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Waste Control and Abatement in the Processing of Sweet Potatoes

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WASTE CONTROL AND ABATEMENT IN THE PROCESSING OF SWEET POTATOES

By

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ABSTRACT

The conventional processing of sweet potatoes produces a very strong caustic waste that is high in organic matter. Present technology does not emphasize recirculation or other control of water use.

Improved technology is available such as high presure low-volume water sprays and a dry caustic peeling process that reduces water use and converts the liquid caustic waste to a semi-solid waste that can be disposed of in sanitary landfills, or sold as cattle feed.

Developing technology offers the potential of lye recovery, and improved steam peel or an infrared dry caustic peel that increases yield.

In-plant control of waste through process modification and/or treatment is economical and may even provide a net return on investment.

Biological treatment is effective.

The majority of the analytical data characterizing sweet potato processing wastes presented in this report were obtained from an in-depth study of one conventional sweet potato processing plant during the 1971 processing season. It was originally planned to follow this in depth study with a full scale demonstration of infrared dry peeling; water conservation through water reuse and high pressure low-volume sprays; in-plant waste separation and treatment; and end of pipe sequential screening, but the plant burned down and the project was terminated.

This report was submitted in fulfillment of Contract No. 12060 FRW by North Carolina State University under the sponsorship of the Environmental Protection Agency. Work was completed as of July 26, 1974.

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SECTION I

CONCLUSIONS

1. The conventional wet caustic method of peeling sweet potatoes (1971) utilizes excessive amounts of water.

2. Wet caustic peeling produces a very strong alkaline waste that is expensive to treat and to dispose of.

3. The disposal of caustic waste by spreading on agricultural soils may render the soils sticky, impermeable, and useless for agriculture. Caustic wastes have been successfully treated in biological treatment systems without neutralization but careful control is necessary.

4. Process modifications in the form of high pressure low-volume sprays and a dry caustic peeling process are in use and show cost advantages over conventional processes.

5. A dry caustic peeling process is in use in the industry that reduces water use by about 50% and reduces the BOD in the liquid waste stream by over 50%.

6. Potential process changes such as infrared dry caustic peeling and lye recovery have been shown to be feasible in laboratory tests.

7. In-plant control of wastes by screening and grit removal are simple processes that can reduce cost of waste treatment.

8. Sweet potato wastes are readily biodegradable but will probably require supplemental nitrogen in biological treatment processes. Phosphorus may be required.

SECTION II

RECOMMENDATIONS

1. Sweet potato processors should adopt water conservation practices such as high pressure low-volume sprays.

2. Recirculated water should be adopted in all preliminary washing processes.

3. Processors should adopt a "dry" caustic peeling process in order to obtain a waste that can be disposed of as a solid. Solids are less mobile than air or water and thus solid wastes are more economically attractive to handle than are liquid wastes. Under adequate ultimate disposal practices solids are less detrimental to the environment.

4. "In-plant" control of wastes by screening and grit removal are cost effective and should be employed in all plants.

5. Equipment manufacturers and processors should support a plant-scale test of the infrared dry caustic peeling process as a method of putting more product in the can and less in the waste stream.

6. Equipment manufacturers and processors should study further the steam peeling process to increase product yield and to reduce production of caustic wastes.

7. The use of biological treatment processes provides satisfactory treatment and the simplest method consistent with the size and scope of the cannery should be provided.

8. Continued exploration and development of by-products and by-product markets should be undertaken by the industry as an alternative method of controlling wastes and increasing profits.

SECTION III

INTRODUCTION

The sweet potato industry is located in the Southern, Middle Atlantic States, and California. The production and consumption of sweet potatoes reached a peak during the depression with 12.7 kg per person being consumed annually and 2,177,280.0 kkg per year being produced. The production and consumption have steadily fallen off since the 1930's to the present level of 3.18 kg per person being consumed compared to 68.0 kg per person for white potatoes. The sweet potato canning has expanded from 1.2 million cases processed in 1940 to 11 million cases processed in 1965. Since that time, however, the industry has remained steady at around 10 million cases per year. [1, 2]

The amount of sweet potatoes processed represents about 40% of the total crop grown, the remaining 60% being sold on the fresh market. As a general rule, roots with diameters 4.45 cm and greater are sold on the fresh market, while those less than 4.45 cm in diameter are sold to the canneries for processing. [2]

Processed sweet potatoes are sold principally as canned whole and/or cuts. In 1971 other products such as puree, wafers, or sweet potato flakes had a limited market value. These other products, however, represent an attempt to convert the potato into a saleable product and keep it out of the waste stream.

Canning sweet potatoes is a seasonal operation restricted largely to the fall months--from September through December. After December a few that have been stored are canned. This processing represents a "fill-in" operation and is primarily determined by market demand and the availability of stored potatoes. Seasonal operation is characteristic of most food processing plant. However, potatoes may be processed in late summer, fall, winter and spring, beans, peppers, and other vegetables in the summer and early fall, so that large plants can operate most of the year.

The profit in canning sweet potatoes is small and is dependent on low capital investment, low cost labor, and low overhead. Most plants use conventional wet causting peeling processes developed during World War II that require manual handling, sorting, and final trimming.

In a conventional plant, as much as 60% of the potato (or as little as 40%) [3] may be lost as waste. The gross pollution load from this waste is high, particularly in suspended solids and BOD. Table 1 gives the load from a conventional process after 20-mesh screening.[4]

TABLE 1

GROSS WASTE FROM CANNING SWEET POTATOES

Parameter	Waste Load From Processing * kg/kkg
BOD-5	12-39
COD	36-92
SS	4-24
Gross Water Consumption	10,000-12,000 l/kkg ** processed
pH	8.0 - 11.5

* Multiply kg/kkg by 2 to obtain lbs/ton **Multiply l/kkg by 0.24 to obtain gal/ton

Until recently, sweet potato wastes were simply discharged to streams and sewers, with only screening or sedimentation. The cost of waste control to a cannery was minimal and generated little concern.

Under present strict antipollution standards and regulations, however, the cost of waste control has become a serious concern. At an assumed cost of $0.111 kg ($.05 pound) of BOD-5 removed and $0.111 kg ($.05 pound) of suspended solids removed, the total cost of treatment for a cannery processing 100 kkg (220,000 lb) per day could range between $176 and $693 per day of production.

A trend in recent years has been to consolidate the canneries into large units with modern equipment and increasing mechanization in order to improve profits. In-plant water and waste control is also being utilized to reduce treatment costs.

New technology of waste abatement and control is directed toward in-plant changes in equipment and processes, more solid waste disposal, and pretreatment; all designed to reduce the amount of waste that must eventually be treated in the wastewater stream.

SECTION IV

CURRENT PROCESSING TECHNOLOGY

Traditionally the fresh sweet potato has been canned while the aged potato is sold on the fresh market. The difference between fresh and cured sweet potatoes becomes significant in processing. [5]

1. The skin of the fresh potato is thinner and more easily removed than that of the aged sweet potato. Accordingly, the sweet potato is processed while it is still fresh, and the aged sweet potato is canned only as a late season fill-in operation or as a way of meeting a high demand for the product.

2. The fresh potato has a higher starch content than the aged potato. Aging results in part of the starch being converted into sugar.

3. After canning, aged sweet potatoes tend to break down in the can and become more mushy than do canned fresh potatoes.

Peeling is the main source of waste and utilizes a caustic process to soften the sweet potato skin and outer layers to facilitate mechanical removal. The peeler itself is an abrasive device that wears away softened material of the potato, flushing it into the wastewater stream.

Current processing technology of sweet potatoes can be divided into two types: the conventional process and the improved process. The conventional process is characterized by high water usage and all waste is discharged into the wastewater stream. The improved process utilizes a dry peeling system characterized by lower water usage and disposes of much of the waste as a solid. Since solids are less mobile, they put less stress on the environment. It is also true that solids disposal by landfill is generally much cheaper than liquid waste treatment.

CONVENTIONAL PROCESSING

The conventional processing of sweet potatoes was adopted during World War II during a period of severe labor shortages. It is a wet caustic process that dumps all waste substances into the municipal wastewater plant for treatment or discharge. The process may be used for both white potatoes and sweet potatoes, though there are some distinctive differences between the two.

The basic steps of the conventional process are as follows:

Receiving and Unloading: The sweet potatoes are brought to the plant by truck and are commonly unloaded into a conveyer hopper using manual labor or a front loader. The potatoes are then dry cleaned on a vibrating screen where stones, some dirt, some of the small potatoes are removed. If the potatoes arrive wet, they are difficult to dry clean by screening.

Cleaning and Washing: After dry cleaning, the potatoes are washed in a reel washer consisting of a rotating drum and a water spray. As the potatoes go through the drum, they are rolled and sprayed. Approximately 5% of the gross weight of the potato trucked in from the field is dirt that is removed during the receiving and cleaning operations.

The receiving and preliminary cleaning operations generate a large amount of grit.

Peeling: The peeling process involves several steps.

1. Preheat: After the potatoes have been cleaned, they are preheated in a hot water bath at 50-65° C. (120° to 150° F) for 2 to 5 minutes. The preheating enchances peel removal and improves the appearance of the finished product according to some.[2,4]

Hot water overflows the bath and whole potatoes may float out of the preheater.

2. Lye bath: After preheating, the potatoes are immersed in a lye bath of 5 to 12% caustic, at 100-102° C (210° to 215° F) for 2 to 8 minutes.[4] The caustic softens the skin and outer layers of the potato and facilitates the peeling. The strength of the lye bath, skin thickness, and the condition of the potatoes determines the length of required exposure in the bath.

Normally fresh dug potatoes are canned. They have a thin skin. Potatoes which are stored develope a tough skin and a thick corky layer that is difficult to remove[5] and requires a harsher caustic treatment.

