
[2]Expressed as mg/l $CaCO_3$

TABLE 5. WASTE EFFLUENTS FROM THE CANNING OF KALE GREENS

Effluent:	A	B	C	D	E	F	G
Processing operation:	Dunker washers	Reel washers	Blancher	Chopper	Tumbler fillers	Receiving shed	Composite
Total solids, mg/l	972 ± 407[1]	623 ± 131	2,637 ± 1,313	7,062 ± 1,907	19,580 ± 2,776	274 ± 131	1,517 ± 520
Fixed solids, mg/l	226 ± 125	151 ± 88	980 ± 496	2,937 ± 1,525	6,735 ± 712	86 ± 64	492 ± 150
Volatile solids, mg/l	746 ± 284	472 ± 126	1,657 ± 822	4,146 ± 512	12,845 ± 2,100	188 ± 112	1,026 ± 404
Suspended solids, mg/l	339 ± 178	91 ± 14	185 ± 263	404 ± 76	1,288 ± 107	28 ± 19	114 ± 46
Dissolved solids, mg/l	633 ± 251	532 ± 123	2,452 ± 1,388	4,555 ± 2,696	18,292 ± 2,680	247 ± 122	1,404 ± 479
Settleable solids, ml/l	2.2 ± 1.2	0.3 ± 0.2	7.0 ± 10.2	10.7 ± 7.3	17.9 ± 10.0	0.1 ± 0.1	1.3 ± 0.8
pH	6.8 ± 0.2	6.8 ± 0.2	6.4 ± 0.2	6.3 ± 0.1	6.2 ± 0.1	7.2 ± 0.2	6.7 ± 0.2
Total acidity, mg/l[2]	20 ± 5	18 ± 3	64 ± 30	261 ± 66	680 ± 65	8 ± 3	38 ± 15
COD, mg/l	875 ± 400	467 ± 105	1,801 ± 924	5,310 ± 1,418	15,619 ± 1,976	131 ± 140	1,045 ± 433
BOD_5, mg/l	318 ± 191	171 ± 35	709 ± 152	2,276 ± 563	6,995 ± 1,036	38 ± 43	453 ± 202

[1]Standard deviation
[2]Expressed as mg/l $CaCO_3$

TABLE 6. THE PRODUCTION OF WASTE COMPONENTS FROM THE CANNING OF COLLARD, TURNIP, MUSTARD, SPINACH, AND KALE GREENS

Effluent	Processing operation	Type of greens[2]	Waste load, lb./ton[1]					
			Total solids	Volatile solids	Suspended solids	Total acidity	COD	BOD
A	Dunker washer	C	4.30bc	3.13b	1.08b	0.08b	2.90NS	1.05NS
		T	6.83a	4.60ab	1.78b	0.16ab	5.12NS	1.60NS
		M	6.49ab	4.85ab	2.83ab	0.19a	5.91NS	1.47NS
		S	8.37a	6.34a	4.54a	0.17a	6.03NS	1.18NS
		K	4.04c	3.10b	1.41b	0.08b	3.64NS	1.32NS
B	Reel washers	C	7.14b	3.95NS	.71d	0.15b	3.68b	1.46NS
		T	8.75ab	6.07NS	1.46b	0.24ab	6.47a	2.19NS
		M	6.83b	5.50NS	1.29bc	0.22b	5.11ab	1.73NS
		S	10.05a	7.00NS	1.09a	0.32a	6.34a	2.23NS
		K	6.94b	5.27NS	1.01cd	0.20b	5.20ab	1.90NS
C	Blancher	C	6.73b	4.55NS	.29b	0.22ab	4.59NS	1.87bc
		T	5.51b	3.43NS	.25b	0.15b	3.37NS	1.48c
		M	7.07b	5.12NS	.24b	0.18b	5.35NS	2.41abc
		S	13.26a	8.38NS	.72a	0.26ab	6.90NS	3.31a
		K	10.30ab	6.48NS	.26b	0.37a	7.04NS	2.77ab
D	Chopper	C	.60NS	.40NS	.03NS	0.02a	0.41NS	0.20NS
		T	.67NS	.44NS	.03NS	0.03a	0.36NS	0.21NS
		M	.79NS	.55NS	.04NS	0.03a	0.60NS	0.30NS
		S	.89NS	.49NS	.05NS	0.01b	0.48NS	0.22NS
		K	.79NS	.46NS	.04NS	0.03a	0.59NS	0.25NS
E	Tumbler fillers	C	5.11NS	3.35NS	.30NS	0.20a	3.75NS	1.73NS
		T	4.20NS	2.72NS	.28NS	0.18a	2.32NS	1.44NS
		M	4.83NS	3.60NS	.28NS	0.20a	3.83NS	2.25NS
		S	4.06NS	2.53NS	.25NS	0.08b	2.51NS	1.24NS
		K	4.37NS	2.87NS	.29NS	0.15ab	3.48NS	1.56NS
F	Receiving shed	C	.10ND	.08ND	.02ND	0.002ND	.04ND	0.02ND
		T	1.45ND	.97ND	.14ND	0.06ND	1.00ND	0.28ND
		M	2.28ND	1.58ND	.37ND	0.07ND	1.63ND	0.43ND
		S	—	—	—	—	—	—
		K	.03ND	.02ND	.003ND	.001ND	.01ND	.004ND
G	Composite	C	25.65NS	17.00NS	1.76NS	0.62NS	16.45NS	6.70NS
		T	30.34NS	19.67NS	3.14NS	0.94NS	18.79NS	8.07NS
		M	32.81NS	21.85NS	2.86NS	1.10NS	20.83NS	8.58NS
		S	39.91NS	24.20NS	4.02NS	1.08NS	22.29NS	9.27NS
		K	31.35NS	21.17NS	2.35NS	0.79NS	21.61NS	9.62NS

