BEET PROCESSING CHARACTERIZATION AND LOAD REDUCTION ANALYSIS

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ABSTRACT

Catelli's fruits and vegetables processing plant at St-Hyacinthe has three different kinds of production depending on the time of the year; the normal production, the fresh pack, and the beetroot production. This seasonal change in production creates variations in the polluting load discharged. The municipality is building a waste water treatment plant, and does not want to overdesign it to accomodate the seasonal production of Catelli. The municipality has limited the polluting load discharged by Catelli to 2300 kg BOD per day. This means that Catelli has to treat its waste water or find an alternative to reduce its polluting discharge during the beetroot production.

A characterization was done on the beetroot processing effluent. The results obtained show that the peeling and cooking are the most polluting operations. No equipment modification was found to be efficient and economically justifiable to reduce enough the polluting load. Other alternatives were suggested. The most interesting one is to stock the waste water excess during the week and to discharge it during the week-end when all other industries have ceased their activities.

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1. INTRODUCTION

In 1983 the municipality of St-Hyacinthe decided to build a waste water treatment plant. Before, there was no real legislation on the industrial waste water discharge, and all effluents were discharged in the Yamaska river.

The Ministry of Environment has done a survey to evaluate this industrial pollution load (Fig. 1.1).

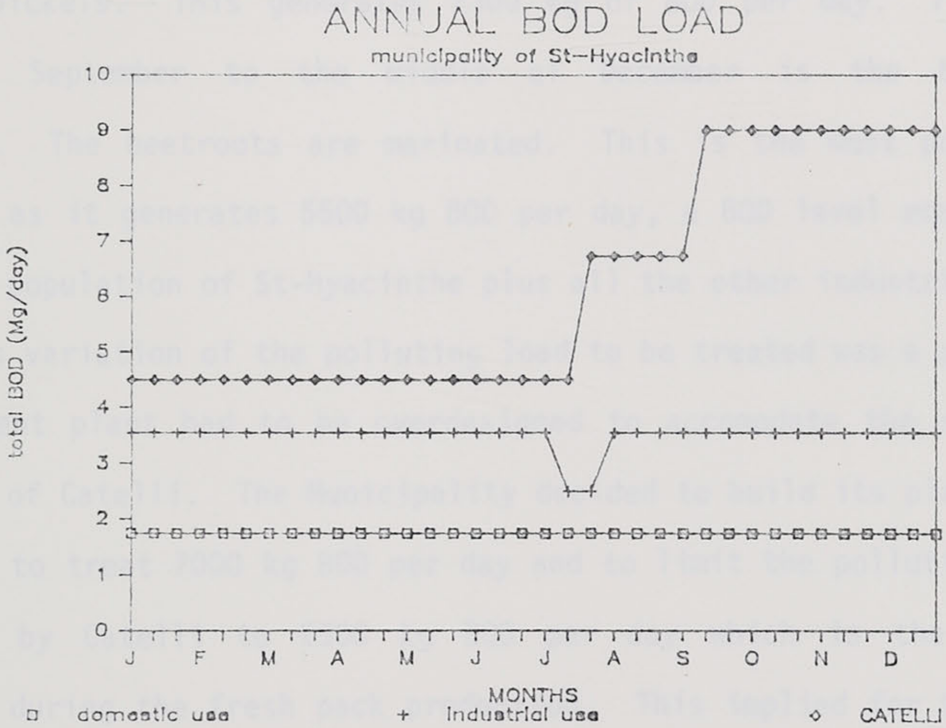

FIG. 1.1 Variations of the polluting load to treat during the year (Municipality of St-Hyacinthe, 1984)

The biochemical oxygen demand (BOD) related to the domestic use, was found as constant during the year as 1700 kg per day. The polluting load discharged by all other industries except Catelli, was found as 1900 kg of BOD per day during 11 months. In July, during the summer shut down, the load discharged was found to decrease to 800 kg of BOD per day. Catelli was found to discharge 1000 kg of BOD per day during its normal production, from the middle of December to the middle of July. During this period, jam, meat sauce, sweet mixes are made. From the middle of July to the middle of September is the fresh pack production. Tomatoes and cucumbers are transformed into ketchup, chow and dill pickels. This generates 2300 kg of BOD per day. From the middle of September to the middle of December is the beetroot production. The beetroots are marinated. This is the most polluting production as it generates 5500 kg BOD per day, a BOD level equivalent to all the population of St-Hyacinthe plus all the other industries.

This variation of the polluting load to be treated was a problem. The treatment plant had to be overdesigned to accomodate the seasonal production of Catelli. The Municipality decided to build its plant with a capacity to treat 7000 kg BOD per day and to limit the polluting load discharged by Catelli to 2300 kg BOD per day which is the amount discharged during the fresh pack production. This implied for Catelli, a treatment installation or effluent alternative to reduce its polluting discharge during the beetroot production. The municipality of St-Hyacinthe has also established a legislative program; all the industries are taxed according to their highest hydraulic and biological polluting load of the year. So the more they pollute, the more they are taxed.

Catelli has set up a used water control program. The first part is to characterize the effluent and to see if there is some way to reduce the polluting load. The second part is to find an adequate technology to treat the effluent if it is impossible to discharge under 2300 kg BOD per day. My project is in the scope of the first part of this program.

2. OBJECTIVES

The objectives of this project were defined as follows:

a) to characterize at different points the effluent of the beetroot process.

b) to compare the COD values obtained with those in the literature.

c) to suggest different alternatives to reduce the polluting discharge to 2300 kg BOD per day during the beetroot production.