3. Peelers: After the lye bath, the potatoes are conveyed to a peeler. The sides of the rotating drum peeler are coated with sand-like abrasive. As the drum revolves, the peel is rubbed off along with some of the potato softened by the lye. As much as 40% of the potato may be removed during this process. The conventional wet-and-dry peeler then employs a high pressure water spray to remove the abraded potato peel from the side of the drum.

The waste from this process is very caustic and high in organic matter.

Snipping: The operation of snipping the ends of the sweet potato may be placed either before or after the lye peeling operation. The snipper is a device that mechanically cuts off the ends of the potatoes.

These ends then go into the clean-up stream. The mechanical snipping operation requires further manual labor to finish trimming the sweet potato.

Scrubbing: Scrubbing is a finishing and polishing process following the peeler and involves two steps.

1. Abrasive peeler: The abrasive peeler is a rotating drum, with a fine sandpaper surface to smooth the potato surface and remove the remaining skin and softened portion of the potato. Water is used to clean the sides and carry the waste to the treatment units.

2. Brush washer: The brush washer employs soft bristles in a rotating drum in combination with water sprays to polish the potato. The unit removes the last traces of caustic and imparts a sheen that is required for customer approval of the sweet potato.

The waste from the scrubbing operation is high in organic matter.

Trimming, Sizing, Slicing, and Grading: These operations follow scrubbing. Manual labor is used to inspect the potatoes and trim and discard the parts not suitable for canning. A rotating drum with different size slots separates the potatoes into the correct sizes for canning. The larger potatoes move through a series of slicers to reduce size before canning. Grading is a final inspection to insure acceptable size and color and requires the bulk of the manual labor used in the cannery.

The trimming, sizing, slicing, and grading operations generate a large amount of solid waste.

Filling: The potato, after grading, moves onto a circular or tumbler hand-pack filler with a series of can-size openings around the perimeter. The potatoes are raked into cans passing below the openings. Waste associated with this process is confined to spillage and can be discarded as a solid waste.

Syruping: The syrup used as a filler in the sweet potato can be principally a sucrose sugar (40-50%). [2] The old style of filling the can involved spillage. The syrup was continuously poured and the cans moved under the stream. This process caused wastage as one can was removed and another took its place. The waste from this operation enters the wastewater stream. A new method of filling the cans with syrup involves an automatic cut off on the syrup stream as the can becomes filled and moved forward. There is little or no spillage involved with this method. There is also a vacuum syruper in use that minimizes spillage.

Exhausting: The filled cans are exhausted, using steam to drive out any air and maintain proper closing temperature before the can is sealed. There is no waste.

Retorting: The retorts are the cookers. The waste associated with this operation comes from spilled syrup on the outside of the can. The potatoes are cooked in the can using superheated water under pressure. Water consumption during this operation accounts for nearly 40% of the total water used. [1]

Cooling: The cooling bath is a large tank through which the cans are moved after retorting and before packing for shipment. Little waste load is associated with this operation.

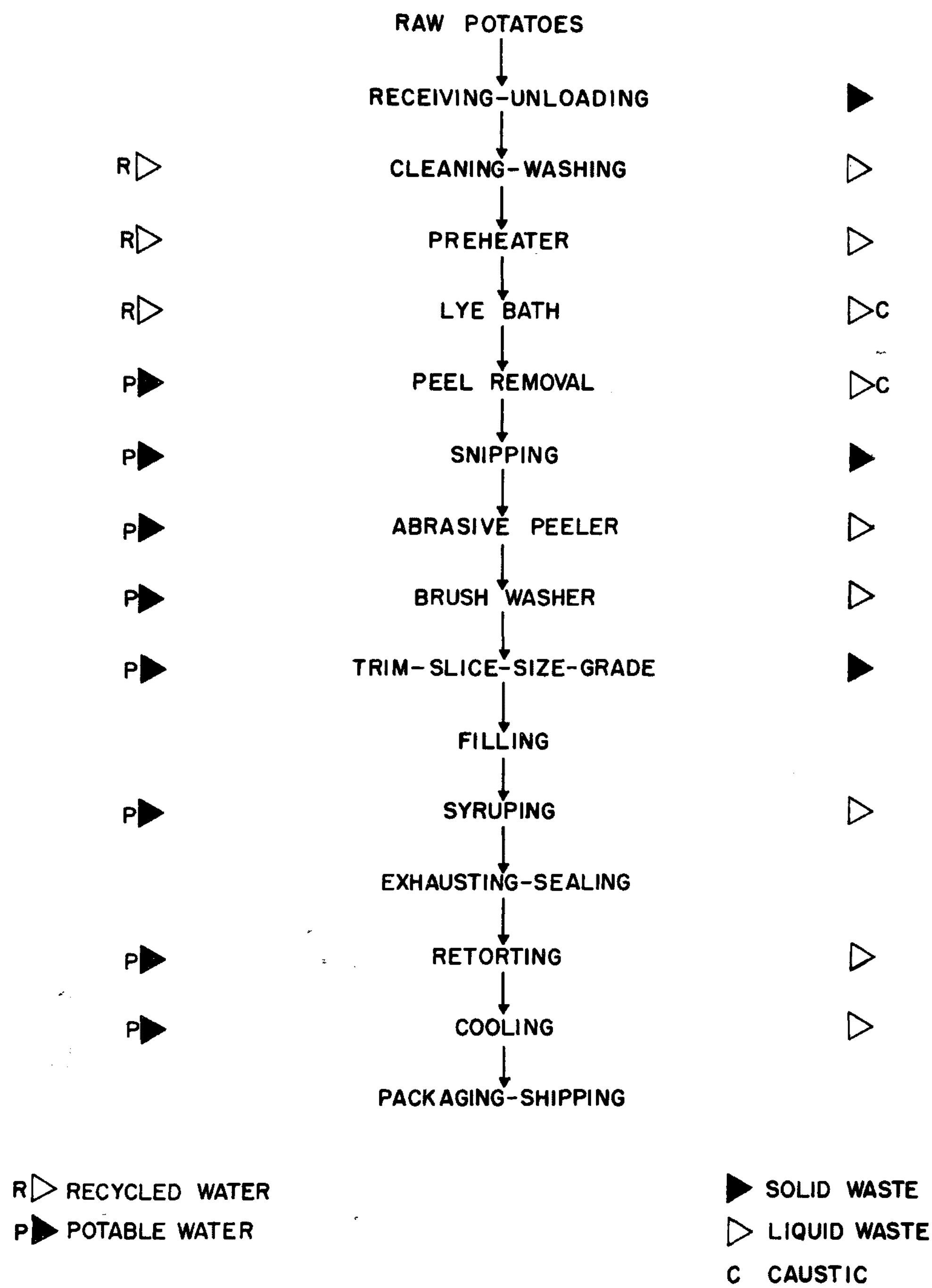
The water from the exhausting, retorting and cooling operation is relatively free of BOD-5.

Figure 1 shows the sequence of operations in a conventional sweet potato canning operation.

Arrow symbols in the left hand side of the diagram show the quality of water commonly supplied to each operation. Arrow symbols on the right hand side of the diagram show which wastes are normally liquified and which are normally solid state, and also the source of the caustic waste.

FIGURE I

WATER USE AND WASTE SOURCES
FOR A CONVENTIONAL SWEET POTATO CANNING OPERATION



For a conventional process, a mass balance of raw product is shown in Table 2.[4]

TABLE 2 *

MASS BALANCE FOR A SWEET POTATO CANNERY

5% of the raw product was field dirt

9.5% of the raw product was unfit for canning but was sold or given away for feed for swine or cattle

40% of the raw product was placed in cans and became a saleable product

25% of the raw product was placed into the liquid waste stream for the treatment plant

20.5% of the raw product was organic snips and solids that are partially removed by a 10-mesh screen and disposed of along with field dirt to land fill

The water use and the character of the waste from each of the processing operations has been studied by Colston and Smallwood[4] at Tabor City Foods which is operating a conventional cannery in Tabor City, N. C.

The schematic layout of the plant is shown in Figure 2. Water meters were installed at locations lettered A through L to measure the water use in the major processing operations. A six-inch Parshall flume was installed to measure the flow of cooling and retort water that was discharged untreated to a small creek. A nine-inch Parshall flume was installed to measure the volume of strong organic waste stream from the processing operations that was discharged to the city sewer.

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*A review of the data presented by the authors in reference 4 showed that the effect of recirculation had been overlooked. Thus, only 25% of the raw material appears in the waste stream after screening rather than the 33% originally reported.

