WASTE CONTROL IN THE PROCESSING OF SWEET POTATOES

by

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INTRODUCTION

In North Carolina plans are underway to develop a vegetable processing industry to complement existing fresh market outlets. North Carolina grows about one third of the nation's total sweet potato crop and ranks second behind Louisiana in processing. This year three North Carolina plants are actively engaged in processing sweet potatoes. Last year there were four--one being forced to discontinue canning operations because of associated water pollution problems. If the vegetable processing industry is to grow in North Carolina, or perhaps even to continue to exist, new and/or improved methods and technology for coping with its local environmental impact must be developed.

Tabor City Foods, Inc., of Tabor City, North Carolina, processes approximately 45 percent of the State's pack. Located in an economically depressed community of 3,000, the plant provides employment for about 500 people and cash-crop outlet for an unknown number of farmers. The plant also contributes the majority of wastes entering the city's outdated sewage treatment facility. The city is presently in the process of building a new sewage treatment facility, which, by necessity, had to be overdesigned to accommodate the canning plant waste. Realizing the associated problems of sweet potato canning, Tabor City Foods sought assistance from North Carolina State University. The industry and the University together developed, sought, and were granted an Environmental Protection Agency Demonstration Grant to help alleviate waste problems, increase plant efficiency, and develop a waste management technology for the sweet potato processing industry.

The project's purpose is to make changes in equipment and operations to demonstrate effective water and wastewater management in sweet potato processing. The project encompasses waste abatement and water use throughout the plant from fresh water intake through pretreatment. The specific objectives are:

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**This investigation was supported by funds from the Environmental Protection Agency, Office of Research and Monitoring, under Grant No. 12060 FRW and Tabor City Foods, Tabor City, N. C.

1) Install and/or modify a dry caustic peeling process and demonstrate its effectiveness for water and waste reduction.

2) Install and demonstrate wastewaters pretreatment facilities for the reduction of waste loads.

3) Determine the economic implications of the water and waste management techniques demonstrated.

4) Formulate guides for water and wastewater management in sweet potato processing.

The 1971 processing season of September through December was used for preliminary studies and analytical evaluations required to establish bench mark quantities and characteristics of water consumption, waste production, and plant operating procedures. This was necessitated by the lack of information regarding the present "state of the art" of sweet potato processing.

CANNING PROCESS

An outline and description of major sweet potato processing operations are essential for understanding water consumption and waste production characteristics. The major processing steps are:

Receiving and Unloading

Sweet potatoes arrive at the plant in trucks which are unloaded either by a front-end loader or a large "vacuum cleaner-like" apparatus. Some field dirt falls off the potato during the transfer operations.

Washing

The potatoes are conveyed through a reel washer to remove dirt attached to the potatoes.

Preheating

The potatoes are preheated in a water bath of approximately 105° F for a couple of minutes to enchance the action of the lye bath.

Lye Bath

Potatoes are immersed in a boiling 15 percent lye solution for approximately two minutes to facilitate peel removal and reduce manual trimming operations. The greater the peel loss, the greater the waste produced and the less usable product left.

Peel Removal

Peels are removed by a rotary washer which removes most of the softened peel and part of the potato.

Snipping

Large rotary snippers are used to remove roots or strings from sweet potato ends.

Abrasive Peelers

Sandpaper-like counter rotating rollers are used to smooth the potato surface.

Brush Washer

Counter rotating bristle rollers impart a final sheen to the surface of the potato.

Trimming

The freshly peeled potatoes are inspected and manually trimmed. Product not suitable for canning is rejected.

Sizing

A rotating drum with variable size openings separates potatoes by sizes.

Slicing

Large potatoes move through a series of cutting machines which first half and then quarter the potatoes.

Grading

Potatoes on the grading belt are manually checked for size and quality.

Filling

The raw product moves onto a circular hand pack filler with a series of openings around its outer edge. Potatoes are then raked into cans passing below as the circular top rotates.

Syruping

Most canned sweet potatoes are packed in a syrup medium of sugar and water heated to a temperature just below boiling.

Closing

A sealing machine places a lid on each can and applies pressure to seal the can.

Retorts

High pressure steam retorts are used to cook the canned product for varying periods of time, depending on can size, syrup content, and the average temperature of the contents when placed in the retorts.