3. LITERATURE REVIEW

Problems and cost associated with waste water treatment are determined by several factors. The first one is the volume, or hydraulic load of waste water. Food processing operations require the use of water which, unfortunately, becomes waste water that must be treated. By minimizing the quantity of water used during the preparation of foods, the quantity of waste water generated from food processing operation can be minimized. An efficient water management is required.

The second important factor which influences the cost of waste water treatment is the strength, or organic load, of the waste water. This is determined by the amount of organic polluant contained therein. Most of the water used in food processing operation comes into direct contact with raw products. Soluble and suspended solids are readily removed from the raw product by water, creating a high organic load effluent. Significant waste load reduction are achievable by eliminating the use of water wherever practicable. In process modifications are required.

The purpose of this section is to review the techniques to reduce the hydraulic and biological loads.

3.1 IN PLANT PROCESS MODIFICATIONS

In the last 20 years, legislations concerning water pollution have emphasized the necessity to investigate processes which introduce these polluting materials into the waste waters. Blanching and peeling are processes introducing large amounts of organic material into the plant processing effluent.

3.1.1 BLANCHER

The blanching treatment produces several desirable changes in the raw vegetables. Primarely, enzymes are thermally inactivated to stabilize the food components against rapid chemical changes. Also the gases, mainly oxygen, are displaced from the food during blanching (Ralls et al., 1972). For the beetroot, the blanching results in physical changes in the vegetable which improves the peeling operation.

One of the main disadvantages of this operation is the production of large volumes of high strength liquid wastes. Rolls and Mercer (1973) reported that on an average in beetroot processing, the blanching and peeling operations are responsible for about 40 % of the total waste load. Lund (1974) calculated that a 90 % reduction in blancher effluent could reduce the total waste flow of a vegetable cannery by 10 to 20 % and the total BOD by 20 to 50 %. Considerable research has been carried out to replace or improve the conventional steam and hot water systems.

3.1.1.1 CONVENTIONAL STEAM AND HOT WATER BLANCHER

Blanchers can be divided into two general categories, steam and water blanchers (Fig. 3.1 and 3.2).

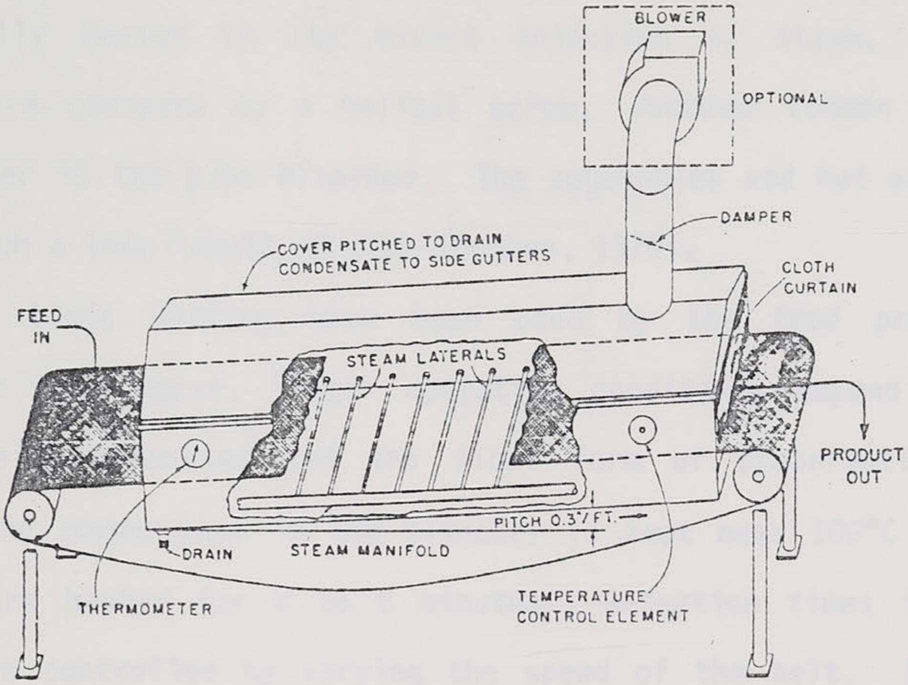

FIG. 3.1 Steam blancher (Bomben, 1979)

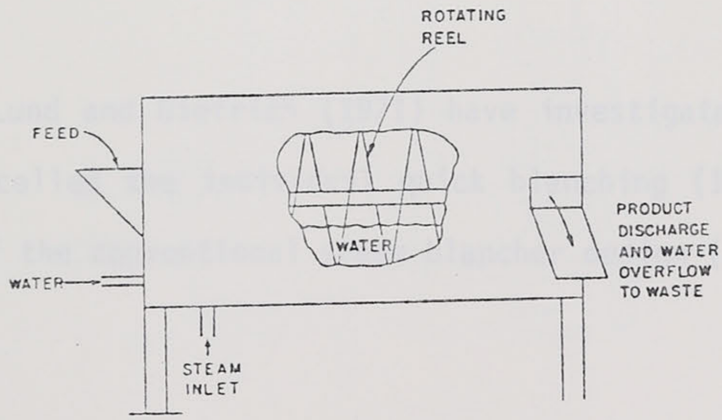

FIG. 3.2 Water blancher (Bomben, 1979)

Steam blanchers are belt conveyors that carry vegetables through a steam chamber. Water blanchers are tanks partially filled with hot water, usually heated by the direct injection of steam, and the vegetables are conveyed by a helical screw. Another common form of water blancher is the pipe blancher. The vegetables and hot water are pumped through a long length of pipe (Bomben, 1979).

These basic designs have been used by the food processing industry for many years. Their operating conditions depend on the vegetable being processed and the final form of preservation but, generally, the temperature in the blancher is kept near 100°C and the vegetables are heated for 2 to 6 minutes. Retention times in steam blanchers are controlled by varying the speed of the belt. In water blanchers the speed of the reel, or the flow rate of water in a pipe blancher determines the retention time.