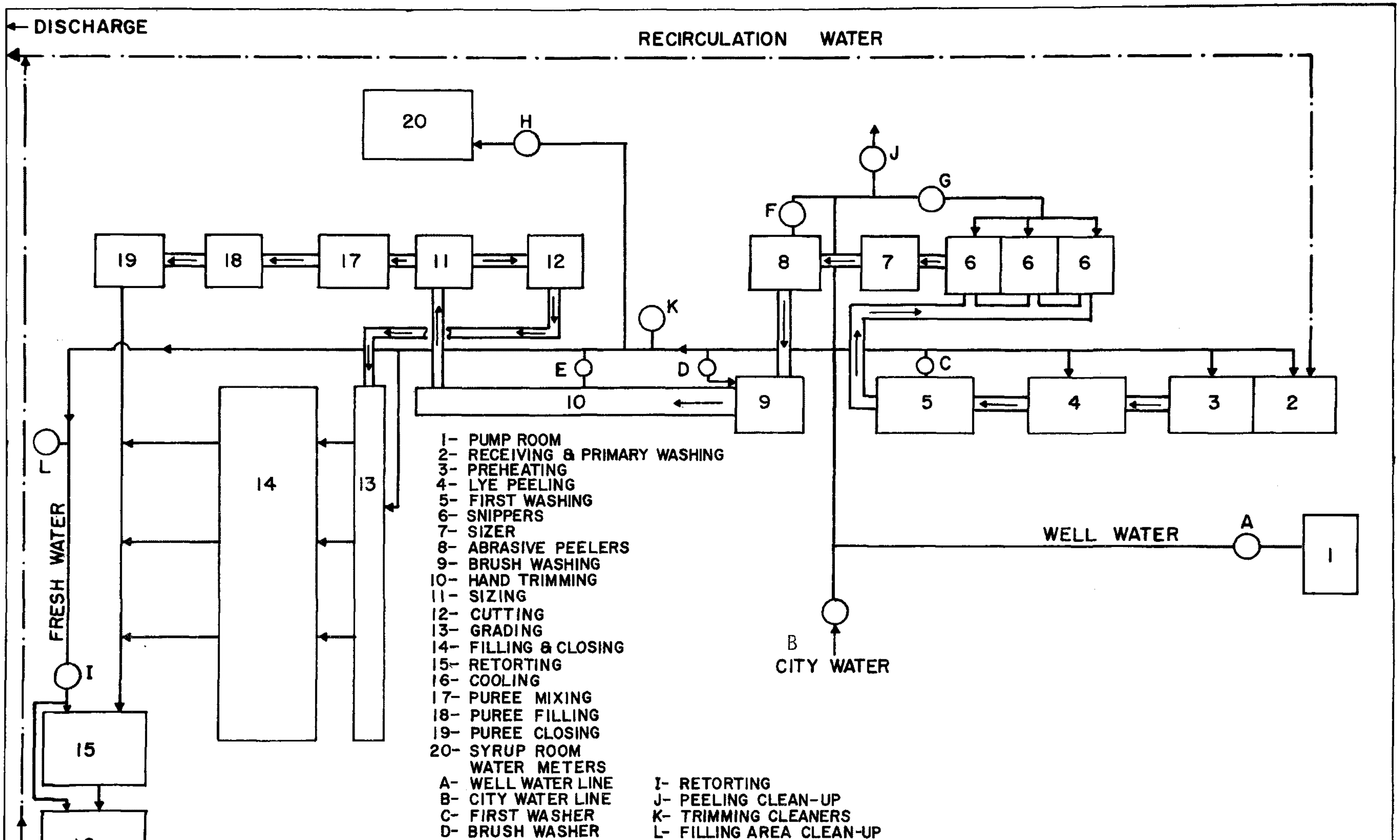


FIGURE 2. LOCATIONS OF WATER METERS AT TABOR CITY FOODS

The gross water use in the process operations is shown in Table 3.[4]

TABLE 3

GROSS WATER USE IN A CONVENTIONAL SWEET POTATO CANNERY PROCESS

Unit Process	l/kkg Input	l/Case *	% of Total Water Use
Cleaning and Washing	321.0	10.6	3.0
Preheater	63.0	2.0	.5
Peeling			
1. Lye bath	50.0	1.7	.4
2. Peel removal	1168.0	37.5	10.8
Snipping	459.0	15.1	4.4
Scrubbing			
1. Abrasive peeler	584.0	18.2	5.3
2. Brush washer	400.0	12.9	3.7
Trim, Slice, Size, Grade	Included in Cleanup		
Filling	" " "		
Syruping (goes into can)	150.0	5.0	1.4
Exhausting, Sealing	-	-	-
Retorting	4170.0	132.5	38.3
Cooling	259.0	3.8	1.1
Packaging - Shipment	0.0	0.0	0.0
Miscellaneous			
1. Boiler water	1732.0	56.8	16.4
2. Belt wetting	542.0	17.8	5.2
3. Cleanup	1002.0	32.6	9.5
	10,900.0		100.0 %

Note: Multiply l/kkg by 0.24 to obtain gal/ton
Divide l/case by 3.8 to obtain gal/case

* Can size - #2-1/2

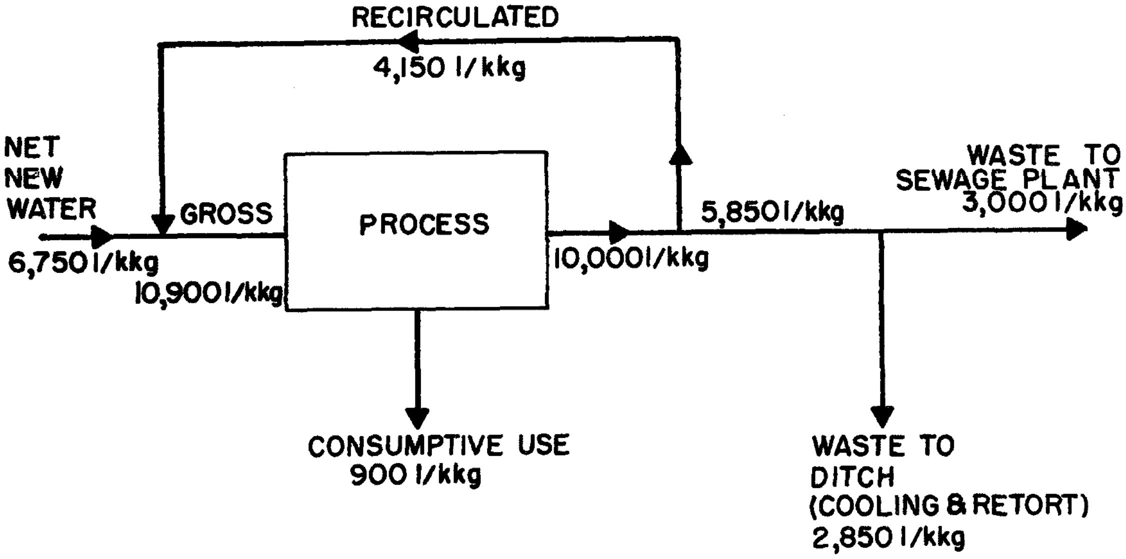
Almost 40% of the gross use is recirculated from retort and cooling operations to be used in the cleaning-washing, preheating and lye bath operations.

There is also a consumptive use of about 8% of the gross water applied to the process, part of which is to product and part to boiler evaporation.

Of the net water to waste a little over half goes to the sewage treatment plant after 10-mesh screening and grit removal. A little less than half of the net use is low BOD-5 cooling water that is discharged to a drainage ditch untreated.

The pattern of water use is shown in Figure 3.

FIGURE 3. RECIRCULATION OF WATER & SEPARATION OF WASTE STREAMS IN A CONVENTIONAL CANNERY



NOTE: MULTIPLY l/kkg BY 0.24 TO OBTAIN gal/ton

Tabor City Foods, Inc. personnel at the plant analyzed liquid waste composited from four grab samples from the principal operations each day during the Fall of 1971 canning season. The effluent to the city sewer was also sampled. This waste received screening through a 10-mesh screen and then before analysis was passed again through a 20-mesh screen.

Biochemical oxygen demand, total nitrogen, total phosphorus, total solids, suspended solids, and settleable solids were determined in accordance with procedures prescribed by the Environmental Protection Agency.[6] The chemical oxygen demand was determined in accordance with Standard Methods for the Analysis of Water and Wastes.[7] Nitrogen and Phosphorus in the waste were analyzed by the laboratory of the North Carolina Office of Water and Air Resources on single composited samples.

The concentrations of the wastes from the individual process streams are shown in Table 4. An independent check of the waste load was obtained from analysis performed on the effluent discharged to the city sewer. Then using the flows from Table 3 and the waste concentrations from Table 4 the waste loads per unit of product were calculated and are shown in Table 5.

The load from the individual processes adds up to 29.8 kg of BOD-5 per kkg (59.6 lb/ton) of sweet potatoes processed. An independent calculation from the strength of the effluent to the city sewer shown in Table 4 and the measured flows shown in Figure 3 yields a waste load of 27.7 kg of BOD-5 (55.4 lb/ton) per kkg of potatoes processed. The agreement is striking and perhaps fortuitous in view of the variability of the collected data.

A separate laboratory study[8] of the raw sweet potato showed that it averaged 76% water. When dried at 103°C (217°F) 1 kilogram of dried potato had a COD of 1.06 kg, a BOD-5 of 0.49 kg, a carbon content of 0.38 kg, a nitrogen content of 0.003 kg, and a phosphorus content of 0.0016 kg. To obtain comparable figures on a wet weight basis each of these figures should be multiplied by 0.24. Thus 1 kg of whole sweet potato would have 0.24 kg of dry matter, 0.254 kg of COD, 0.118 kg of BOD-5, 0.72 g of N and 0.4 g of P.

TABLE 4

THE STRENGTH OF CONVENTIONAL SWEET POTATO WASTES
AFTER 20-MESH SCREENING 4

Unit Process	BOD-5 (mg/l)			COD (mg/l)			Total Nitrogen as N(mg/l)			Total Phosphorus as P(mg/l)		
	M	s	n	M	s	n	M	s	n	M	s	n
Cleaning & Washing	990	680	8	3,700	2,560	9	12	7	3	1	1	2
Preheater	3,700	1,020	5	9,300	2,800	13	45	-	1	17	-	1
Peeling: Lye bath Peel Removal	13,000	4,600	13	32,000	9,400	19	320	210	4	40	19	4
Snipping	5,900	1,800	13	16,000	8,700	19	140	53	4	23	11	3
Scrubbing: Abrasive Peeling	14,000	3,750	11	22,000	10,400	19	330	175	4	50	12	4
Brush Washer	3,500	1,120	69	6,400	2,040	20	71	64	5	9	8	4
Retort	76	24	7	210	48	7	-	-	-	-	-	-
Cleanup	2,200	2,100	7	3,800	2,900	7	-	-	-	-	-	-
Effluent to City Sewer *	9,250	3,150	8	22,000	2,550	16	210	43	6	29	12	6

* Excluding Retort Waters

M - mean or average value
s - standard deviation
n - number of samples analyzed

TABLE 4 (continued)

