

**AN ECONOMICAL ULTRAVIOLET-IRRADIATION UNIT
FOR PASTEURIZING FLOWING MAPLE SAP**



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CAUTION

When the ultraviolet irradiation unit is in operation, the lights should be shielded to protect the operator's eyes from the injurious effects of ultraviolet rays. Sheets of aluminum foil, which can be purchased in any grocery or hardware store, make effective ultraviolet shields.

AN ECONOMICAL ULTRAVIOLET-IRRADIATION UNIT FOR PASTEURIZING FLOWING MAPLE SAP

J. C. Kissinger and R. A. Bell^{1/}

ABSTRACT

A basic ultraviolet pasteurizer, which can be assembled from commercially available components, is described. Operating conditions necessary for effective pasteurization are discussed. Raw maple sap pasteurized by this unit can be held for 48 hours at 65° F. without excessive bacterial growth.

INTRODUCTION

The modernization of the maple industry has brought an increased awareness of the importance to the sirup producer of sanitation in sap collection, transportation, and storage (6).^{2/} Sirup producers have recognized that the quality of sirup (flavor, color, and ropy texture) depends to a great degree on the sanitary condition of the raw sap used in its manufacture. Because of this, maple producers have made wide use of dairy sanitizers for cleaning equipment, germicidal taphole pellets (1), covered buckets, plastic bags (4) and plastic tubing for sap collection, tanks and pumps designed to meet food-industry sanitation standards, and germicidal ultraviolet (U.V.) lights to maintain sap in good sanitary condition during handling and storage before processing (5).

Germicidal ultraviolet (U.V.) lights have been used by maple producers primarily for the control of microbial growth in stored sap during periods when profuse sap flows exceed an evaporator plant's sirup-processing capacity. Since the lethal U.V. rays do not penetrate deeply into statically stored maple sap, sap storage for periods up to 5 days can be carried out only by using agitation to renew the surface of the sap exposed to U.V. irradiation (3). However, in cases requiring less than 48 hours' storage, the sap

^{1/} Research microbiologist and chemist, respectively, at the Eastern Marketing and Nutrition Research Division, Agricultural Research Service, U.S. Department of Agriculture, Philadelphia, Pa. 19118.

^{2/} Underscored numbers in parentheses refer to Literature Cited, p.

usually can be safely held by passing it through an in-line ultraviolet irradiation unit of the type used to sanitize home water supplies (2). Since the surviving bacteria multiply at a rate controlled by the sap temperature, it is possible that, in abnormally warm weather, degradation could take place in even less than 48 hours after pasteurization.

One of the major deterrents to the use of in-line U.V. irradiation units in the maple industry has been their cost. A commercial in-line U.V. irradiation unit suitable for a small maple evaporator plant costs in excess of \$500.00. Because of this, the in-line U.V. irradiation unit has not been used by many maple sirup producers. But the concept of using U.V. irradiation to pasteurize flowing maple sap is technically sound, and an inexpensive U.V. unit capable of performing this function could be of value to the small maple producer. This paper describes the construction and operational characteristics of an economical basic U.V. unit, which the maple producer can assemble or fabricate from readily available materials.

MATERIALS USED

Feed tank.--A 150-gallon galvanized-iron tank 2 feet wide x 6 feet long x 2 feet high.

Pump.--A centrifugal pump producing flow rates up to 9 gallons per minute (g.p.m.) through the irradiation troughs.

Control valve.--A gate valve in the pump discharge line to control flow rates.

Flow meter.--A Fischer and Porter Flowrator,^{3/} calibrated in 0.2 g.p.m. increments from 0 to 12 g.p.m., was used to measure flow rates.

Irradiation troughs.--Two irradiation troughs were constructed of dull-finish stainless steel with dimensions identical to those of commercially available 5-inch box-type guttering (fig. 1).

A 3-inch sheet-metal dam was placed at the feed end of each trough to create a well for the sap. Splashing and foaming was minimized by feeding sap into the well below the surface of the contained sap, and the even flow of sap over the dam eliminated cavitation of the sap-flow pattern through the irradiation area. A 1/2-inch ridge of sheet metal was emplaced 7 feet downstream from the dam, directly before the sap-outlet line. This maintained the sap at a depth of 1/2 inch in the irradiation area and helped provide turbulent flow through the trough.