Bomben (1979) has concluded that water blanchers tend to produce a larger hydraulic load than steam blanchers, but they produce about the same organic waste load.

3.1.1.2 IQB BLANCHER

Lazar, Lund and Dietrich (1971) have investigated a new concept in blanching, called the individual quick blanching (IQB). This is a modification of the conventional steam blancher design (Fig. 3.3)

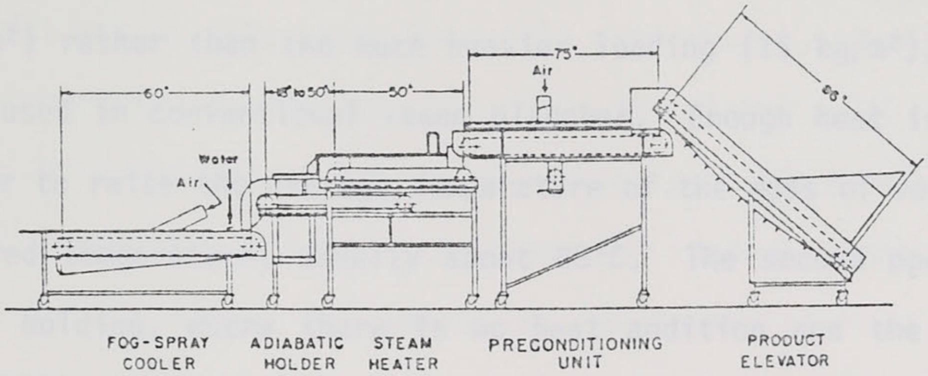

FIG. 3.3 IQB blancher (Bomben, 1979)

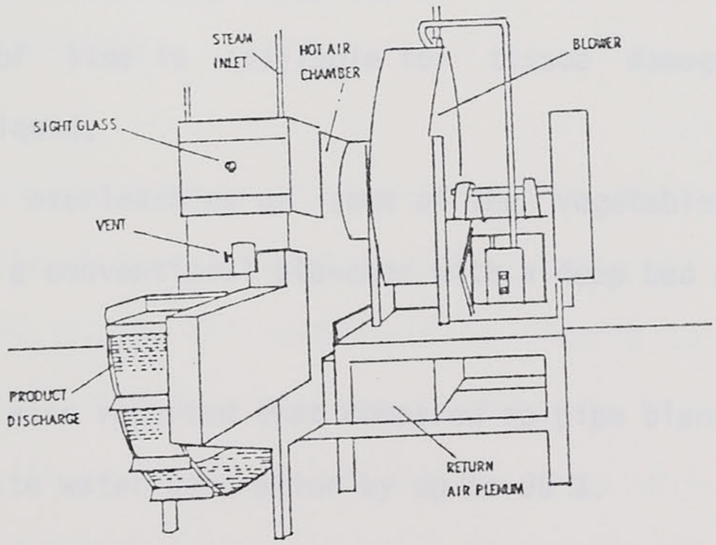

FIG. 3.4 Hot gas blancher (Bomben, 1979)

The IQB process is a two stage operation; heating and holding. Heating is done in a condensing steam chamber, the same as a conventional steam blancher, except that the vegetable particlules are only one layer deep (4.9 kg/m²) rather than the much heavier loading (15 kg/m²), which is normally used in conventional steam blancher. Enough heat is added in the heater to raise the average temperature of the mass of vegetable to the desired temperature, usually about 88°C. The second operation is adiabatic holding, where there is no heat addition and the vegetable pieces leaving the heater are loaded on the belt in a deep bed (49 kg/m²) and given enough time to achieve a uniform temperature and enzyme inactivation.

Lund (1974) has concluded that the IQB process gives less waste load for the following reasons:

(1) steam condensation is limited to that required for heating the product to the blanching temperature.

(2) a minimum of time is available for tissue damage and loss of vegetable liquid.

(3) there is no overleaching of some of the vegetables as would be the case in a conventional blancher with a deep bed of vegetables.

Lund (1973) also reported that compared to pipe blanching the IQB process reduced waste water generation by up to 99 %.

3.1.1.3 HOT GAS BLANCHER

This process has been studied by Ralls et al., (1972). It reduces effluent by using the combustion products of natural gas as a heat transfer medium instead of water or steam. Hot gas alone dehydrates the vegetables, thus it was necessary to use a combination of steam and combustion gases to achieve high enough temperature for blanching and to reduce the amount of dehydration in the vegetable (Bomben, 1979). The basic configuration of a Hot-Gas Blancher is that of a steam blancher, but a gas burner and a circulating blower are also added (Fig. 3.4).

Rall and Mercer (1973) have shown that the organic load of the effluent can be reduced as an average by 98 % compared to the conventional water blancher. However, the major inconvenience is that hot gas blanchers depend on the burning of hydrocarbons, which in the long run becomes expensive.

3.1.1.4 MICROWAVE BLANCHER

Much research has been done to use microwave heating as a means of blanching with low effluent generation (Rolland Mercer, 1973; Huxsoll et al. 1970). Even if the effluent could be reduced up to 99 %, it could not be completely eliminated. Some steam had to be used to obtain uniform heating of the vegetables. The capital costs were too high for the system to be economically feasible for a seasonally operated plant.

3.1.2. PEELER

Beetroots are peeled prior to further processing. For several decades conventional methods were used. The peel was mechanically removed or was loosened by steam or chemicals, and removed by voluminous amounts of water. The peels introduced into the plant effluent increased the amount of organic material. According to Weckel et al. (1968) this waste represented approximately 50 % of the total plant effluent and more than 90 % of the total plant solid waste. Research has been done to replace the conventional methods.