Unit Process	Total Solids (mg/l)			Suspended Solids (mg/l)			Settleable Solids (ml/l)		
	M	s	n	M	s	n	M	s	n
Cleaning & Washing	2,100	2,320	14	1,200	475	6	28	9	20
Preheater	8,400	1,320	14	1,600	860	5	32	16	18
Peeling: Lye Bath Peel Removal	35,000	9,250	23	7,700	2,300	14	530	105	24
Snipping	13,000	3,100	21	3,800	2,200	9	280	110	20
Scrubbing: Abrasive Peeling	23,000	7,200	20	4,400	1,800	9	470	166	29
Brush Washer	4,300	1,650	17	1,200	1,300	11	74	34	30
Retort	300	39	8	-	-	-	-	-	-
Cleanup	2,700	590	3	870	210	5	-	-	-
Effluent to City Sewer *	26,000	18,000	13	3,800	2,600	6	250	130	25

* Excluding Retort Waters

M - mean or average value
s - standard deviation
n - number of samples analyzed

TABLE 5

WASTE LOADS FROM A CONVENTIONAL SWEET POTATO CANNERY[4] AFTER 20-MESH SCREENING

Unit Process	BOD-5 kg/kkg	COD kg/kkg	Total Solids kg/kkg	Suspended Solids kg/kkg
Cleaning & Washing	.32	1.2	0.7	0.4
Preheater	.23	0.6	0.6	0.1
Peeling				
1. Lye bath	Carried over to peel removal			
2. Peel removal	15.80	39.0	43.0	9.4
Snipping	2.71	7.4	6.0	1.8
Scrubbing				
1. Abrasive peeler	8.05	12.9	13.4	2.6
2. Brush washer	.14	2.5	1.7	0.5
Trim, Slice, Size, Grade	Included in the cleanup operation			
Filling	" " " " "			
Syruping	" " " " "			
Exhausting, sealing	" " " " "			
Retorting	.32	0.9	1.2	0.0
Cooling	0.0	0.0	0.0	0.0
Packaging - Shipment	Included in the cleanup operation			
Miscellaneous				
1. Boiler	0.0	0.0	0.0	0.0
2. Belt wetting	0.0	0.0	0.0	0.0
3. Cleanup	2.2	3.8	2.7	0.9
Total Waste	29.8	68.3	69.3	15.7

Note: Multiply kg/kkg by 2 to obtain lb/ton.

Table 5 shows that about 30 kg of BOD-5/kkg of sweet potatoes processed is discharged to the municipal treatment plant or that the BOD-5 discharged will amount to about 30% by weight of the potatoes. Since BOD-5 of whole sweet potatoes is about 12% by weight, it appears that at least 25% of the raw potato processed is delivered to the waste treatment plant in this conventional wet lye processing plant. Another 20% of the potato is removed by the 10-mesh screens (refer to Table 2) and disposed of along with the field dirt as a solid waste.

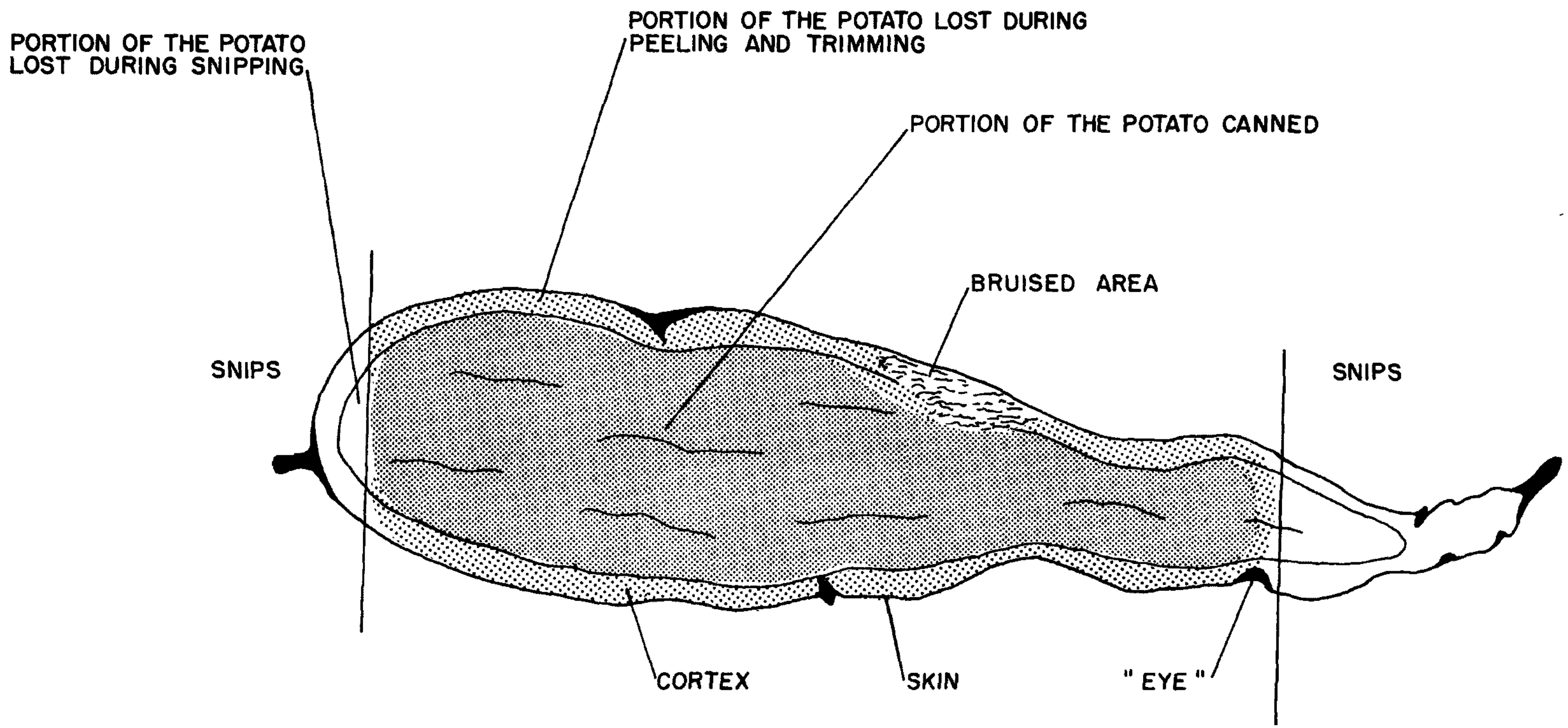
IMPROVED PROCESSING

In recent years the conventional wet caustic process has been abandoned in some plants for a dry peeling system. The system replaces the conventional wet peel removal and abrasive peeler and brush washer with a low water use "dry peeler" and a low water use brush washer. The low water content permits the waste from the peeler and from the brush washer to be disposed of either as a feed for cattle or hogs or as a semi-solid waste that can be buried.

The chief concern in the peeling operation is removing the eyes and skin of the sweet potato in order to produce a clean, saleable product. It is also important to remove the cortex layer, shown in Figure 4, that gives the canned potato a pasty look.

FIGURE 4

PORTIONS OF THE SWEET POTATO LOST DURING PROCESSING



The dry peeler equipment[9] employs rubber studs rather than the conventional sand abrasive on planetary rollers in a rotating drum. In concept the rubber studs are flexible and facilitate a more efficient removal of the potato eyes and the skin surrounding irregularities. Abrasion by contrast is not flexible and must remove all of the potato to the depth of the eye. Rubber studs may be provided in different length, sizes, and stiffness, allowing for interchange and combinations that provide the most efficient peeling operation. Magnuson[10] estimates that 45-50% of the raw potato will end in the can in contrast to only 40% by the conventional peel. The rapid rotation of the planetary rollers discharges the peel waste to the interior wall of a containing drum where it can be scraped off. Only a small quantity of water is needed to lubricate the planetary rollers. The waste can be disposed of as a semi-solid.

The washer is similar to the "dry-peeler" but employs nylon bristles in place of fingers to polish the potato and prepare it for the sorting, trimming, and slicing operation.

Inquiries were made of several canneries using the "dry-peeling" system. Inquiries to five plants elicited only 2 replies, In one case the canner reported that he had reduced his water use by about 50%. In another case the canner reported that all of the waste from his peelers and brush washer was being buried. However no data was provided so only estimates can be made of the improvement. Reference to Tables 3 and 5 permits the following estimates to be made of possible benefits from employing a "dry-peeler" system:

Gross water use can be reduced from 10,900 l/kkg to 5450 l/kkg (2620 gal/ton to 1310 gal/ton).

BOD-5 in the plant effluent can be reduced from about 30 kg/kkg (60 lb/ton) to about 6 kg/kkg (12 lb/ton) since the peeling and scrubbing waste is removed from the effluent stream and disposed of as a solid waste.

Table 6 tabulates the comparison of Conventional with Improved Technology.

Thus a dry-peeler system offers a means of eliminating the very caustic and very strong organic waste from the effluent. The remaining wastes are readily treated by a system as simple as spray irrigation or as complex as two stage activated sludge.

It would be desirable to have field data on waste reduction by the dry peeling process.

TABLE 6

COMPARISON OF CONVENTIONAL AND IMPROVED
PROCESSING TECHNOLOGY

Parameter	Observed Conventional Wet Peeling	Estimated Dry Peeling
Product Yield %	40	45-50
Water Use 1/kkg	10,900	5,000-8,000
BOD-5 kg/kkg	30	6-8
COD kg/kkg	68	13-15
Suspended Solids kg/kkg	16	4-6
Total Solids kg/kkg	69	10-15
pH	9.5-11.5	7-8

SECTION V

POTENTIAL PROCESSING CHANGES

The potential process changes have not been demonstrated successfully in full scale plant operations, and their value to the "state of the art" rests in their "potential." The following processes have been investigated on an experimental basis or have experienced some use in some part of the industry:

1. Steam peeling

2. Infrared dry caustic process

3. Lye recovery

4. By-product consumption

STEAM PEELING

Steam peeling has been reported to be successful on white potatoes.[11] However, personal communication from a major canner reported that a three-year trial of the process on sweet potatoes was unsuccessful.[12] The failure resulted from poor sheen on the potato as well as from erosion of valves by grit and gumming of feed parts by sweet potato latex. Steam peeling works well for other sweet potato products, such as flakes and puree, where sheen is not important.

