SANITATION STUDIES OF A REVERSE OSMOSIS UNIT USED FOR CONCENTRATION OF MAPLE SAP

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ABSTRACT

Sanitation studies of an industrial-scale reverse osmosis unit used for the concentration of maple sap are discussed. Bacterial plate counts of the concentrate and permeate effluent streams declined steadily during the initial 10-12 hr of operation, followed by respective increases in count from 2.8×10^4 per ml (12 hr) to 2.0×10^8 per ml (36 hr) and from 3.3×10^3 per ml (12 hr) to 2.4×10^4 per ml (36 hr). Membrane modules were maintained in good sanitary condition in the reverse osmosis unit pressure vessels for as long as one month when the modules were kept in contact with an acidified chlorine dioxide sanitizer.

Production of 1 gal of maple sirup requires the concentration of 35-40 gal of maple sap (2-3° Brix). In modern maple evaporator plants, this is usually done by boiling the sap in oil-heated atmospheric evaporator pans. Since the characteristic color and flavor of maple sirup are developed during boiling, a modicum of heat must be used in sirup production. But a typical maple evaporator plant consumes 3 gal of fuel oil for every gallon of sirup produced, and the prolonged exposure of sap to heat during the concentration process favors the production of darker colored sirup which has a lower market value.

Partial concentration of maple sap by reverse osmosis offers an attractive alternative to the conventional boiling process. Up to 75% of the water can be removed from sap by this process at about 1/25 the energy cost required for evaporation by conventional methods *(5)*. The concentrated sap can then be rapidly boiled to standard sirup density in a small oil or steam heated finishing pan evaporator which eliminates much of the danger of scorching encountered when large evaporator pans are used. Thus, the sirup producer could cut processing costs and run less risk of product damage from scorching by utilizing reverse osmosis in his plant. An additional advantage lies in the fact that reverse osmosis equipment is compact, requiring little floor space in comparison to that needed for the evaporator pans in current use. However, these advantages must be weighed against the current high cost of reverse osmosis equipment.

The use of reverse osmosis as an intermediate step in the production of maple sirup poses several problems to the sanitarian. Raw maple sap is readily contaminated by the microflora of the farm-forest environment in which it is harvested and can contain bacterial counts well above 1.0×10^6 per ml when it is delivered to the evaporator plant. Once at the plant, bacterial growth in the sap can be controlled by ultraviolet irradiation *(2)* until the sap is sterilized by the boiling process. However, passage of raw sap through a reverse osmosis (R.O.) unit exposes the sap to further contamination. The concentration of sap by R. O. implies an increase of bacterial count in the concentrate commensurate with the volume of water removed by permeation through the membranes. Bacterial slimes also may develop on the membrane surfaces and impair permeation of water through the membranes thereby cutting operating efficiency. These latter factors are further complicated by the fact that the R.O. units operate as a closed system which cannot be readily disassembled for cleaning. Hence, C.I.P. cleaning techniques must be used in the course of normal plant operation with only occasional shut-downs for more rigorous clean-up.

Initial small scale studies conducted at this laboratory indicated the feasibility of partial concentration of maple sap by reverse osmosis *(6)*. Based on these findings, a large pilot scale reverse osmosis concentrator (EUROC) was designed and built *(4)*. The operational characteristics of the EUROC were tested and optimum operating conditions established in a series of short, 2-6 hr, runs using a 2.5° Brix sucrose solution. Bacterial counts were made on samples taken from the EUROC effluent streams, and a C.I.P. system for sanitizing the unit was developed *(3)*. These studies showed that bacterial growth took place in the unit during short periods of idleness, and that bacterial populations in the effluent streams decreased from beginning to end of a short period of operation. They gave no indication of the sanitation problems which might arise in the course of prolonged operation and concentration of raw maple sap under typical field conditions.