3.1.2.1 CONVENTIONAL PEELING METHODS

Three techniques were currently used for beetroot peeling.

1) ABRASIVE PEELERS:

This method is to remove peels by tumbling the vegetables against a coarse abrasive coated surface. The degree of tumbling action determines the extent of peeling. This requires constant cleaning. Water sprays are generally used to flush peel material from the peeler (Schultz and Green 1979).

2) HOT WATER AND STEAM PEELER:

Hot water and steam serve to soften the product skin, facilitating removal of peels which is done by high pressure water sprays, (Katsuyama, 1979).

3) CHEMICAL PEELER:

This process consists of immersing the vegetable in a lye solution of 10 to 20 % concentration at a temperature of 60° to 90°C for 1 to 5 minutes. Following the lye treatment, a short draining and holding period is used to allow time for the lye to react with the vegetable surface tissue. The softened tissue is then removed by high pressure water spray (Schultz and Green, 1979).

3.1.2.2 DRY CAUSTIC PEELER

This new approach is based on the chemical peeling method described above with the major difference being that a mechanical method for removing peel material is substituted (Fig. 3.5). Lee and Downing (1973) have adapted this peeling method for beetroot processing. They have found that a lye concentration of 4 - 7 % at temperatures ranging from 88° to 93°C followed by a holding time of 5-7 min were the optimum conditions. Softened peel and underlying tissue were removed by mechanical abrasion and discharged separately as a solid waste to avoid contamination of the plant effluent. The BOD of the effluent from the peeler was reduced by 90 %.

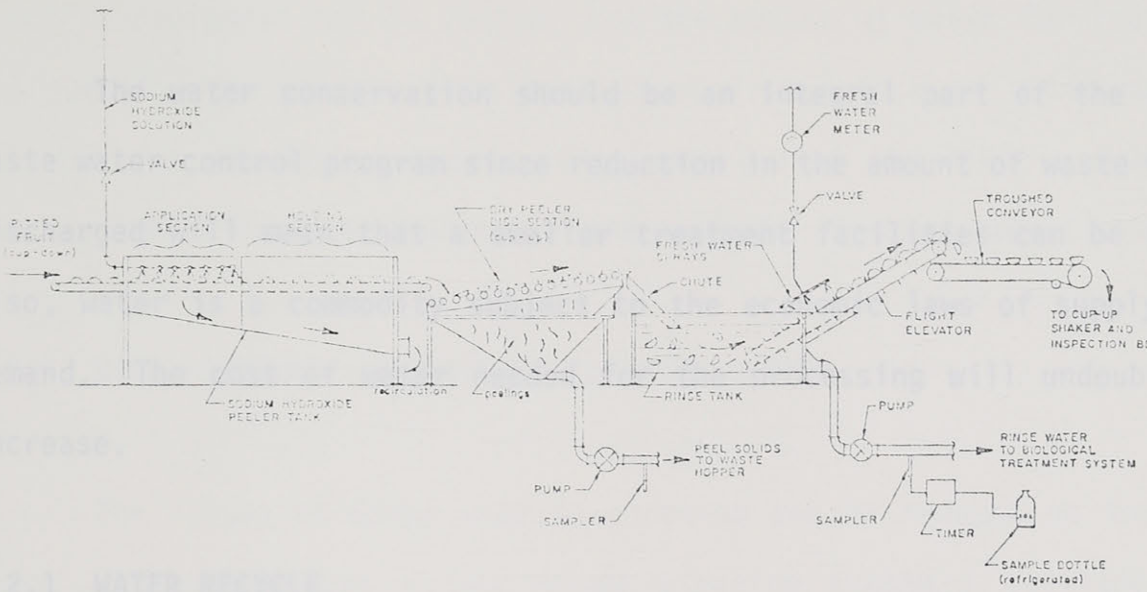

Fig. 3.5 Dry Caustic Peeler

The solid waste from the beetroot dry caustic peeling operation can be used as animal feeding. The peels must be fermented to decrease the pH before being fed to cows, together with corn silage as a 1 : 4 mixture (Lee et al. 1973).

3.1.3. WASHER

The approach to alter the process in such way to reduce the water consumption and pollution has been applied also to the cleaning process. Krochta et al. (1973) have investigated a dry cleaning method for tomatoes. But this system has been found efficient only for vegetables with a smooth peel.

3.2 IN PLANT WATER CONSERVATION

The water conservation should be an integral part of the plant waste water control program since reduction in the amount of waste water discharged will mean that a smaller treatment facilities can be used. Also, water is a commodity subject to the economic laws of supply and demand. The cost of water needed for the processing will undoubtedly increase.

3.2.1 WATER RECYCLE

The reuse of treated wastewater will result in a reduction in the total wastewater flow. However, there are financial and sanitary constraints associated with the reuse of wastewater in a food processing plant. Theoretically, excellent quality water can be obtained after primary and biological treatment, followed by filtration, carbon adsorption and chlorination. However, the large variations in wastewater strengths and flows present difficult operational problems and can result in an effluent of variable quality (Stanley Ass. Eng. Ltd., 1977). It is not anticipated that wastewater treated by these methods would be of drinking water quality standards required in the final inplant processes. However, it could be used in other operations being carried out earlier in the processing line.

The National Canners Association (1971) has produced a water economy 'check list' which is presented in Appendix A. This table gives the process operations or the equipment used in the industry which are major water users. It also indicates whether or not the water from specific equipment may be reused, and the source of water for reuse in the specific equipment. From this check list, reuse of water may be possible for the beetroot processing water, from the first washing of the vegetables from the lye peeler and from the clean up operations.