The continuous steam peeler consists of a pressure chamber with an internal screw conveyor and feed and discharge valves. In operation, sweet potatoes must first be throughly washed in single or double washing units, depending on the amount of soil on the surface of the product. After washing, the product is conveyed upward on an inclined timing feed elevator and discharged through the pressure feed valve to the pressure chamber. The screw conveyor inside the pressure chamber carries sweet potatoes the length of the chamber. The product is subjected to steam under pressure to loosen the skin. At the discharge end, the product is transferred through a second pressure valve to a rotary washer, where loosened skins are washed off.

The batch peeler is equipped with a charging door and mounted on hollow axles to permit rotation of the peeler during operation. After charging with the proper amount of sweet potatoes, the door is closed and steam is admitted. After 30-45 second exposure to 4.2 kg/sq cm (60 psi) pressure steam, the steam is released rapidly from the pressure chamber, the sweet potatoes are discharged, and the softened tissue is removed by brushes or water sprays.

The steam pressure and the exposure time may be varied to regulate accurately the depth of heat penetration desired, depending upon the type and the condition of sweet potatoes.

Boyer[13] reported that superheated steam at atmospheric pressure was very effective in peeling both new and old white potatoes.

Eidt and MacArthur [14] compared the peeling losses on white potatoes from different methods and concluded that on the average the losses from steam peeling are 18%, lye peeling 17%, and 25% for abrasive peeling. Hammond [5] has reported that a peel and trim loss of 50% is common and that 40% is considered excellent for sweet potatoes in a conventional caustic peeler.

The reported advantages of steam peeling over conventional lye peeling are summarized:

1. Since steam attacks all surfaces of the product uniformly, the shape of the potato has minor effect on peeling efficiency.

2. Steam pressure and time of exposure can be easily adjusted to meet specific peeling requirements of a potato variety or condition.

3. No preheating step is required.

4. Elimination of caustic costs.

5. Elimination of caustic waste.

The disadvantages of steam peeling relative to conventional lye peeling:

1. High cost of continuous peeling equipment.

2. High maintenance cost.

3. Steam peeling leaves a heat ring on the peeled surface which is discernible in the finished product and usually reduces consumer acceptance except in products such as potato chips from white potatoes.

4. Steam peeling might result in discoloration, although, adequate cooling and post treatment can minimize this effect to a great extent.

5. The raw product must be absolutely free of grit to prevent abrasion of steam parts.

6. The latex exuded from broken and bruised potatoes gums up the steam parts.

INFRARED DRY CAUSTIC PROCESS

In 1967-68, Graham, Huxsoll, et al,[15] at the USDA's Western Utilization Research and Development Division, Albany, California, announced the development of a new method of peeling potatoes. Their peeling method was based on the application of infrared heat to light caustic treated potatoes followed by mechanical peel removal.

The infrared dry caustic peeling process for potatoes involves several steps. Wet-washed potatoes are immersed in a hot dilute lye solution. The excess lye is drained and the potatoes stand for about 5 minutes to allow the caustic to penetrate. Following the holding period, the potatoes are subjected to infrared heat for 1 or 2 minutes. The infrared heat activates the caustic and dries the surface layer of the potato. After conditioning by the heat, the potatoes are placed in a rubber-tipped mechanical peeler which removes the treated outer surface of the potato. Finally the potatoes are brush washed to remove a very small amount of soft sticky residue from their surfaces.

The gas-fired infrared heaters are of the type commonly used for space heating. Combustion takes place just in front of a ceramic mantle which radiates at 860° to 890° C (1550° to 1600° F). A nichrome wire screen protects the mantle from contact with the potatoes.

The peeling equipment consists of the dry peelers and scrubbers already described.

The advantages [15] of this process over the conventional wet process are reported as follows:

1. Lye consumption may be reduced 24% to 56%.

2. Overall water consumption may be reduced 20% by minimizing water sprays in the peeling and brush washing operations.

3. Raw product canned may be increased by 12% to 25% because of lower peel loss.

4. Waste control is enhanced by disposal of the peel as a solid waste.

The principal disadvantages of this process are:

1. The process has not been demonstrated on a plant scale on the sweet potato, although it appears to work well on white potatoes.

2. The process tends to leave a heat ring on the white potatoes that is undesirable in the finished product if exposure to heat is not carefully controlled.

3. Special conveyors are needed to rotate the potato as it passes beneath the infrared burners to insure uniform and complete exposure.

4. Additional capital expenditures for burners.

5. Unavailability of economical energy source for infrared units at all locations.

Huxsoll has conducted bench scale experiments at the USDA Western Utilization Research and Development Division, using a one-potato process. Pilot plant studies, also sponsored by USDA at a plant in Louisiana and at Tabor City Foods, N. C.,[16] studied the application to sweet potatoes. The results were reported favorable, but no full-scale experiment has been made.

LYE RECOVERY

A principal advantage of lye recovery is in removing it from the wastewater stream and reusing it. Many wastewater treatment problems are associated with caustic:

1. Sodium reacts with soil making the clays sticky and impermeable. Spray irrigation is not recommended[17] as a treatment process for a caustic waste water.

2. High caustic wastes may inhibit biological action unless completely mixed aeration systems are used.

3. High caustic concentrations tend to dissolve solid organic matter in the wastewater and increases soluble BOD and COD loadings.

4. Special facilities must be incorporated into the treatment system to handle high caustic wastes.

The use of a lye recovery system is not common to the potato processing industry, though it has been useful in mercerizing plants[18] of the cotton textile industry. It seems probable that the control of sodium discharge will sooner or later result in lye recovery.

A laboratory study demonstrated that the use of a rotary drum filter for reconditioning lye by removing solids and carbonate offered a potential for cost savings by reducing new lye consumption by 15% to 50%.[19] The lye was simply evaporated to concentrate to 12% total alkalinity after filtering. No difference in the quality of peel was observed in the laboratory.

BY-PRODUCTS

The use of by-products from the sweet potato processing operation offers the potential to partially recover costs associated with product wastage. Saleable food products such as puree, wafers, and instant sweet potato flakes have potential markets. At this time, only puree has gained any consumer acceptance. All the other products noted are feasible.

The solid wastes have also been studied as potential feed for cattle. White potato waste has been used extensively as an animal feed and has[20,21,22] the nutritional value equivalent to corn when fed to cattle. Laboratory studies to determine the potential of using sweet potato waste as cattle feed concluded that:

1. Feeding dried sweet potato waste to cattle is feasible.[23]

2. Cost of drum drying the waste, however, is too high at \$.044/1[24] of water removed for conventional waste in consideration of food value obtained.

3. Direct feeding of the waste from the dry peelers is possible if it is mixed with trim wastes and allowed to ferment for 24 hours to reduce pH to 9.0[25] because of high pH neutralization required.

4. Cost of drying the sludges from sweet potatoes is higher than that of white potatoes, so no direct comparison should be made between the two.

5. No animal feeding studies have been conducted to test acceptability of the product to animals.

6. Market conditions may well bring by-product materials into favor as feed sources.

SECTION VI

IN-PLANT WASTE CONTROL

In-plant waste control and abatement is directed at reducing waste discharges and water consumption. Techniques (discussed below) can be applied to almost every plant. Many are already used in recently built plants.

WATER RECIRCULATION

An operation in which recirculated water is clearly useful and beneficial is the reel washer. The water used in this process does not need to be of a particularly high quality. The primary source of grit in the wastewater comes from this washing of field dirt from the potatoes.

Recirculation systems should include a method of settling or hydrocloning to remove this grit to prevent excessive wear on the equipment. A simple settling basin is satisfactory.

In a conventional cannery as shown in figures 1 and 3 as much as 40% of the gross water applied in the process is recirculated from retort and cooling operations and used in the cleaning, washing, preheating and lye operations. Even so, a larger amount of relatively clean water is discharged without any required treatment to an open ditch. With chlorination this water could be used for belt wetting or for cleanup. Assuming that all of the clean water could be recirculated and reused 2850 l/kkg (675 gal/ton) plus 4150 l/kkg (1000 gal/ton) then new water could be reduced to 3900 l/kkg (940 gal/ton) which represents a 35% additional savings on water.

The application of counter flow principals would suggest that cooling water could be chlorinated and reused in retorts, peel removal, preheater and cleaning-washing operations. Then the return of water from the retorts to preheater and cleaning-washing operations would be efficient use of fuel.

WATER PRESSURE CONTROL

Conventional canneries allow water to flow without control in all operations whether potatoes are moving or not. High pressure low-volume water spray systems could be used in the conventional process for water conservation in the reel washer, the abrasive peeler, and snipper. The lowered use of water not only would serve to reduce the amount and cost of the water but also increases the concentrations of the waste and facilitates treatment. The total cost of installing high pressure low-volume water sprays should be determined in light of equipment costs, power consumption, water reduction, and wastewater treatment costs. An example calculation of cost effectiveness is included in the next section.

High pressure low-volume sprays could be used in all preliminary operations except the syruping and subsequent operations.

GRIT SEPARATION

Grit from the field dirt vibrated or washed from the potatoes is a significant problem in sweet potato canneries. The grit fills up basins, wears equipment, and clogs piping. Removal of this grit before waste treatment or pumping represents a savings in maintenance costs. Grit should be removed from any water recirculating system. It can be removed in settling chambers or through hydroclones located after the washer.

SCREENING

Conventional canneries often employ either 10 or 20-mesh screening of waste effluent from processing operations within the cannery and remove a very substantial amount of suspended solids from the total waste load. Screening of the combined plant effluent before discharge or treatment is also useful. Suggested screen sizes for each operation are summarized in Table 7.