Cooling

On removal from the retorts, cans are passed through a cooling canal.

Labeling and Packaging

Labels are pasted on cans and the cans are placed in cases for storage and eventual shipment.

Before the existing conventional process could be modified, a season's operating data on the relationship of water usage and waste characterization to plant production had to be established. The existing laboratory at the plant was geared up to make typical sanitary engineering analytical tests, and the laboratory technician was brought to North Carolina State University for a week of intensive training. Necessary equipment, chemicals, and supplies were purchased for the plant laboratory.

The plant installed nineteen (19) water meters to determine unit process use rates. Daily readings were taken of tons of input, operating hours, and daily production. The breakdown of water consumption per ton of sweet potatoes processed and per case of number 2-1/2 cans produced are given in Table 1.

The retorting operations utilizes the largest amount of water (38.8%) of any single operation. There is no substantial amount of organic material in this water. The water utilized for steam generation and syrup production is consumptive in that it is either packed in cans or evaporates.

Analytical quality measurements were made at Tabor City Foods and at North Carolina State University. All procedures were in accordance with the 1971 Environmental Protection Agency Methods for Chemical Analysis of Water and Wastes. In addition, all samples were passed through a twenty-mesh screen prior to analysis at the request of the Environmental Protection Agency. A composite sample consisting of four grab samples were taken at each sampling station each operating day, or as often as feasible. Chemical oxygen demand, settleable solids, temperature, and pH observations were made on each

TABLE 1

Unit Process Water Use in Conventional Sweet Potato Processing

Unit Process	Gal/Ton Input	Gal/Case #2-1/2 Cans	% of Total Water Use
First Washer	79	2.8	3.0
Preheater	15	0.54	0.5
W/D Washer	280	9.9	10.9
Snippers	110	4.0	4.4
Abrasive Peeler	140	4.8	5.3
Brush Washer	96	3.4	3.7
Retort	1000	35.0	38.5
Cleanup	240	8.6	9.5
Cooling	31	1.0	1.1
Boiler Water	415	15.0	16.5
Belt Wetting	130	4.7	5.2
Syruping	36	1.3	1.4
TOTALS	2572	91.0	100.0

sample collected. Biochemical oxygen demand, suspended solids, dissolved solids, nitrogen, and phosphorus measurements were made less frequently. The range and average concentrations of wastes flows for the conventional unit processes are presented in Table 2.

Whole sweet potatoes were studied in the lab to determine the pounds of COD, BOD, carbon, nitrogen, and phosphorus per pound of whole dry weight. The sweet potatoes examined had an average moisture content of 76 percent. One pound of sweet potatoes (dried at 103° C) was found to produce 1.06 pounds COD, 0.49 pound BOD_5, 0.38 pound of carbon, 0.0184 pound of nitrogen, and 0.0016 pound of phosphorus. If the poundage was based on the wet weight of the potato, these figures have to be multiplied by 0.24. This means that for every pound of sweet potato not put in cans and entering a liquid waste stream, one can expect 0.252 pound COD, 0.118 pound BOD_5, 0.091 pound of total carbon, 0.0044 pound of nitrogen, and 0.000384 pound of phosphorus.

The total pounds of BOD_5, COD, total and suspended solids discharged per ton of raw product input from conventional unit processes utilized in sweet potato processing are presented in Table 3. The data presented represents the waste load after passing samples through a twenty-mesh screen. It is interesting to note that the major sources of waste production (synonymous with product loss) are created by peel removal, abrasive peeling, and snipping operations. All figures shown in this table end up in the liquid waste stream.

Studies were undertaken to define and/or identify the mass balance of sweet potatoes through the processing plant. As a result of these investigations, the following information was generated:

1) Raw product studies revealed that 5 percent (100 lbs/ton) of the product when received was field dirt.

2) Solid waste generation studies revealed that 9.5 percent (190 lbs/ton) of raw product, unfit for canning for various reasons, was trucked away for disposal.

3) Product yield studies revealed that 40 percent (800 lbs/ton) was placed in cans and became a saleable product.

4) Liquid waste studies revealed that 160 pounds of solids dried at 103° C were generated per ton of raw product input (Table 3) after screening. Dividing the 160 pounds by 0.24, the percent total solids in a raw sweet potato, gives 680 pounds of solids per ton of raw product input. Or, 33 percent of the raw product ends up in a liquid waste stream.