3.2.2 HIGH PRESSURE - LOW VOLUME CLEANING SYSTEM

The volume of water used in clean-up can be reduced up to 25 % using a high pressure - low volume cleaning system (Vaillancourt, 1986). The pump can achieve pressures in the range of 700 - 1750 kPa and delivers 40 - 48 l/min. A single pass with a wand delivering 700 kPa will surpass the level of cleanliness of 10 passes of a wand delivering 70 kPa. This represents a more efficient cleaning using less water.

Casado and Robe (1973) have shown how these high pressure - low volume cleaning systems reduce plant cleaning costs and water consumption.

3.3 SUMMARY OF LITERATURE REVIEW

To reduce the polluting load discharges by the fruits and vegetables transformation industries, two alternatives were suggested. The first is to do some in plant process modifications. Individual quick blanching and dry caustic peeling methods were presented. The second alternative was to reduce the amount of water use. Water recycle and high pressure - low volume cleaning system were presented.

4. MATERIALS AND METHODS

4.1 SAMPLING PROCEDURE

The first step was to identify the polluting equipments in the process line. As showed on the flowchart (Fig. 4.1) the beetroots are discharged, washed, blanched, peeled, inspected, pumped to the second floor where they are sliced, cooked and sent to the packing line.

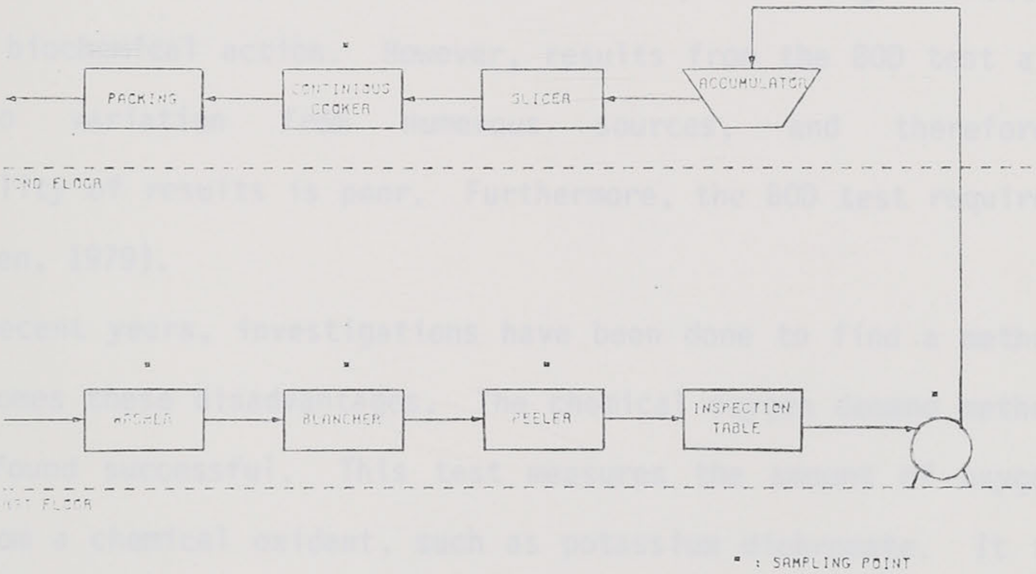

Fig. 4.1 Beetroot Processing Flowchart

All the apparatus with important outflow were selected for the characterisation. Grab samples were taken from the washer, blancher, peeler, hydro pump and the continious cooker. To check fluctuations caused by changes in raw product volume and quality, samples were taken at 9:00, 11:00, 13:00 o'clock. Because of the delay before analyses, 2 ml of concentrated sulfuric acid were added to the 500 ml samples for preservation. Care was taken to completely fill the jar to have no air space.

4.2 COD ANALYSIS METHOD

For many years the standard method for measuring the pollutional strength of wastewaters has been the biochemical oxygen demand (BOD) test, which determines the amount of dissolved oxygen , in milligrams per liter, required during stabilisation of decomposable organic matter by aerobic biochemical action. However, results from the BOD test are subject to variation from numerous sources, and therefore, reproducibility of results is poor. Furthermore, the BOD test requires 5 days (Green, 1979).

In recent years, investigations have been done to find a method which overcomes these disadvantages. The chemical oxygen demand method (COD) was found successful. This test measures the amount of oxygen consumed from a chemical oxidant, such as potassium dichromate. It is carried out under conditions which can be exactly reproduced and the results are obtained quickly.

It must be understood that the BOD and COD tests involve separate and distinct reactions. Chemical oxidation measures carbon and hydrogen, but not nitrogen in organic materials. Furthermore the COD test does not differentiate between biologically stable and unstable compounds. For example, cellulose is messured by chemical oxidation, but is not measured biochemically under the aerobic processes usually found in streams (Katsuyama, 1979). Despite these differences, a reliable relationship between BOD and COD values can be obtained for all types of food processing wastes. In the industry of Catelli, for the beetroot waste water, Jannard (1984) has found this ratio

$$\frac{BOD}{COD} = 0.6$$

For each samples, two COD tests were done according to the Dichromate Reflux Method from the Standard Methods for the Examination of Water and Wastewater (1981).

5. RESULTS AND DISCUSSION

5.1 RESULTS

The biological and hydraulic loads obtained are presented in tables B.1, B.2 and B.3, Appendix B. For each apparatus an average COD value was calculated and then converted to the corresponding BOD value. These results are presented in Figure 5.1.