TABLE 7

SUGGESTED SCREEN SIZES FOR SWEET POTATO CANNERIES

Operation	Size	Expected % Removal of Applied Suspended Solids
1. Receiving	6-10 mesh	est. 80%
2. First Wash	20-40 mesh	" 80%
3. Snippers	6-10 mesh	" 80%
4. Brush Washer	40-50 mesh	" 60%
5. Trimming, Slicing, Grading	20 mesh	" 80%
6. Combined Plant Effluent (after 10-mesh screening)		
a. Vibrating Screen	20 mesh	4 %
b. Rotary Screen	120x600 mesh	60 % - 90%
c. Single Screen	20-50 mesh	20 % - 40%

Following is a check list of locations and processes where screening or hydroclones should be considered for waste control:

1. Receiving: Vibrating screens or dry reels can be used during the receiving process to remove dirt and unusable potatoes. No water should be used with this screen and the waste should be disposed of as a solid waste.

2. First Washing: Mud that is not removed in receiving and unloading is the primary waste from the first wash. Other materials, however, may be present. Sticks, roots, leaves, debris, small potatoes, etc., may be easily screened.

3. Snippers: The snipping operation involves cutting off the ends of the potato. The snips are relatively large and easily screened.

4. Brush Polishers: The brush polishers create suspended solids not easily removed by screening. The solids consists of bits of peeling and a sticky outer portion of the potato. Screens for this operation must be self-cleaning.

5. Trimming, Slicing, Sizing, Grading: The wastes from this operation will be solids, consisting of discarded portions of the potato.

6. Combined Plant Effluent: Screening of a combined plant effluent and plant cleanup water can remove many solids that escape other processes. Laboratory studies by Swope[26] indicated that a vibrating screen followed by a rotary screen, could remove about 60% of the suspended solids. The authors are not aware that this combination is used in sweet potato canneries. Screens used in this process should be self-cleaning. Other studies by Hamza[19] showed that 90% of the suspended solids could be removed when 2% fly ash was added to the waste.

The value of screening can be measured in terms of treatment cost reduction. A waste pretreatment system consisting of a vibrating screen followed by a rotating drum can remove approximately 60% of the suspended solids and BOD associated with these solids. The cost saving is determined by the difference between costs of in-plant waste collection and disposal and the charges assessed by the city for treatment of these solids.

SECTION VII

COST EFFECTIVENESS OF WASTE CONTROL

INTRODUCTION

In many cases, adoption of waste control and abatement measures not only reduce pollution but provides savings (profit) to the cannery. Calculations made by Dr. W. S. Galler illustrate the point and are presented based on data for one conventional cannery company.[27] Each plant would have different figures but methodology would remain the same.

ASSUMPTIONS

1. Production rate in 1972 was 13.61 kkg/hr (30,000 lb/hr). The 1972 work day averaged 10 hours for six days per week for a six week season.

2. The adoption of the infrared dry peeler process will reduce the amount of lye required from 29 kg/kkg (58 lb/ton) to 9.65 kg/kkg (19 lb/ton) and will reduce the amount of potatoes required to maintain current production from 13.61 kkg/hr to 11.34 kkg/hr in accordance with estimates from USDA[10] and Magnuson Engineers, Inc.[15]

3. The costs offered by the processor are correct:
   Power @ $0.02/kwh
   Water @ $0.000105/1 ($0.0004/gal)
   Potatoes @ $40.85/kkg ($37.00/ton)
   Lye @ $0.154/kg ($.07/lb)

4. The maintenance cost of a system will be 10% of its original installed cost.

5. The systems may be amortized over a 10-14 year period at an interest rate of 10.5% (based on 1973 prime interest rate of 9.5%) using straight line amortization.

6. The system has zero salvage value at replacement time.

7. The municipal charge for the treatment of a unit weight of BOD and/or a unit weight of suspended solids from an industrial plant will be $0.11/kg ($0.05/lb).

8. A unit weight of dissolved solids will have the same ultimate BOD as a unit weight of suspended solids.

9. There is 0.49 kg of BOD per kg (0.49 lb/lb) of dry sweet potato solids.[8] (Based on NCSU laboratory studies of cleaned sweet potatoes dried at 103°C to constant weight.)

10. The cannery shown in Figure 2 discharges waste to the municipal treatment plant through a 10-mesh screen and a small sedimentation basin. Thus, the data of the mass balance shown in Table 2 shows that the system will prevent the dirt and snips (20.5%) from entering the effluent leaving the plant, but that 25% of the raw potatoes entering the plant will leave the plant in the waste stream.

11. The water use in the plant (1972) is shown in Figure 3 and in Table 3.

WATER RECIRCULATION

The data of Figure 3 shows that the plant reduces water consumption by reusing water from retorting and cooling for washing and peeling. The saving on the cost of water that is achieved by recirculation over a once-through system is readily calculated.

Cost of Water

Once through (10,900 x 136.1 x 36 x $0.000105)	$5,608
With Recirculation and Reuse (6,750 x 136.1 x 36 x $0.000105)	3,473
Net Saving on Water	$2,135

However, if it is necessary to add a pump and piping to achieve recirculation, the amortization of the investment must be considered. In another context, it was proposed that a high pressure, low-volume water spray system be added with costs as follows:

Pump	$1,500
Pipe and Nozzles	1,200
Installation	1,687
Capital Cost	$4,387

However, a recirculating system would still require a pump but only half as much pipe and none of the nozzles. Installation costs are estimated to be half as much without the nozzles and ancillary equipment, so that for a simple recirculation system similar to the one in the plant in 1972 costs are estimated.

Pump	$1,500
Pipe	600
Installation	843
	$2,943

Annual costs may be calculated.

Capital Cost x CRF (14 yr @ 10.5%)	$ 411
Maintenance	294
Power (522 kwh @ $0.02/kwh)	10
Annual Cost	$ 715
Water Cost with Recirculation	3,473
Total Annual Cost	$4,188
Savings over a once-through system ($5,608 - 4,188)	$1,420
Return on Investment (1,420 x 100/2,943)	48.25%

Thus, it is clear that the recirculation system is a good investment.

WATER CONSERVATION

The high pressure, low-volume spray nozzle system already mentioned was estimated to be capable of reducing gross and net water use by a third. The system would reduce water purchases from 6,750 l/kkg (1,620 gal/ton) to 4,498 l/kkg (1,080 gal/ton). The capital cost as previously noted was $4,387, but the increase in investment over that required to provide recirculation is only $1,444.

Annual Cost Increment	
Capital Cost x CRF (14 yr @ 10.5%)	$201
Maintenance	144
Power, assume no change	
Annual Cost	$345

Cost of Water	
(4,498 x 136 x 36 x $0.000105)	$2,312
Savings on Water ($3,473 - 2,312) (low-volume spray over recirculation)	$1,161
Net Annual Saving ($1,161 - 345)	$816

The return on the investment in the high pressure, low-volume feature is 816 x 100/1,444 = 56.5%

COMBINED RECIRCULATION AND CONSERVATION

The combined recirculation and high pressure, low-volume spray system would also yield a satisfactory return on investment.

Capital Cost = $4,387

Annual Cost	
Capital Cost x CRF (14 yr @ 10.5%)	$ 612
Maintenance	439
Power (522 kwh @ $0.02/kwh)	10
	$1,061
Cost of Water	2,312
Total Annual Cost	$3,373
Annual Cost of Once-Through Water	$5,608
Net Savings	$2,235
Return on Investment ($2,235 x 100/4,387)	50.95%

During the first year only it would be possible to take an additional 7% investment tax credit[28] that would improve the return. However, the savings could not be realized in future years and so is neglected in these calculations.

WASTE SCREENING

An existing 10-mesh screen and settling basin assures that rejected potatoes, dirt, and snips and trim wastes do not enter the liquid waste stream leaving the plant under conventional processing (Table 2). Twenty-five percent of the raw product still leaves the plant in the liquid waste stream. It was determined by Hamza[19] from laboratory studies that a two-stage screening system proposed by Swope[26] could remove a large fraction of this 25% leaving the plant. Sixty percent of the suspended solids could be removed by a rotating fine drum screen (600 x 120 mesh, 30 micron). The associated BOD was also removed. If 2% fly ash was added as a filter aid, 90% of the suspended solids and associated BOD could be removed. The BOD load is determined by multiplying the dry suspended solids by 0.49.

The cost of a two-screen system installed was estimated at:

System Cost	$43,216

The annual cost of the two-screen system was then estimated to be:

System Cost x CRF (10 yr @ 10.5%)	$ 7,185
Maintenance (at 10%)	4,322
Power (estimated)	300
Total Annual Cost	$11,807

The total charge for treatment to the processor (assume 10-mesh screening) by the municipal treatment plant was calculated.

Total Suspended Solids/Season Before Additional Screening
293,976 kg (647,000 lb)
(136.1 x 36 x 25% x .24)

BOD-5 of Suspended Solids at 0.49 kg/kg
144,048 kg (317,000 lb)

Estimated Annual Municipal Charge for Removal of Suspended Solids and BOD-5 without Two-stage Screen at Plant:
438,024 kg @ 0.11/kg (964,000 lb @ 0.05/lb) $48,183

If the in-plant pretreatment removes 90% of the suspended solids and associated BOD, the charge by the city for the remaining 10% would be $4,818. (The fly ash is assumed to be generated at the plant and thus free.)

The annual cost of pretreatment for 90% reduction would then be:

Screening System Annual Cost		$11,807
City Treatment Charge for Remaining 10%		4,818
Total Cost		$16,625
Charge without System	$48,183	
Charge with System	16,625	
Net Savings	$31,558	
% Return on Investment	73%	

If removal is only 60%, the total cost increases to $31,079 and the net savings would be only $17,106 for a return on investment of 39.5%.