The EUROC was installed in a central evaporator plant and was used for partial concentration of maple

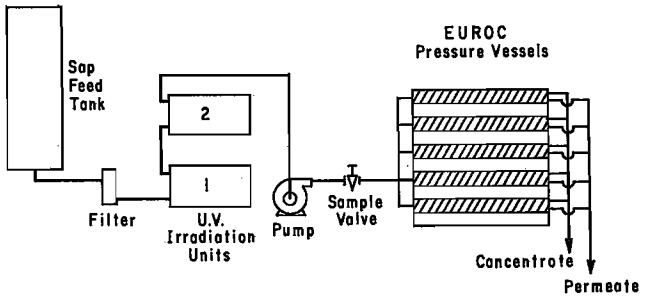

Figure 1. Flow diagram of EUROC maple sap concentration system.

sap during two sap runs late in the sap flow season of 1968. This paper reports the results of sanitation surveys conducted while the EUROC was used to concentrate raw sap delivered to the evaporator plant by independent sap producers or collected by plant employees from plant-owned sugar bushes.

MATERIALS AND METHODS

Reverse osmosis unit

(a) A reverse osmosis unit (EUROC), capable of processing sap at feed rates up to 12 gpm and pressures up to 700 psig was designed and constructed at this laboratory *(4)*.

(b) The modified cellulose acetate reverse osmosis membranes were spirally wound modules (ROGA[1]) 4 inches in diameter x 12 inches long containing approximately 10 ft² of membrane and were obtained from Gulf General Atomic[1].

Operation of EUROC unit

A flow diagram of the EUROC maple sap concentration process is shown in Fig. 1. As raw sap was received at the plant, it was pumped into the sap feed tank from which it was passed first through a Cuno P 110 cartridge filter and then through the UV irradiation units. The filtered, irradiated sap was pumped into the pressure vessels of the EUROC. The concentrated sap effluent from the pressure vessels was fed to a conventional finishing pan evaporator, where it was evaporated to standard density (65.5° Brix) sirup. The permeate effluent was discarded.

Sampling and plating

Samples for bacterial counts were taken aseptically from the sap feed tank; the sample valve located in the pump discharge line and from both concentrate and permeate effluent lines (see Fig. 1). Dilution and plating procedures were carried out by A.P.H.A. standards methods *(1)*. Standard tryptone glucose extract agar (Difco) was used for all bacterial counts, with incubation at 30 C for 48 hr. Counts were made using a Quebec colony counter.

RESULTS AND DISCUSSION

After the EUROC was emplaced at the central evaporator plant, it was sanitized with a 100-gal rinse of an acidified sodium hypochlorite solution containing 50 ppm available Cl_2 which had been adjusted to pH 4.5 with glacial acetic acid *(3)*. The pH adjustment was made on the advice of the manufacturer of the modules to avoid possible adverse effects caused by alkaline pH on the membranes. The fresh sap was pumped through the EUROC at 6 gpm and 600 psig. Sap feed temperatures ranged from 52-57 F during the period of operation. Samples for bacterial counts were taken as previously described at the start of operation and at 6-hr intervals, during 36 hr of continuous operation.

The data from this sampling program are shown in Fig. 2. The bacterial count of the raw sap held in the feed tank was low, never exceeding 1.0×10^5 per ml during the 36 hr of operation, and the in-line irradiation units effectively reduced this population so that the sap entering the pressure vessels of the EUROC contained less than 5.0×10^3 per ml. The zero hour samples of the concentrate and permeate had bacterial counts of 9.5×10^6 and 9.0×10^5 per ml, respectively, indicating that a considerable buildup of bacteria had taken place in the EUROC pressure tubes during the period of idleness. The bacterial counts in the effluent streams decreased rapidly to 2.8×10^4 per ml in the concentrate and 3.3×10^3 per ml in the permeate after 12 hr of operation. Then the counts of both discharge streams increased until at the end of the 36-hr operating period the concentrate contained 2.0×10^5 per ml and the permeate 2.4×10^4 per ml. This increase indicated a progressive build-up of bacterial growth in the pressure vessels which could ultimately produce sliming of the membranes with a resulting loss of operating efficiency.

During the 36 hr of continuous operation, 13,000 gal of maple sap were concentrated; and a top grade, light amber, delicately flavored sirup was made from the concentrated sap.