TABLE 2

Waste Concentrations for Unit Processes Utilized in Conventional Sweet Potato Processing≠

Unit Process	BOD (mg/L) Average	BOD (mg/L) Range	COD (mg/L) Average	COD (mg/L) Range	Total Nitrogen as N (mg/L) Average	Total Phosphorus as P (mg/L) Average
First Washing	990	460-2400	3,700	1300-8900	12	1.1
Preheater	3,700	2400-4500	9,300	4700-14000	45	17.0
Peel Removal	13,000	7800-23000	32,000	10000-45000	320	40.0
Snippers	5,900	2600-8600	16,000	8100-40000	140	23.0
Abrasive Peeling	14,000	7900-20000	22,000	1600-40000	330	50.0
Brush Washer	3,500	1300-4700	6,400	2000-9600	71	9.2
Retort	76	44-110	210	130-260	0	0
Cleanup	2,200	530-6200	3,800	2200-10000	-	-
TOTAL EFFLUENT*	8,600	4000-13000	22,000	12000-31000	210	29.0

≠After 20-mesh screening
*Excluding Retort Waters

TABLE 2 (continued)

Unit Process	Total Solids (mg/L) Average	Range	Suspended Solids (mg/L) Average	Range	Settleable Solids (ml/L) Average	Range
First Washing	2,100	800-8700	1,200	300-1500	28	6-40
Preheater	8,400	6500-11000	1,600	600-2660	32	5-64
Peel Removal	35,000	12000-48000	7,700	2500-10500	530	350-750
Snippers	13,000	5300-18000	3,800	600-7100	280	75-500
Abrasive Peeling	23,000	6600-36000	4,400	1100-6700	470	60-730
Brush Washer	4,300	2800-8700	1,200	350-4500	74	18-160
Retort	300	260-370	0	0	0	0
Cleanup	2,700	2200-3200	870	630-1100	-	-
TOTAL EFFLUENT*	26,000	7000-67000	3,800	1400-8000	250	60-570

≠After 20-mesh screening
*Excluding Retort Waters

TABLE 3

Waste Loads Per Ton of Input for Unit Processes
Utilized in Conventional Sweet Potato Processing*

Unit Process	BOD lbs/ton	COD lbs/ton	Total Solids lbs/ton	Suspended Solids lbs/ton
First Wash	0.7	2.4	1.4	0.8
Preheater	0.5	1.2	1.1	0.2
Peel Removal	30.0	75.0	83.0	18.0
Snippers	5.5	15.0	12.0	3.6
Abrasive Peeling	16.0	25.0	26.0	5.1
Brush Washer	2.8	5.1	3.4	1.0
Retort	0.6	1.8	2.5	0
Cleanup	4.4	7.7	5.5	1.8
Miscellaneous	0	6.8	25.1	0
TOTAL EFFLUENT	60.0	140.0	160.0	30.0

*Rounded off and after 20-mesh screening

5) The sum of the percentages accounted for as dirt, solid waste, yield, and liquid waste is 87.5 percent. The remaining 12.5 percent is believed to represent the quantity of sweet potato discharged into the liquid waste stream that will not pass a twenty-mesh screen. All waste samples were passed through a twenty-mesh screen prior to analysis at the request of the Environmental Protection Agency. This would indicate that a total of 45.5 percent (910 lbs/ton) of the raw product enters the liquid waste stream prior to screening. Therefore, all figures presented in Tables 2 and 3 should be adjusted upward by 1.4 (45.5 ÷ 33) to represent waste generation before screening.

A summary of water use, lye consumption, and waste generation per ton and per case of number 2-1/2 cans for conventional sweet potato canning is presented in Table 4.

PROPOSED CHANGES AND PROCESS MODIFICATIONS

The 1971 processing data gathered from Tabor City Foods is believed to represent the current "state of the art" of conventional sweet potato canning technology. Table 4, the characterization summary, dramatically indicates the severity of the problem facing sweet potato canners. Each of these problem areas bears directly on a processor's economic competitiveness and imposes a potential pollutional load on the local environment. A processor, for example, who is able to realize a greater yield, not only has more saleable product for the same expenditure but reduces his cost of waste treatment. A twofold gain!