In either case the investment in additional screens is worthwhile.

WASTE CONTROL BY PROCESS MODIFICATION

The use of process modification to control waste and abate pollution can be illustrated by the infrared dry caustic peeler system. Assumptions are the same as mentioned at the beginning of the section.

The estimated installed cost of an infrared dry caustic peeler system was $83,960. It was estimated that this process would change the yield of product[10] and nature of waste (from Table 2) as shown in Table 8.

TABLE 8

COMPARISON OF YIELD AND WASTE FROM CONVENTIONAL WET CAUSTIC PROCESS AND INFRARED DRY CAUSTIC PROCESS

	Conventional Process % Raw Potato	Infrared Process % Raw Potato
Yield	40	48
Dirt	5	5
Solid Waste	9.5	13.5
Snips	20.5	20.5
Waste to Treatment Plant after 10-mesh Screening	25	13

The solid waste from the infrared process will be added to the snips and screenings and removed from the liquid waste stream.

The two-stage screen of the previous paragraph without a filter aid is capable of further reducing the waste in the liquid waste stream leaving the plant from 13% of the potato (Table 8) to 5%.

The peel waste, which was formerly part of the liquid waste stream, will be part of the solid waste stream for the infrared dry caustic peeler system, thus increasing the solid waste stream from 9.5% to an estimated 13.5% of the raw potato weight.

If the current daily output was maintained, the raw potato requirements could decrease from 136.1 kkg per day (300,000 lb/day) to 113.4 kkg per day (250,000 lb/day). If raw sweet potatoes cost $40.85 per kkg ($37.00/ton), the net savings would be $33,351 per season. In addition, if lye costs $0.154 per kg, then it is estimated that the amount of lye needed[15] could be reduced from 29 kg/kkg (58 lb/ton) to 9.65 kg/kkg (19 lb/ton) for a net savings on lye of $12,165 per season. In addition, if the same through-put rate was maintained (13.61 kkg/hr), the work day for the peeling process will be reduced 16.7% for the same total output, but this is ignored in the calculation.

The additional cost analysis is given below:

Cost of New Infrared Dry Caustic Peeling System (13.61 kkg/hr)	$83,960
Annual Cost	
Cost x CRF (14 yr @ 10.5%)	$11,710
Maintenance (at 10% of cost)	8,396
Power (estimated)	1,000
Total Annual Cost of the New Infrared Dry Caustic Peeling System	$21,106
Waste Treatment Cost of Infrared Dry Caustic Peeler (based on 13% of the raw product ending up in the liquid wastestream after 10-mesh screen only)	
Suspended Solids (113.4 x .13 x 36 x .24)	127,371 kg (280,216 lb)
BOD of Suspended Solids (127,371 x 0.49)	62,412 kg (137,306 lb)
Treatment Cost at $.11 per kg (.05 lb)	$20,876
Waste Treatment Cost with Conventional Peel (10-mesh screening) (136.1 x 36 x 25% x 24% x (1+0.49) x 0.11)	$48,183
Net Reduction in Waste Treatment Cost by Adopting New System ($48,183 - 20,876)	$27,307

Comparison: Conventional Caustic Peeling System vs Infrared Dry Caustic Peeler Including High Pressure Water System and Screens but not Labor (annual costs based on six-week season)

1. Comparison of Peel Systems

	Conventional	New
Peel Equipment	Amortized	$ 11,710
Maintenance	$ 5,000 (est.)	8,396
Power	750 (est.)	1,000
Sweet Potatoes	200,105	166,754
Lye (136.1 x 36 x 29 x .154)	21,878	
(113.4 x 36 x 9.65 x .154)		6,066
Cost of Peel Systems	$227,733	$193,926

Net Saving ($227,733 - 193,926) $33,807

Yield on Investment ($33,807 x 100/83,960) 40.27%

2. Comparison of Liquid Waste Treatment Charges (after existing 10-mesh screen)

	Conventional	New
(136.1 x 36 x .25 x .24 x 1.49 x .11)	$48,183	
(113.4 x 36 x .13 x .24 x 1.49 x .11)		$20,876
Net Savings in Treatment Charge		27,307
Yield on Investment (27,307 x 100/83,960)		32.52%
Combined Yield (61,114 x 100/83/960)		72.79%

3. Effectiveness of Adding Two-Stage Screening to Infrared Peeling System

	Conventional	New
Annual Cost of Adding Two-Stage Screen	$11,807	$11,807
Treatment Charge after Additional Screen		
(136.1 x 36 x .25 x .24 x .4 x 1.49 x .11)	19,273	
(113.4 x 36 x .13 x .24 x .4 x 1.49 x .11)		8,350
Cost of Two-Stage Screen	31,077	20,157
Costs of Conventional vs Infrared Dry Peel plus Two-Stage Screening	258,810	214,083
Net Savings	$44,727	
Yield on Combined Investment $44,727 x 100 (83,960 + 43,216)	35.17%	

SUMMARY

These studies illustrate that pollution abatement and control through in-plant conservation and pretreatment and through process modification can be an effective way of reducing costs and increasing the return on investment.

SECTION VIII

WASTE TREATMENT

INTRODUCTION

Waste treatment costs can be minimized by careful attention to pretreatment in the plant. The disposal of solids by feeding to animals or by burial is economical and reduces the load on subsequent biological treatment units and, thus, should receive highest priority.

Capital investment in sweet potato waste treatment, may be limited by the seasonal operation of many plants. Accordingly, discussion will proceed from the simplest to the most complex. Only in very large plants should the two-stage biological treatment be considered.

Work has been done on the wastewater treatment of white potato wastes,[29,30,31] however, this work should not be directly related to the sweet potato because of the following differences in the two potatoes.

1. The white potato, on a weight basis, is about 21% dry material, while the sweet potato is 24% dry material. Consequently, the sweet potato may produce more solids and BOD per pound of peel loss than the white potato.[4]
2. A number-one peel (the requirement for a number-one peel is that the product be clean, smooth, and require a minimum of trimming) on white potatoes gives a weight loss of approximately 20%, while a number-one peel would waste approximately 25% of sweet potatoes. The increase in peel loss for sweet potatoes is caused in part by the thickness of the stringy layer under the skin that must be removed and in part by the tails that are removed.
3. Field data indicates a lye consumption of 13.36 to 26.72 kg (30 to 60 pounds) of caustic per ton of white potatoes peeled and a corresponding figure of 18.14 to 36.28 (40 to 80) for the sweet potato.[5]
4. Sweet potato processing is a seasonal operation, while the white potato industry is not. This means that any biological treatment scheme must be able to handle the tremendous shock load part of the year and yet survive during the off season.
5. Sweet potatoes are typically canned with syrup, whereas white potatoes are not. The overflow of syrup from the cans may contribute a substantial amount of BOD to a plant's waste stream.
6. Sweet potatoes when damaged exude a latex that is sticky enough to cause clogging of steam processing equipment.
7. The skin of the sweet potato thickens more than the white potato when stored.

CAUSTIC PEELING WASTE

The caustic peeling waste in conventional wet canneries should be separated from other wastes because of its high strength and high pH. It has been pointed out that "improved technology" and "potential technology" is directed at producing a low-water content peel waste that either can be buried or can be neutralized and sold for feed.

The high sodium content of the caustic peeling waste can destroy the structure of clay soils so these wastes should be applied directly to agricultural soils only with careful consideration of future use of the soils.[17]

The waste may be neutralized and/or held in a holding lagoon to allow anaerobic fermentation and carbon dioxide from the atmosphere to neutralize the excess caustic.

A neutralized waste may then be further treated in aerobic lagoons or in aerated lagoons. Loadings of different types of lagoons are noted in Table 9.

The high starch and other carbohydrate in the peel waste will ferment rapidly when the caustic is reduced below a pH of 10. The primary products of the fermentation are odorous volatile fatty acids. These products will definitely attract the unfavorable attention of neighbors. Accordingly, the waste should be given additional treatment as rapidly as possible.

NUTRIENT SUPPLEMENTS

High carbohydrate wastes are usually deficient in nitrogen and phosphorus, and these elements must be added when treatment is by biological processes. Sawyer[32] has proposed that nutrient ratios should be no larger than:

BOD to N = 32 to 1
and BOD to P = 150 to 1.

Higher ratios will result in bulking.

Unpublished studies by Tyler[8] show that for sweet potatoes the

BOD to N = 107 to 1
and BOD to P = 194 to 1.

In the same studies, white potatoes showed:

BOD to N = 130 to 1
and BOD to P = 137 to 1.

These figures suggest that for sweet potato, the waste is deficient in both nitrogen and phosphorus, while for the white potato, the waste is deficient in only nitrogen.

The amount of supplemental nitrogen would be 2.3 parts for each part in the sweet potato waste.

The amount of supplemental phosphorus would be 0.3 part for each part in the sweet potato waste.

Streebin, Reid, and Hu[11] found that supplemental nutrients were required at Stillwell Cannery Company to prevent bulking of the suspended solids in the aeration basins. Their work called for maintaining the ratio of total Kjeldahl-nitrogen to volatile suspended solids at 5%.

LAND IRRIGATION

Irrigation is popular as a method of treatment where low-cost land is available close to the cannery. Spray irrigation is readily adaptable to the new technology associated with the dry caustic peeler and in-plant waste control.

General concepts for a land irrigation system are as follows:

1. Agriculture requirements are about $7m^3$/day/ha (750 gpd per acre) for water to support crops in areas where rainfall is around 100 cm/yr.

2. Cultivated agricultural soils can take $28m^3$/day/ha (3000 gpd per acre).

3. Grassed lands may take up to $240m^3$/day/ha (25,000 gpd per acre). The upper limit is governed by the perviousness of the soil.

4. The sodium concentration of the wastewater should be low enough to prevent clogging of the soil. (Do not apply caustic wastes.)