At the end of the maple season, the EUROC was stored in an air-conditioned room (65 F). The main-

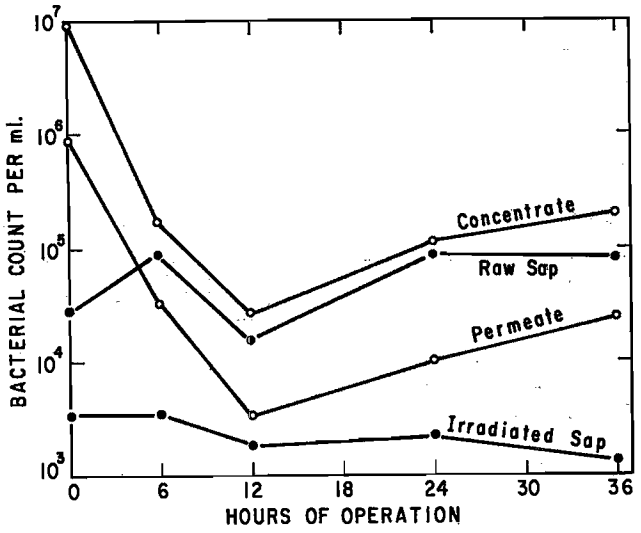

Figure 2. Numbers of bacteria in raw sap, irradiated sap, and effluent stream during 36 hr of continuous operation of EUROC.

[1]Mention of company or trade names does not imply endorsement by the Department over others not named.

TABLE 1. BACTERIAL COUNT OF SAMPLES TAKEN FROM REVERSE OSMOSIS UNIT PRESSURE VESSELS AFTER SANITATION AND DURING STORAGE

Sanitizer	Storage time (weeks)	Bacterial count per ml	
		Concentrate	Permeate
Acidified Hypochlorite with H_2O rinse	0	<10.0	4×10^1
	1	2.6×10^5	2.7×10^4
	2	4.6×10^6	2.3×10^6
Acidified ClO_2 with H_2O rinse	0	<1.0	<1.0
	1	1.1×10^5	1.1×10^2
	2	1.5×10^5	4.4×10^4
Acidified ClO_2 held in R.O. tubes	0	<1.0	<1.0
	1	<1.0	<1.0
	2	<1.0	<1.0
	3	<1.0	3.0×10^1
	4	7.0×10^2	1.2×10^3

tenance of good sanitary conditions in the EUROC during long-term storage (8 month) was difficult because it was designed for experimental purposes and therefore was fitted with a more intricate system of valves, controls, flow meters, and piping than would be used in commercial practice. Moreover, the configuration of the spiralwound membrane modules supported by latex-glass bead backing materials further complicated C.I.P. sanitation procedures by impeding turbulent flow across membrane surfaces, and it was also possible that the high pressures exerted in the tubes during operation had compacted the modules creating small "dead" areas which could not be readily sanitized by these procedures. These problems suggested the need for rigorous sanitation techniques.

The following sanitation procedures were studied during the 8-month storage period:

(a) One-hundred gallons of a sodium hypochlorite sanitizer (50 ppm available Cl_2) acidified to pH 4.5 with glacial acetic acid were pumped through the EUROC. The final portion of the sanitizer was allowed to stand in contact with the membranes for 30 min. Then, the sanitizer was rinsed from the unit with 200 gal of ultraviolet irradiated tap water.

(b) The above procedure was repeated using a chlorine dioxide sanitizer (50 ppm available Cl_2) acidified to pH 4.5 with glacial acetic acid.

(c) One-hundred gallons of the acidified chlorine dioxide sanitizer were pumped through the unit. The final portion of the sanitizer was allowed to remain in the unit in contact with the membranes for the duration of the storage period.

Bacterial counts were made on samples taken from both the concentrate and permeate sectors of the EUROC at the beginning of each storage period and at weekly intervals thereafter, until the rise in bacterial counts indicated the need for further sanitization.

The bacterial counts made during the final tests of each of the three sanitization techniques are shown in Table 1. The hypochlorite sanitizer did not maintain the unit in good sanitary condition. After 2-weeks of storage, bacterial counts of samples taken from both sectors of the pressure tubes exceeded 2.0×10^6 per ml and a foul odor was associated with the samples. Because of these results and a persistent hypochlorite flavor residue problem, the use of this sanitizer was discontinued.

A more rigorous sanitizer which could be readily rinsed from the unit was required, and the use of a chlorine dioxide sanitizer (FDA approval for food sanitation pending) was investigated. When this sanitizer was rinsed from the unit with 200 gal of irradiated tap water, as described in procedure *(b)*, a slower build-up of bacterial growth took place, but after two weeks of storage, samples taken from the concentrate and permeate sectors had counts of 1.5×10^5 and 4.4×10^4 per ml, respectively. The strong odor noted in the previous study was not present in the samples taken from either sector of the unit. However, the growth of bacteria in the pressure tubes indicated that this system would not permit long-term storage of the modules in the pressure tubes.