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Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade or company name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

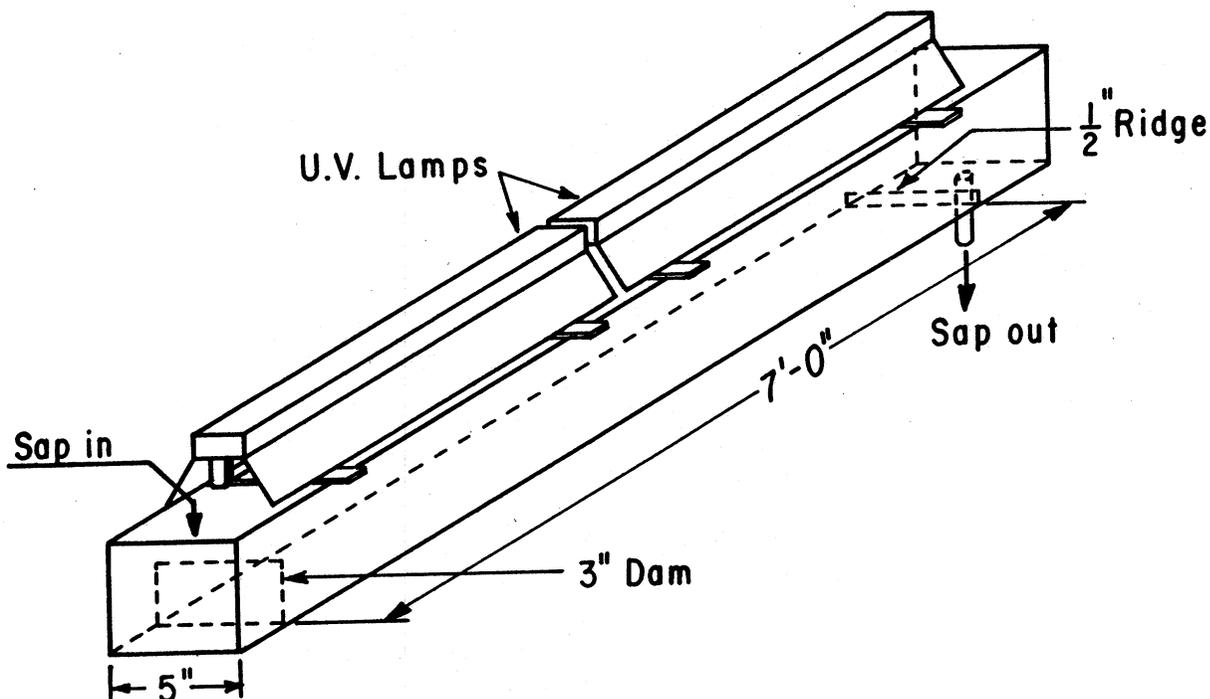


Figure 1.--Diagram of assembled sap-irradiation trough unit.

Ultraviolet lamps.--Two single-tube fluorescent lamp fixtures with white enameled reflectors were mounted in series directly above the irradiation area of each trough. The fixtures were fitted with General Electric G30T8 ultraviolet light tubes. The lights were placed on the top of the trough to minimize splashing of sap on the light tubes. Splashing and subsequent drying of sap on the lamp tubes would have drastically decreased the intensity of U.V. rays emitted by the lights. Sheets of aluminum-foil wrap were placed over the lights to shield the operator's eyes from the U.V. rays when the unit was in operation.

Tubing lines.--Shelby-Jones Transtube plastic dairy hose was used for all tubing lines.

Simulated sap.--Since large volumes of maple sap were not available at the time this work was done, all large-scale experimentation was carried out with a simulated sap made by diluting a light-amber, standard-density sirup to 2.5° Brix with sterile water and adding 0.9 g. of sugar sand per gallon.

Microbial stock cultures.--A mixed culture containing Pseudomonads, Leuconostocs, Bacilli, and other genera was isolated from commercially produced maple sap. The culture was maintained on tryptone glucose extract (T.G.E.) agar slants at 30° C. and kept viable by transferring at 48-hour intervals.