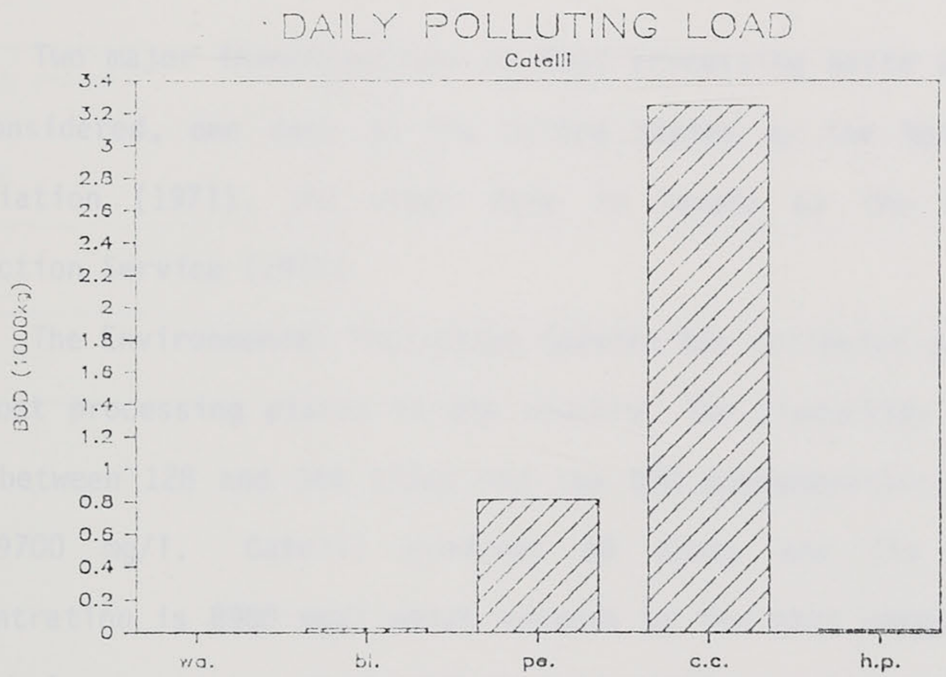

Fig. 5.1 Daily Polluting Load Discharges by Different Processing Units.

From this graph we can see that the peeler and the continious cooker are the more polluting apparatus. The peeler discharges 814 kg BOD and 393 m^3 of waste water per day, corresponding to 20 % of the daily biological load and 85 % of the daily hydraulic load. The continuous cooker discharges 324 kg BOD and 36 m^3 of waste water per day, which corresponds to 78 % of the daily biological load and 8 % of the daily hydraulic load. The polluting effluent from the washer, the blancher and the hydro-pump is negligeable. So, modifications have to be done to reduce the polluting load discharges from the peeler and the continuous cooker.

5.2 COMPARISON WITH LITERATURE

Two major investigations on food processing waste water have to be considered, one done in the United States by the National Canner Association (1971), the other done in Canada by the Environmental Protection Service (1977).

The Environmental Protection Service has collected data from nine beetroot processing plants in the country. The production was found to vary between 128 and 244 t/day and the BOD concentration between 1420 and 9700 mg/l. Catelli produces 68 t/day and its average BOD concentration is 8900 mg/l which exceeds by for this range. The waste water balance summary of the EPS is quite different from that of Catelli (TABLE 5.1).

TABLE 5.1 WASTE WATER BALANCE SUMMARY FOR BEETS (CATELLI-ENVIRONMENTAL PROTECTION SERVICE)

	Catelli		Environmental Protection Service	
Unit peration	% Total Flow	% Total BOD	% Total Flow	% Total BOD
washer	2	--	35	7
peeler	85	20	33	44
blancher	3	1	2	27
continuous cooker	8	78	--	--
hydro pump	2	1	--	--
cooler	--	--	12	9
filler	--	--	4	2
clean up	--	--	14	11

-- no date available

The EPS identifies the peeler as the most polluting unit discharging 33 % of the total hydraulic flow. Catelli's peeler discharges 85 % of the BOD, indicating that in general, the beetroot processing plant in Canada must have some dry caustic peeling processes. Because of this, it is quite difficult to compare these two wastewater balances.

The waste water balance summary from the National Canners Association (1971) is presented in Table 5.3.

TABLE 5.2 WASTE WATER BALANCE SUMMARY FOR BEETS (NATIONAL CANNERS ASSOCIATION)

Unit Production	% Total Flow	% Total BOD
washer	20	17
peeler	35	55
slicer	23	20
blancher	--	--
fill brine cooker	22	8
cooler	--	--

Here again the percent hydraulic load discharged by the peeler is lower, 35 % compared to 85 % from Catelli's peeler but the biological load is higher which can be explained by the presence of the dry caustic peeler. In the United States they must have equivalent technology for the blanching since the average polluting load discharged by the blancher is negligeable.

5.3 TAXATION POLICY

The legislation of the municipality of St-Hyacinthe concerning the wastewater discharged by the industries is not published yet. To estimate the taxation cost imposed to Catelli the calculations are based on the taxation policy of the municipality of Granby who has a similar use water treatment plant.

Granby taxes its industries according to their hydraulic and biological load; 40$ per 1000 m^3 of waste water and 34$ per 1000 kg BOD. Catelli during the beetroot production discharges 464 $m^3$of waste water and 4116 kg BOD per day (Table B.1). But they are restricted to 2300 kg BOD per day. Assuming that this restriction is respected, 6300$ must pay for the biological load and 1500$ for the hydraulic load. A total of 7800$ has to be paid for the four months of beetroot production.

Again, the problem is to find a way to discharge only 2300 kg of BOD per day. Different alternatives have been suggested.

5.4 ALTERNATIVES

5.4.1 EQUIPMENT MODIFICATION

As seen in section 2. one way to reduce the polluting load is to do some in plant process modifications. From the results it is concluded that modifications have to be done to reduce the polluting load discharge from the peeler and the continuous cooker.