The final sanitization procedure in which the sanitizer was permitted to remain in contact with the membrane modules was more effective in controlling bacterial growth, but at the end of four weeks of storage bacterial counts of 7.0×10^2 per ml in the concentrate sector sample and 1.2×10^3 per ml in the permeate showed that the sanitary condition of the EUROC was deteriorating. Tests for the presence of Cl_2 in the samples were negative. More study is required to develop better cleaning procedures for the EUROC and methods for maintaining spiralwound membranes in good sanitary condition during prolonged storage.

CONCLUSIONS

(a) During 36 hr of continuous operation, the bacterial counts of the concentrated sap and permeate effluents decreased steadily for the first 12 hr, but then, though the bacterial count of the feed declined, the count of the concentrate increased from 2.8×10^4 per ml (12 hr) to 2.0×10^5 per ml (36 hr) and that of the permeate increased from 3.3×10^3 per ml (12 hr) to 2.4×10^4 per ml (36 hr). This indicated that bacteria could survive and multiply in the EUROC pressure vessels while the unit was in operation concentrating maple sap.

(b) C.I.P. cleaning of the EUROC with 200 gal of

an acidified chlorine dioxide sanitizer (pH 4.5-4.7, 50 ppm available Cl_2) effectively reduced bacterial populations in the effluent streams to <1.0 per ml.

(c) When the sanitizer was flushed from the EUROC tubes with irradiated tap water, a slow build-up of bacterial contamination took place during 2 weeks of storage.

(d) An acidified chlorine dioxide sanitizer (pH 4.5-4.7, 50 ppm available Cl_2), when left in the EUROC pressure vessels in contact with the membrane modules, maintained the pressure vessels in good sanitary condition for a storage period of one month.

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AUTHORS' NOTE

Shortly after the completion of this work, a new spiral wound membrane module became available. This module has new backing material, improved separators, and its rigid construction resists compaction. The new modules should eliminate much of the sanitation problem posed by the now obsolete modules used in the work reported here.

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NUTRITIONAL ASPECTS OF DAIRY PRODUCTS[1]

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ABSTRACT

The materials used in building the human body must be chosen with care so that good health and long life are possible. Research in the study of nutrition has shown that certain food nutrients are essential in promoting physical fitness. When taken into the body in adequate amounts, these nutrients, together with good habits of health and hygiene, promote growth and sound physical development.

As the study of nutrition continues, the value of milk in the diet becomes more apparent. Everyone needs milk every day in order to receive the essential food nutrients their bodies require daily.

Millions of Americans are crumbling on the inside while showng no outward sign. The fault lies with a "hidden hunger" for calcium—a hunger that could easily be met and overcome by proper diet. Milk is the best source of calcium in our food supply. It is almost impossible to supply the amounts of calcium recommended unless milk in some form is used daily and cheese and other milk containing products are eaten frequently.

Calcium is just one of many nutrients found in milk. Altogether, at least 100 chemical components have been identified. Milk's value as a whole is greater than just the sum of its known components.

Milk gives more food for the money than any other food material available. A quart of milk weights 2.15 pounds. It is a package of nutrients, safety, convenience, flavor, and economy. A true daily investment in health.

In order to fully appreciate the nutritional aspects of dairy products, I think it good to take a moment and think about the meaning of the word nutrition. Nutrition does begin with food, but it is more than food. It is the food itself plus all the things that happen to it from the time it is eaten until it actually nourishes the body. Nutrition is really a process in which food is digested and its nutrients are absorbed and finally distributed to the parts of the body where they are utilized in all metabolic activities. This process may be entirely successful, or it may be faulty in varying degrees at different points. The faults may consist of too little, too much, or the wrong kinds of food; or there may be functional failure in any of the steps through which food passes

(Continued on Page 334)

[1]Presented at the Fifty-Sixth Annual Meeting of the International Association of Milk, Food, and Environmental Sanitarians, Inc., Louisville, Kentucky, August 17-21, 1969.