The inoculum for large-volume studies was prepared by washing the bacteria from six 48-hour T.G.E. slants with 10 ml. per slant of simulated sap, which had been sterilized by autoclaving at 15 pounds per square inch gage

(p.s.i.g.) for 15 minutes. The washings were pooled, and 10-ml. volumes of the pooled culture were used to inoculate each of six 1-gallon jugs of the sterile simulated sap. After 48 hours' incubation at 30° C., the 6 gallons of inoculum were pooled, and the cell concentration of the inoculum was estimated microscopically by use of a hemacytometer. Based on this estimate, an amount of inoculum was added to 100 gallons of simulated sap in the sap tank to provide a cell concentration of 5.0×10^5 per ml.

Irradiation system.--A flow diagram of the irradiation system is shown in figure 2. The inoculated simulated sap was pumped from the sap-feed tank and successively passed through the flow-control valve, flow meter, and irradiation troughs, and then it was discharged.

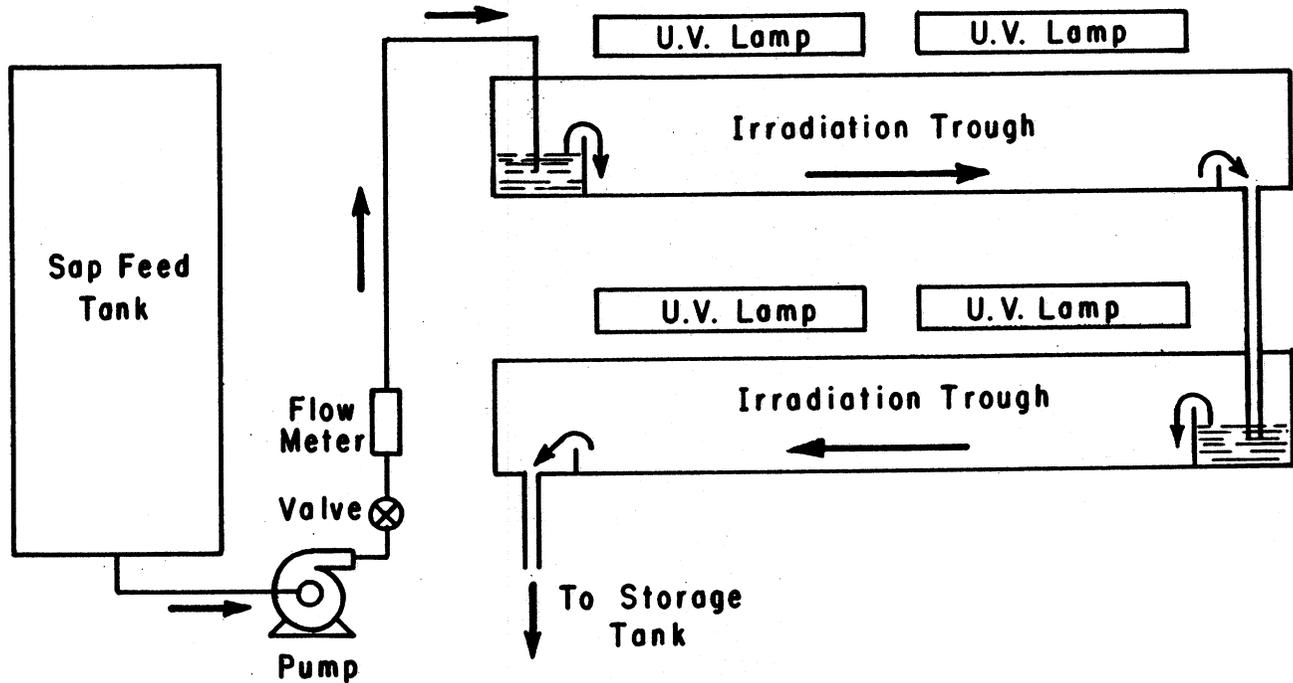


Figure 2.--Flow diagram of sap-irradiation trough system.

PROCEDURE

Operation

The trough and light systems were assembled and leveled. The equipment was sanitized by washing it with 0.5 percent sodium hypochlorite solution, followed by three successive rinses with irradiated tap water. The tank was immediately filled with 100 gallons of simulated sap, and the inoculum was added. The inoculated sap was stirred to disperse the inoculum. It was then pumped through the system at rates from 1.0 to 9.0 g.p.m., beginning with the slowest flow rate. This procedure was followed by using one, two, three, and four U.V. lamps in series as sources of germicidal irradiation.