In Catelli's the beetroots are peeled with an abrasive peeler. It uses a lot of water and the peels are not removed from the effluent. One alternative to reduce the polluting load is to use a dry caustic peeler. A budget price of $250,000 was estimate for the purchase and installation of a dry caustic peeler with the capacity to peel 3000 kg of beetroots per hour. From the literature (Lee et al., 1973) the use of a dry caustic peeler instead of a conventional one can reduce the biological load up to 90 % and the hydraulic load to 50 %. This corresponds to an elimination of 730 kg BOD per day. The final load discharged will be 3386 kg BOD which is still far from 2300 kg BOD. Considering the capital cost this alternative has been eliminated to reduce the polluting load discharged by the continuous cooker, who is responsable for 78 % of the total BOD. No research is mentioned in the literature. It is quite a specific problem, because the beetroots are sliced, then cooked. As soon as they are sliced, the beetroots exude. This introduce a lot of organic matter in the effluent. Here more research on filtration is needed.

5.4.2 PRODUCTION SCHEDULE MODIFICATIONS

Another alternative is to modify the production schedule. Instead of having three large batches of beetroot production per day, the proposition is to have two batches of beetroot combined with an unpolluting production such as jam or sauce. This will reduce the daily polluting load by one third. The load discharged will be around 2800 kg BOD per day which is still over the imposed limit. Others disadvantages are that the beetroot production period has to be elongated to 5.5 months and storage will be required for the beetroot. This alternative has been abandoned.

5.4.3 STOCK WASTE WATER EXCESS

Table B.1 shows that beetroot cooking results in a low hydraulic load (36 m^3/d) and a high biological load (3249 kg BOD/d).

Taking into account this low waste water volume, the more interesting solution is to separate the waste water from the main effluent and to stock it in some reservoirs during the week to discharge it during Saturday and Sunday when most other industries have stopped their activities. So the municipal treatment plan can accepted this excess without problem.

The waste water storage can be done in three 60 m^3 wooden reservoirs at the outside of the plant. These reservoirs are normally used for the pickle fermentation. An impermeable membrane should be applied on the inside for water tightness.

To respect the limit of 2300 kg BOD per day, the waste water from the continuous cooker of the second and third batches (24 m^3) must be stocked. A total of 11000 kg BOD (120 m^3) have to be discharged during the week end. This mean that 5500 kg BOD per day will have to be discharged during the week-end which is above the imposed limit. But as explained earlier since most other industries do not produce during the week-end, this will be probably acceptable for the treatment plant. Here, negotiations are required with the municipal authorities.

Another problem is the odor control. Since this polluting load is very soluble, it is also very biodegradable. To control the biological activity and the odor the pH will be increased to around 9.5 - 10 by adding some caustic. Presently it is difficult to evaluate the required amount and some on site testing will have to be done.

It is a simple solution that only involves only liquid transfer and presents few disadvantages.

6. CONCLUSIONS

From the previous discussion on the analysis of the BOD test results and the various alternatives proposed, it is concluded that;

(1) The continuous cooker is the most polluting unit, contributing 70 % of total BOD. The second is the peeler with 28 % of total BOD.

(2) No equipment modification is efficient and economically justifiable to reduce effluents to 2300 kg BOD per day the polluting load discharged by the seasonal beetroot production.

(3) The most interesting solution to respect the required limit on Catelli's polluting discharge is to stock the waste water excess during the week and to discharge it during the week end when virtually all others industries have ceased their activities.

7. RECOMMENDATIONS

Before taking a decision concerning this project the following recommendations are given.

(1) A study must be done to evaluate the cost of the possible waste water treatment technologies.

(2) Chemical analysis and filtration experiments should be done on the effluent from the continuous cooker.

(3) Negotiations must be held with the municipality concerning the possibility of discharging 5500 kg BOD per day during the week end without penalty.

APPENDIX A. WATER ECONOMY CHECK LIST, NATIONAL CANNERS ASSOCIATION (1971)

NATIONAL CANNERS ASSOCIATION WATER ECONOMY CHECK LIST **

OPERATION OR EQUIPMENT	MAY RECOVERED WATER BE USED?	MAY WATER FROM THIS EQUIPMENT BE REUSED ELSEWHERE IN PLANT?	SOURCE OF WATER FOR REUSE IN EQUIPMENT*
1. Acid dip for fruit	yes	no	Can coolers
2. Washing of product			
A. First wash followed by 2nd wash	yes	yes*	Can coolers
B. Final wash of products	no	yes*	
3. Flumes			
A. Fluming of unwashed or unprepared product (peas, pumpkin, etc.)	yes	yes*	Can coolers
B. Fluming partially prepared product	yes	yes*	
C. Fluming fully prepared product	no	yes	
D. Any fluming of wastes	yes	no	Any wastewater
4. Lye peeling	yes	no	Can coolers
5. Product-holding vats; product covered with water or brine	no	no	
6. Blanchers - all types			
A. Original filling water	no	no	
B. Replacement or make-up water	no	no	
7. Salt brine quality graders followed by a fresh water wash	yes	Only in this Equipment	
8. Washing pans, trays, etc.			
A. Tank washers - original water	no	no	
B. Spray or make-up water	no	no	
9. Lubrication of product in machines such as pear peelers, fruit size graders, etc.	no	yes*	Can Coolers
10. Vacuum concentrators	yes	in this equipment after cooling and chlorination	
11. Washing empty cans	no	no	
12. Washing cans after closing	yes	yes	Can Coolers
13. Brine and syrup	no		
14. Processing jars under water	yes	for processing	Can Coolers and processing waters
15. Can Coolers			Waters from these coolers may be reused satisfactorily for cooling cans after circulating over cooling towers, if careful attention is paid to proper control of replacement water, and to keeping down bacterial count by chlorination and frequent cleaning.
A. Cooling canals			
1. Original water	no		
2. Make-up water	yes		
B. Continuous cookers where cans are partially immersed in water			
1. Original water	no		
2. Make-up water	yes		
C. Spray coolers with cans not immersed in water	yes		
D. Batch cooling in retorts	yes	This water may be reused in other places as indicated.	
16. Clean-up purposes			
A. Preliminary wash	yes	yes*	Can coolers
B. Final wash	no	no	
17. Box washers	yes	no	Can coolers

* A certain amount of water may be reused for make-up water and in preceding operations if the counterflow principle is used with the recommended precautions.