5. One overland flow irrigation system operated at $67m^3$/ha/day (7200 gpd per acre) and showed a 6 ppm BOD in the effluent of a canned soup waste.[33]

6. The spray irrigation system used by a processor at Dunn, N. C.[34] treats wastes from a sweet potato processing plant employing "dry peeling." The treatment system has been in operation for two years (1973) without any operational difficulty. This plant discharges $45m^3$/ha/day (200 gpm) to a field planted primarily in fescue. The soil type is sandy clay loam. There is no runoff from the field and to date no evidence of groundwater contamination has been found. The plant showed investment of $250,000 in a 24.28 ha (60-acre) spray irrigation system or about $10,300 per ha ($4000 per acre). A large share of those costs was land acquisition. Operating cost (1972) have been estimated at $25,000 per year or about $1,030 per ha per year ($400 per acre) at a load of $45m^3$/ha/day (4800 gpd per acre).

ANAEROBIC LAGOONS

Anaerobic lagoons do not normally afford better than 50% removal of BOD-5 from cannery wastes (Porges[35]). However, they may be operated at very intensive loadings of 48 to 160 g/day/cu m (150-500 kg/day/ha in a 3 m deep lagoon). Accordingly, anaerobic lagoons offer a high degree of organic removal per unit area, but the effluents will require additional treatment to meet 1973 standards of performance.

Anaerobic lagoons are designed with small surface area and depths of ten feet or more to minimize loss of heat and escape of odorous volatile fatty acids that are produced. Dostal[36] reports that detention periods of 30 days are required to obtain the best treatment efficiency.

Deep ponds are subject to hydraulic short circuiting, that is, large amounts of waste may flow quickly through the pond without permitting time for decomposition. In addition, anaerobic processes require considerable time for the buffering capacity to build up, so that the fatty acids that are produced do not stop the decomposition reaction. Bulking or floating of suspended solids is another common difficulty that arises from the attachment of fermentation gas bubbles to suspended particles when gas production is very rapid.

Despite the low treatment efficiency and operating difficulties, anaerobic lagoons may be used as an economical use of surface area for preliminary treatment and as a treatment that can improve the settling properties and the dewatering properties of the colloidal solids from canneries.

AEROBIC LAGOONS

Aerobic lagoons with detention periods of as much as 37.5 days have afforded 98% removal of BOD-5 from canneries at loadings as high as 7.4g/day/cu m (20 lbs. per acre ft. per day)[35] (substantially lower than the reported loadings on anaerobic lagoons).

Very shallow lagoons, less than 1.22 m (4 ft.), depend upon natural surface aeration and algal production to supply oxygen. The loadings upon such ponds in warm sunny latitudes will range from 4g/day/cu m of BOD-5 in the winter to 12g/day/cu m of BOD-5 in the summer. At higher loadings, 85% removal is expected with detention periods of 30 days.

Deeper aerobic lagoons will be between 1 to 2 m deep (3 to 6 ft.). The bottom will probably be anaerobic, but enough oxygen will be supplied through the surface and by algal production that the dominant action will be aerobic. Loads as high as 36.8g/day/cu m of BOD-5 have been reported with removal efficiencies of 90%.[24] The aerobic-anaerobic action is commonly termed "facultative."

The aerobic and facultative (aerobic-anaerobic) ponds are subject to short circuiting and care must be taken to assure that flow is distributed uniformly to all parts of the ponds.

The ponds may become "attractive nuisances" to children and frequently must be fenced. Since the land requirements for potato canneries are high, the combined cost of land and fencing may force consideration of more intensive treatment.

AERATED LAGOONS (Completely Mixed)

In the context of this report, aerated lagoons are defined as simple earthen lagoons about 3 m (10 ft.) deep in which mechanical aerators are employed to transfer increased amounts of oxygen to the liquid waste. No provision for the separation and recirculation of biological suspended solids is included, since in this discussion it is assumed that they are discharged with the effluent.

The objective of an aerated lagoon is to provide a moderately high degree of treatment that requires less space and lower detention periods, than simple aerobic lagoons, and which can accept the fairly high unit loadings of plants such as canneries.

Dostal[36] reports 81% removal of BOD-5 at loadings of 183g/day/cu m and a detention period of less than eight days. The power input to achieve this degree of treatment was about 7.2 kwh/kg of BOD-5 removal. In this same instance the removal of soluble BOD-5 was 93% indicating that a more sophisticated treatment system with a final settling tank and provisions for solids disposal could improve the quality of effluent substantially.

The design and performance of completely mixed aerated lagoons are described by mathematical equations developed by both McKinney[38] and Eckenfelder[39].

AERATED LAGOONS (Incompletely Mixed)

In the "incompletely mixed" aerated lagoon an earthen lagoon of about 3 m depth is employed as in the completely mixed system.[37] However, a smaller mechanical aerator is employed so that complete mixing is not achieved. Part of the BOD-5 in the influent and synthesized suspended solids is removed by sedementation in the bottom of the basin and is not discharged with the effluent. Accordingly one would expect results somewhere between those of a simple aerobic lagoon and a completely mixed aerated lagoon.

An illustration may be taken from work by Dostal[36] on white potatoes. A small lagoon of 171 cu m capacity was loaded at 143g/day/cu m of BOD-5. A 3.7 kw aerator supplied 0.022 kw/cu m.

The removal of BOD-5 was 84% at a detention of 8.8 days. The power requirement was 0.023 kwh/kg BOD-5 removed.

Benjes[37] points out that performance of the incompletely mixed aerated lagoon is not completely predictable by the McKinney[38] or Eckenfelder[39] mathematical relationship.

TWO-STAGE BIOLOGICAL TREATMENT

Streebin, et al,[11] have reported a remarkable efficient two-stage process of aeration in presence of solids, that is, capable of removing 97% of the COD at loadings that are of the order of 27,000 kg/day/ha of BOD-5. (See Table 9) The energy requirement was of the order of 0.83 kw-hr per kg BOD-5 removed in comparison to the 7.15 kw-hr/kg reported by Dostal on aerated lagoons. Such a plant would be desirable in large canneries that operate on a year-round basis.

Schematically the plant consists of a preliminary aeration basin operated at 8,000 gms/cu m/day of BOD-5 for a detention period of 4.8 hours. The high load unit is followed by parallel extended aeration basins operated at 640 gms/cu m/day of BOD-5 for a detention period of 36 hours. A final clarifier designed at an overflow rate of 32.64 cu m/day/sq m provides 1.89 hours of settling at a weir loading of 124 cu m/day/m.

Solids are digested anaerobically in an open lagoon.

The system provides for recirculation of settled solids to either one or both of the aeration basins.

In practice, the first aerator basin operates with a mixed liquor suspended solids concentration of about 3500 mg/l at about 85% volatile solids. The solids do have a tendency to bulk, which is controlled when the total Kjeldahl nitrogen is raised 5% of the volatile suspended solids.

The extended aeration unit also operates at a high mixed liquor suspended solids concentration of over 3000 mg/l at 83% volatile solids.

A chemical feed unit provides 454 kg (1,000 lbs.) per day of supplemental nutrient to control bulking during the season when potatoes (both sweet and white) are processed. The feeder is operated until the total Kjeldahl nitrogen to volatile suspended solids ratio in the primary aerator reaches 5% (i.e., 180 mg/l per 3600 mg/l).

Dissolved oxygen in the primary aeration basin is maintained near 4 mg/l with two 56 kw aerators. Dissolved oxygen in the extended aeration unit is also maintained near 4 mg/l with 6 surface aerators (3 in each unit) of 30 kw each.

TABLE 9

SOME COMPARATIVE ASPECTS OF LAGOON TREATMENT SYSTEMS

	Spray Irri-gation	Anaer-obic Lagoons	Aerobic Lagoons	Incompletely Mixed Aerated Lagoons	Completely Mixed Aerated Lagoons	Extended Aeration 2-Stage*
Approximate Load Intensity gms/day/cu m	(25,000) $234 m^3$/day/ha	48-160	4-12	143	180	900
kg/day/ha	22-44	150-500 at 3m deep	5-15 at 1m deep	4,290	5,400 at 3m deep	27,000 at 2.5m
% Removal BOD-5	90	50	85.0	84	90	97
Detention Period Days	-	30	30.0	88	7-8	2
Power kwh/kg BOD-5 removed				4.3	7.2	0.83

*The design in the primary aeration basin is to transfer about 0.8 kg of oxygen per kg of BOD removed, and it is estimated that about 40% of the BOD will be removed at these high loadings.

The design of the extended aeration unit aims at transferring about 1.2 kg of oxygen for each kg of BOD-5 removed and about 60% of the load is removed in this unit.

SECTION IX

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16. Abstract

The conventional processing of sweet potatoes produces a very strong caustic waste that is high in organic matter. Present technology does not emphasize recirculation or other control of water use.

Improved technology is available such as high pressure low-volume water sprays and a dry caustic peeling process that reduce water use and convert the liquid caustic waste to a semi-solid waste that can be disposed of in sanitary landfills or sold as cattle feed.

Developing technology offers the potential of lye recovery, an improved steam peel or an infrared dry caustic peel that increases yield.

In-plant control of waste through process modification and/or treatment is economical and may even provide a net return on investment.

Biological treatment is effective.

This report was prepared to make available the data collected under the first phase of the Environmental Protection Agency's Grant Number 12060 FRW. The majority of the analytical data characterizing sweet potato processing wastes presented in this report were obtained from an in-depth study of one conventional sweet potato processing plant during the 1971 processing season. Grant 12060 FRW was terminated prior to initiating the second and final phase of the grant. The second phase was to be a full scale demonstration of infrared dry peeling; water conservation through water reuse and high pressure low-volume sprays; in-plant waste separation and treatment; and end of pipe sequential screening.

17a. Descriptors

Sweet potatoes, In-plant control, Waste treatment, Pollution costs, Chemical recovery.

17b. Identifiers

17c. COWRR Field & Group

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