Sampling and Plating

Samples for bacterial counts were taken aseptically from the feed tank at the start of operation and from the discharge line. Following each change in flow rate, 2 minutes were allowed for equilibration of flow before samples were taken from the discharge line. Tryptone Glucose Extract Agar (Difco) was used as the plating medium for bacterial counts. All plates were incubated at 30° C. for 48 hours. Counts were made with a Quebec colony counter.

RESULTS AND DISCUSSION

Preliminary studies were made to determine the intensity of ultraviolet irradiation at selected points along the bottoms of the irradiation troughs with all lights in operation. U.V. intensity was measured with an Ultra-violet Products, Inc. BLAK-RAY ultraviolet-intensity meter. The U.V. intensity was found to be 100 μ -watts per cm^2 at points directly beneath the light tubes. At points 6 inches beyond the ends of the light fixtures, the intensity dropped to 40 μ -watts per cm^2 . Zero readings were recorded at points 1 foot from the ends of the fixtures. This indicated that the main lethal effect of the U.V. rays would take place during the passage of sap directly beneath the U.V. tubes and that the U.V. reflectance from the dull-finish metal trough was minimal.

Because of the poor U.V. reflectance, the exposure times for sap flowing through the troughs at different flow rates were calculated on the basis of an irradiation area 1/2 inch deep x 5 inches wide x 36 inches long, since the length of a single U.V. lamp was 36 inches. The volume of sap contained in an exposed area with the above dimensions is 0.39 gallon. The exposure time for sap flowing through the irradiation area is expressed by the equation:

$$\frac{\text{Volume of sap (gal.) in exposed area}}{\text{Rate of flow (gal./min.)}} = \text{Exposure time in min.}$$

Table 1 shows the exposure times in seconds for sap passing through this unit beneath series of 1, 2, 3, and 4 germicidal lamps.

Simulated sap contaminated with the bacteria from natural sap was pumped through the irradiation unit as previously described. The lethal effects of the U.V. rays on the bacterial population of simulated sap passed through the troughs at different flow rates are shown in figure 3. A single U.V. lamp proved to be impractical for use as a sap pasteurizer because a 95-percent kill of the sap-bacterial population could be achieved only at flow rates of 3 g.p.m. or lower. When two lamps were used, efficiency increased slightly and a 95-percent reduction in the bacterial count was noted at flow rates up to 6 g.p.m. This flow rate, however, is too low to satisfy

TABLE 1.--Exposure times for 1, 2, 3, and 4 U.V. lamps in series for different sap-flow rates

Flow rate (g.p.m.)	Irradiation time in seconds			
	1 Light	2 Lights	3 Lights	4 Lights
1 -----	23.4	46.8	70.2	93.6
2 -----	11.7	23.4	35.1	46.8
3 -----	7.8	15.6	23.4	31.2
4 -----	5.8	11.7	17.5	23.4
5 -----	4.7	9.4	14.1	18.8
6 -----	3.9	7.8	11.7	15.6
7 -----	3.4	6.7	10.1	13.4
8 -----	2.9	5.9	8.8	11.7
9 -----	2.6	5.2	7.8	10.4

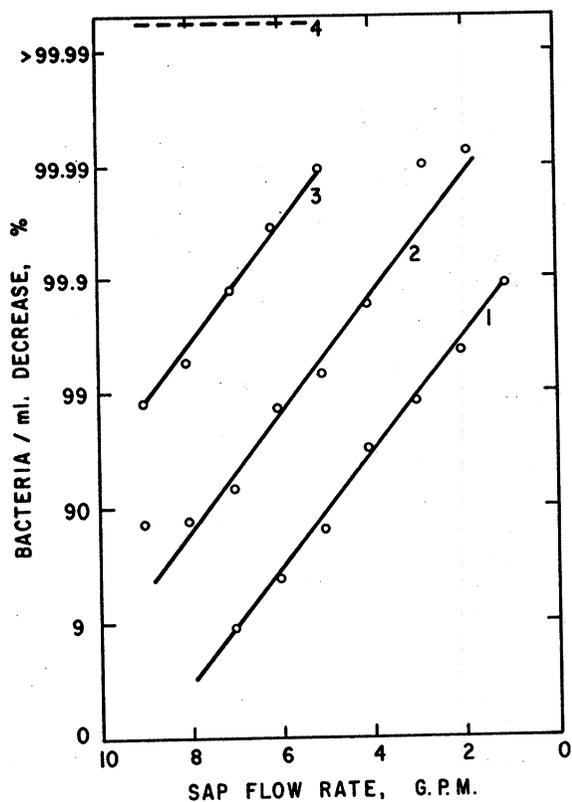


Figure 3.--Percent decrease in bacterial populations of maple sap passed through the irradiation troughs at flow rates of 1.0 to 9.0 g.p.m. Numbers on curves indicate number of U.V. lamps used in series.