** Townsend, C. T. and Somers, I. I. "How to Save Water in Canneries", Food Industries, 21, W11 - W12 (1949).

APPENDIX B. EXPERIMENTAL DATA PRESENTED IN TABLES

TABLE B.1. AVERAGE DAILY HYDRAULIC AND BIOLOGICAL LOADS

Apparatus	BOD (mg/l)	Daily Hydraulic loads (l)	Daily biological loads (kg BOD)
washer	275	10920	3
blancher	1770	16392	29
peeler	2070	393120	814
continuous cooker	91520	35496	3249
hydro pump	2604	8184	21
TOTAL		464112	4116

TABLE B.2. AVERAGE DAILY BIOLOGICAL LOAD

Apparatus		COD (mg/l)	COD (mg/l)	COD (mg/l)
washer	1. a	476		
	b	464		
	2. a	488	459	275
	b	472		
	3. a	440		
	b	416		
peeler	1. a	3600		
	b	3000		
	2. a	4200	3450	2070
	b	3600		
	3. a	3600		
	b	2700		
blancher	1. a	3300		
	b	2400		
	2. a	2100	2950	1770
	b	3300		
	3. a	2700		
	b	3900		
continuous cooker	1. a	154000		
	b	149600		
	2. a	151800	152533	91520
	b	114400		
	3. a	187000		
	b	158400		
hydro pump	1. a	4800		
	b	4440		
	2. a	4680	4340	2604
	b	4320		
	3. a	4560		
	b	3240		

TABLE B.3. AVERAGE DAILY HYDRAULIC LOAD

Apparatus	Flow (l/h)	Hydraulic Load (l)
washer	455	10920
peeler	16380	393120
blancher	683	16392
continuous cooker	1479	35496
hydro pump	341	8184
TOTAL	19338	464112

APPENDIX C. LABORATORY RESULTS

COD Analysis
October 23
Batch #1.

apparatus	sample #	dilution	titrant (ml) start	end	total	COD (mg/l)
peeler ①	1	1/75	.8	21.1	20.3	3600
	1	1/75	21.1	41.6	20.5	3000
peeler ②	2	1/75	.5	20.6	20.1	4200
	2	1/75	20.6	40.9	20.3	3600
blancher ②	3	1/75	.3	21.1	20.8	2100
	3	1/75	21.1	41.5	20.4	3300
blancher ①	4	1/75	.8	21.2	20.4	3300
	4	1/75	21.2	41.9	20.7	2400
blancher ③	5	1/75	.4	21.0	20.6	2700
	5	1/75	21.0	41.2	20.2	3900
hydro pump ②	6	1/30	.3	17.9	17.6	4680
	6	1/30	17.9	35.8	17.9	4320
hydro pump ①	7	1/30	.5	16.6	17.5	4800
	7	1/30	17.5	35.3	17.8	4440
Blank	8		.4	21.9	21.5	

Sample ① - 9 hr
② - 11 hr
③ - 13 hr

OD Analysis
ctober 26
Batch #2.

apparatus	sample	dilution	titrant (ml)			COD
			start	end	total	mg/l
ont peeler	1	1/550	.3	15.3	15.0	154000
①	1	1/550	15.3	30.5	15.2	149600
ont peeler	2	1/550	.3	15.1	14.8	158400
②	2	1/550	14.8	31.6	16.8	114400
ont peeler	3	1/550	.4	15.8	15.4	145200
③	3	1/550	contamination			
washer	4	—	.8	10.9	10.1	476
①	4	—	10.9	21.3	10.4	464
washer	5	—	.2	10	9.8	488
②	5	—	9.8	20	10.2	472
washer	6	—	.6	11.6	11.0	440
③	6	—	11.6	23.2	11.6	416
peeler	7	1/75	.6	21.1	20.5	4500
③	7	1/75	contamination			
blank	—	—	17.0	39.0	22.0	

Sample ① - 9hr
② - 11hr
③ - 13hr

COD Analysis
October 26
Batch # 3

apparatus	sample	dilution	titrant start	titrant end	titrant total	COD (mg/l)
peeler	1	1/75	.4	20.4	20	3600
(3)	1	1/75	20.4	40.7	20.3	2700
...ash cooker	2	1/550	.2	12.9	12.7	187000
(5)	2	1/550	12.7	26.7	14.0	153400
...ysin	3	1/30	.6	18.0	17.4	4560
pump (5)	3	1/30	18.0	36.5	18.5	3240
peeler	4	1/75	.5	20.5	20	3600
(1) T	4	1/75	20.5	40.1	19.6	4800
peeler	5	1/75	.4	20.6	20.2	3000
(5) T	5	1/75	20.6	40.3	19.7	4500
peeler	6	1/75	.7	20.5	19.8	4200
(3) T	6	1/75	- - - contamination - - -			
blank	7		.6	21.8	21.2	

Sample (1) - 9 hr
(2) - 11 hr
(3) - 13 hr

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