The purpose of the second year of the EPA demonstration grant is to design, install, demonstrate, and evaluate four techniques of increasing yield, lowering canning costs, and reducing the environmental impact of sweet potato canning. Specifically, four means of assisting the processor and the environment will be demonstrated. These are dry caustic peeling, lye reconditioning, high pressure water system, and pretreatment of waste.

Dry Caustic Peeling

Conventional vat type (hot dip) lye peeling became the major technique of removing the peels of fruits and vegetables during World War II. The simplicity, economy, and labor saving advantages of lye peeling allowed the U.S. to meet the demand for processed fruits and vegetables at a time when there existed acute shortages of labor and materials. The techniques of lye peeling developed during World War II are still used today.

TABLE 4

Characterization Summary of Conventional Sweet Potato Processing*

Parameter	Per Ton	Per Case
A. Liquid ≠		
BOD (lbs)	60	2.1
COD (lbs)	140	5.0
T. Solids (lbs)	160	5.7
S. Solids (lbs)	30	1.0
B. Solid Waste (lbs)	200	7.1
C. Dirt	100	3.5
D. Water (gallons)	2600	92.0
E. Lye (50%) (gallons)	9.2	0.32

*Rounded off

≠After 20-mesh screening

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

A ten ton per hour infrared peeling system, based on the Graham-Huxsoll model, is scheduled for installation in the Tabor City Foods' plant this summer. The anticipated changes in operating characteristics from application of this new technology are: 1) lower peel loss, 2) lower water consumption, 3) lower lye consumption, 4) increased product yield, and 5) disposal of generated solids as a solid waste.

Lye Reconditioning

The use of a rotary drum filter for reconditioning lye by removing solids and spent lye from the lye vat is expected to reduce the lye consumption by increasing the useful life of the lye.

High Pressure Water System

Through the use of high pressure spray nozzles, equal or superior removal efficiency can be obtained using less water. The use of less water also means waste concentrations will be greater, facilitating easier pretreatment.

Waste Pretreatment

The installation of a vibrating screen followed by a rotary drum filter is expected to reduce the waste load to the municipality and reduce sewer use surcharges. The solids removed by the vibrating screen and rotary drum filter will be disposed of in a sanitary landfill.

The total anticipated effect of new technology utilized in sweet potato processing as opposed to conventional technology is presented in Table 5.

The economic implications of the water and waste reduction techniques demonstrated will be determined for individual processes and for the total plant. Budgeting procedures will be used to determine costs, returns, and changes in net revenue due to the new technology. Economic implications for devising water and waste reduction policies will be determined from a comparative analysis of the cost of inplant water and waste reduction and wastewater treatment costs.

TABLE 5

Anticipated Effect of New Technology Utilization in Sweet Potato Processing as Compared to the Conventional "State of the Art"

Parameter	Conventional Technology	Advanced Technology
Product Yield	40%	45-50 %
Water (gal/ton)	2600	1400-1600
BOD (lbs/ton)	60	10-15
COD (lbs/ton)	140	25-35
Suspended Solids (lbs/ton)	30	1-5
Total Solids (lbs/ton)	160	35-45
Solid Waste (lbs/ton)	200	600-700
Lye Consumption (gal/ton)	9.2	4-7

Guides for water and wastewater management for the sweet potato processing industry will be formulated. The results of this demonstration grant can be used as management guidelines for applications of infrared peeling, lye reconditioning, high pressure water systems, and pretreatment in the sweet potato processing industry.

SUMMARY AND CONCLUSIONS

The conclusions that can be drawn from the first year of the demonstration grant on water and waste management in sweet potato processing are:

1) The saleable product yield utilizing conventional practices of sweet potato canning is 40 percent.

2) The rate of water consumption is 2,600 gallons per ton of raw product input, or 91 gallons of water per case of 2-1/2 cans produced.

3) Conventional sweet potato processing will produce 60 pounds BOD, 140 pounds COD, 160 pounds total solids, and 30 pounds suspended solids per ton of input after twenty-mesh screening.

4) If the sweet potato canning processors are to continue to exist in North Carolina, steps must be taken to increase product yield, lower peel loss, lower water consumption, and significantly reduce the local impact of the waste released from the plants.