the requirement of any maple producer other than a small-scale hobbyist. A series of three U.V. lamps gave a 95-percent kill at flow rates up to 9 g.p.m. This configuration of lamps could be regarded as the minimum needed for effective sap pasteurization in a small maple-processing plant. More than 99 percent of the bacterial population in the sap was killed by the exposure of the sap to the U.V. rays from a series of four lamps at all flow rates used in this study. This is shown as a broken line on the graph (fig. 3). However, it can be estimated from the exposure times shown in table 1 and the times required for 95-percent kills noted with the series of 1, 2, and 3 lamps in figure 3 that a 4-lamp series would effectively pasteurize sap at flow rates as high as 12 g.p.m. through a trough unit.

An irradiation trough is, admittedly, a crude device, but the efficiency of this unit compares favorably with that of the in-line U.V. units that were used in previous studies of irradiation pasteurization in this laboratory (2). Exposure of sap to U.V. rays for 7.8 seconds during its flow through the trough unit resulted in a decrease of more than 95 percent of the sap-bacterial population. Similar results were obtained by passage of sap containing comparable microbial populations through commercial in-line irradiation units with a 7-second exposure time. As could be expected, the commercial unit was somewhat superior to the trough unit as a sap pasteurizer, but the trough unit is quite capable of meeting the need of the average maple sirup producer for a method of storing sap for periods as long as 48 hours.

Sap that was treated by passage through the trough pasteurizer had storage stability similar to that of sap passed through a commercial in-line irradiation unit (2). Storage of the treated sap at 65° F. for 48 hours resulted in bacterial growth that restored the bacterial population to pre-pasteurization levels. Therefore, the maple producer must regard U.V. irradiation pasteurization as only a temporary measure, permitting storage of sap for periods as long as 48 hours. It should be further noted that the 48-hour storage time can be valid only for sap stored in a carefully cleaned and sanitized tank. Storage of pasteurized sap in an unclean tank can result in immediate massive contamination and rapid deterioration of the sap, without regard to its sanitary quality at the time of storage.

CONCLUSIONS

A basic U.V. pasteurizer can be constructed from components readily available on the open market.

Reflectance of U.V. rays was minimal in the dull-finish, stainless-steel troughs used in this work.

Ultraviolet irradiation of sap containing a bacterial-cell concentration of 5.0×10^5 per ml. resulted in a decrease of 95 percent in the bacterial population when the following combinations of germicidal lamps and flow rates were used:

G.p.m.

- 1 lamp - 3
- 2 lamps - 6
- 3 lamps - 9
- 4 lamps - 12 (extrapolated)

Ultraviolet-pasteurized sap can be stored for periods as long as 48 hours at 65° F. without excessive bacterial growth.

The trough-type unit described in this paper, although not quite as efficient as a commercial in-line irradiation unit, will effectively pasteurize sap when used within the previously described limitations of flow rates and number of U.V. Lamps placed in series.

COST OF MATERIALS

For the purpose of this paper, it is assumed that the pump, flowmeter, flow-control valve, and piping or sanitary dairy hose necessary to convey sap from a gathering tank to the U.V. unit are part of the existing evaporator house equipment. The materials needed for assembly of the unit described in this paper and the approximate costs of these materials are as follows:

Item	Cost estimate for single item	Number required
1. White enameled gutter trough (sold in 10-foot lengths) - - - - -	\$ 4.00	2
2. End cap for gutter trough - - - - -	.30	2
3. Drop outlet for gutter trough - - -	1.30	2
4. Fluorescent light fixture, 36 inches long, single tube with white enameled reflector - - - - -	17.00	4
5. Ultraviolet lamp tube G30T8 - - - - -	<u>9.00</u>	4
Estimated cost - - - - -	\$115.00	

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