[1]Values followed by the same letter in each column and effluent are not significantly different at the 5% level.
NS, mean square values not significantly different at 5% level.
ND, significance not determined.
[2]C, collard greens; T, turnip greens; M, mustard greens; S, spinach greens; K, kale greens.

The only significant differences at the 5% level in the analytical results obtained on Effluent D from the chopper and Effluent E from the tumbler fillers were observed in total acidity. The results obtained for solids, COD, and BOD were not significantly different. In the case of the composite effluent, no significant differences at the 5% level were found among the different greens for any of the waste components shown in Table 6.

Based on these results, it would be statistically valid to average those data which were shown to be not significantly different at the 5% level. Although effluents A-C showed significant differences among the five types of greens for some waste components, the composite effluent did not. It was decided, for illustrative purposes, to average all of the data on a particular effluent to represent all leafy greens.

Table 7 shows the results obtained by averaging 28 samples of each unit effluent analyzed in duplicate. Standard deviation values are shown along with the means. The numbers in parentheses represent the percentage of the composite load of a specific waste component found in that particular unit effluent. For example, the average COD load contributed by the dunker washers was 4.7 ± 1.8 lb./ton which accounted for 23% of the composite waste load of COD.

A number of comparisons can be made between the percentages shown in Table 7 and those which were estimated by NCA. The flow of waste water from the dunker washers and reel washers accounted for 73% of the composite flow. NCA estimated cleaning water for spinach greens to account for 20-60% of the water usage *(8)*. The effluent from the tumbler fillers contained 16% of the composite COD load in only 1.3% of water flow. Thus, the processor could reduce the composite waste load of solids, acidity, COD and BOD by 14-19% by segregating this concentrated, low-volume effluent from the tumbler fillers and treating it separately. A simple physical-chemical treatment method, such as that reported by Bough and Shewfelt *(2)* to reduce the waste load of concentrated pimiento canning effluents could be applied to this effluent.

Considerable variation was observed in the load of suspended solids from the dunker washers. Spinach and mustard greens were significantly higher than the other greens (Table 6), but whether this is a real difference between types of greens is not clear. Other factors such as weather and growing location can have an effect. Intermittent dumping of the dunker washers as controlled by an operator appeared to be more a function of a subjective decision based on the condition of the greens than of time between dumpings. The dunker washers would be operated differently for greens grown on a muck farm than on a sandy loam soil. The variation of approximately 57% (with respect to the composite load) in the suspended solids load from the dunker washers accounts for the error in summing up the unit effluents; namely effluents A-F accounted for 158% of the composite load.

NCA estimated the generation of water, BOD or COD, and suspended solids from the blanching of greens to account for 10-40%, 30-60%, and 20%, respectively, of the total loads of these particular wastes *(8)*. Results obtained in this study averaged 17%, 28%, and 14% of the composite load of water, BOD, and suspended solids, respectively.

The results of this study present analytical data on the contributions of unit effluents to the loads of waste solids, acidity, COD, and BOD. Expressed as percentages of the composite waste load, the washing and blanching operations were shown to contain 77% of the composite COD load in 90% of the composite water flow. These results agree with NCA's estimates on spinach *(8)* which indicate that cleaning and blanching generate most of the waste load from the canning of greens.

Data presented in NCA reports on the total waste load from processing spinach greens gives the BOD and suspended solids loads as 25-28 lb./ton and 10-18 lb./ton, respectively *(8, 12)*. The results obtained in this study indicate that the BOD load for all greens was 8.5 ± 2.8 lb./ton, and the suspended solids load was 2.8 ± 1.2 lb./ton in the final or composite effluent. These figures are at least 50% less than those given by NCA *(8, 12)*. Admittedly, the present study has dealt with only one plant, but since it is the largest packer of leafy greens other than spinach in

TABLE 7. THE CONTRIBUTION OF UNIT EFFLUENTS TO THE AVERAGE COMPOSITE LOAD OF WASTE COMPONENTS FROM THE CANNING OF LEAFY GREENS

Effluent	Processing operation	Average Waste Load, lb./ton						Flow, gal/ton
		Total solids	Volatile solids	Suspended solids	Total acidity	COD	BOD	Waste water
A	Dunker (washers	6.0 ± 1.7[1]	4.4 ± 1.5	2.3 ± 1.6	0.14 ± 0.05	4.7 ± 1.8	1.3 ± 0.4	563 ± 93
	(% of Composite)	(19)	(21)	(82)	(15)	(23)	(15)	(21)
B	Reel washers	7.9 ± 1.8	5.6 ± 1.7	1.3 ± 0.3	0.23 ± 0.07	5.4 ± 1.3	1.9 ± 0.6	1,400 ± 220
	(% of Composite)	(25)	(27)	(46)	(25)	(27)	(22)	(52)
C	Blancher	8.6 ± 3.5	5.6 ± 2.7	0.4 ± 0.1	0.23 ± 0.10	5.4 ± 2.6	2.4 ± 0.8	459 ± 82
	(% of Composite)	(27)	(27)	(14)	(25)	(27)	(28)	(17)
D	Chopper	0.8 ± 0.2	0.5 ± 0.1	0.04 ± 0.01	0.02 ± 0.007	0.5 ± 0.2	0.2 ± 0.06	14 ± 2
	(% of Composite)	(2.5)	(2.4)	(1.4)	(2.2)	(2.5)	(2.4)	(0.5)
E	Fillers	4.5 ± 1.4	3.0 ± 1.0	0.3 ± 0.1	0.16 ± 0.06	3.2 ± 1.2	1.6 ± 0.6	34 ± 9
	(% of Composite)	(14)	(14)	(11)	(18)	(16)	(19)	(1.3)
F	Receiving shed	1.2 ± 1.1	0.82 ± 0.76	0.1 ± 0.2	0.04 ± 0.04	0.5 ± 0.5	0.2 ± 0.2	122 ± 138
	(% of Composite)	(4.8)	(3.9)	(3.6)	(4.4)	(2.5)	(2.4)	(4.6)
G	Composite	32.0 ± 8.6	20.8 ± 5.9	2.8 ± 1.2	0.91 ± 0.38	20.2 ± 5.7	8.5 ± 2.8	2,666 ± 427
	(Sum of waste loads, % found in A-F)	(92.3)	(95.3)	(158.0)	(89.6)	(98.0)	(88.8)	(96.4)

[1]The mean values and standard deviations shown were obtained by averaging 5-6 replicates for each type of greens: collard, turnip, mustard, spinach, and kale.

the United States, the results are significant.

The lower values obtained in this study may have a bearing on EPA's assessment of the "best practicable control technology," as required by Sections 301 and 304 of PL 92-500 *(11)*, and which apply to the reduction of processing wastes from greens. The summary report issued by EPA on the results of the SCS Engineers study projects the achievable effluent levels for the composite waste from spinach processing to contain 3.9 lb./ton BOD, 3.1 lb./ton suspended solids, and 16 lb./ton COD *(3)*. Corresponding values given by Jones who gives EPA as the source of his information are 3.1, 2.7, and 12.8 lb./ton, respectively, for immediate targets. Jones also gives eventual targets (as of 1976) for spinach of 2.0 lb./ton BOD and 2.7 lb./ton suspended solids *(5)*.

If the suspended solids load is as low as indicated in this study, then the achievable effluent level proposed in the SCS Engineers report to EPA *(3)* can be met with few changes needed in pollution control equipment. On the other hand, if assessments about "best practicable control technology" are based on needing to reduce the suspended solids load from 10-18 lb./ton *(8, 12)* to 2.7-3.1 lb./ton, a recommendation for solids reduction equipment may be necessary. While such considerations are less relevant to plants processing multiple lines of vegetables, they are of economic importance to those plants which only process leafy greens.

The results presented in this study should be useful to processors, consultants, and researchers concerned with in-plant control of vegetable wastes, and should also be considered by engineers and regulatory officials in the setting of effluent standards applicable to leafy greens.

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