

Reduction of the Microbial Population of Apple Cider by Ultraviolet Irradiation

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SUMMARY

The microbial population of fresh cider was greatly reduced by specially designed ultraviolet (UV) lamps. The percentage of microbial kill was affected by the clarity of the cider, the length of UV exposure and the presence of potassium sorbate. The total viable microbial count in a thin film of flowing cider was reduced 99% by 40 sec of UV irradiation. UV treatment prolonged the storage life of apple cider without affecting the flavor.

INTRODUCTION

Apple juice as it comes from the press is at its peak of quality. It has good body, it is light to amber in color, and it has many desired flavor and

aroma components. It has distinctive consumer appeal, and large quantities are marketed in the apple growing areas during the fall and winter months. Freshly pressed apple juice, or fresh cider, contains many microorganisms which cause deterioration within two days at room temperature unless they are inhibited or destroyed.

Forgacs (1942), Marshall *et al.* (1951, 1952a,b), and Lüthi (1959) reported that plant sanitation, fruit condition, and temperature are all very important in determining the number and types of microorganisms found in fresh cider. Other workers (Ferguson *et al.*, 1957; and Weaver, *et al.*, 1957) reported that the rate of fresh cider deterioration is influenced by the num-

ber and type of microorganisms initially present, pH, the storage temperature, and the type and amount of chemical microbial growth inhibitors added.

Robinson *et al.* (1959) found that treating cider with sodium sorbate and mild heat (120°F for 5 min) was effective in reducing the microbial count and prolonged its storage life to 20 days at 70°F. Harrington *et al.* (1966) reported that diethyl pyrocarbonate (DEPC) destroyed most of the yeasts, mold, and bacteria present in fresh cider, and when combined with potassium sorbate prolonged the storage life of fresh cider to 13 days at 80°F. Hope (1965) studied the temporary preservation of apple juice by several

preservatives adjusted to different pH levels.

These attempts at improving the storage life of apple cider by the use of heat or chemicals usually involved a noticeable change in the characteristic fresh flavor of the product. In one case, DEPC, the material has not yet been approved for general food use.

Kissinger *et al.* (1966a, 1966b) describe the application of UV irradiation for control of microorganisms in maple sap. Robe (1965) describes the use of special UV irradiating equipment to reduce the microbial contamination of liquid sugar solutions under commercial storage conditions.

Mack *et al.* (1959) reported that UV irradiation extended the shelf life of raw cider but the product had a poorer flavor than either canned juice or the original cider. Two-thirds of the tasters disliked the product.

The present paper describes a UV irradiation procedure which greatly reduces the microbial population of fresh apple cider without altering the flavor.

MATERIALS AND METHODS

Cider. Freshly pressed cider, made from a blend of apple varieties, was obtained from a local commercial producer. Each test used a single lot of cider.

Standard plate counts. Appropriate serial dilutions of cider were plated on

tryptone glucose extract nutrient agar (Difco Laboratory, Detroit, Mich.), pH 7.0 and incubated at 90°F (32°C) for 48 hr to estimate the total number of bacteria per ml of cider. Similar appropriate dilutions of cider were plated on Difco Wort Agar plates, pH 4.8, incubated at room temperature, 70 to 77°F (21 to 25°C) for 5 days to estimate the combined yeast and mold counts per ml of cider (APHA 1960). In this paper the sum of both Wort and Nutrient Agar plate counts is referred to as "total" counts.

Potassium sorbate. A commercial grade of potassium sorbate was added as a 10% aqueous solution. Its level of concentration in the cider was determined by the dilution method of Harrington *et al.* (1962).

Irradiation equipment. The component parts and the final assembly of the UV lamp are shown in Fig. 1. The germicidal lamp tube (a) is the G36T6, 33¾ in. × ¾ in. single pin with high UV intensity (13 UV watts). The inner quartz sleeve (b) is 30½ in. × 1 in. O.D. and has good transmission at 2537 Å. A ½-in stainless steel ribbon, spiraled around the quartz sleeve, directs the internal cider flow to give maximum cider surface renewal for UV exposure. Fig. 1 (c) shows the stainless steel outer case, 28½ in. × 1¾ in. I.D. It is fitted with opposing inlets and outlets. The end components and seals for sealing the inner quartz sleeve to the outer case are shown. Fig. 1 (d) shows the holder for the UV germicidal tube and outer case (37 in. × 2 in. × 4 in.). The holder contains the electrical starting and tube lighting components. Fig. 1 (e) shows the completely assembled UV germicidal lamp.

The auxiliary equipment and the operational arrangement of the 3 series-connected UV germicidal lamps are shown in Fig. 2. A small centrifugal pump is shown. A larger Moyno pump

was later substituted for it. The Moyno pump's rate can be changed quickly from 22 to 90 gal per hr (gph).

The sampling or bottle filling points are a, b, c, d, and e. This arrangement permits cider sampling before and after the pump, and before and after each UV germicidal lamp treatment. Therefore the effect of each UV treatment upon the cider's microbial count can be measured. The average volume of cider held by each lamp is 345 ml (0.091 gal). The UV exposure time in seconds can be calculated as follows:

$$\frac{\text{gallon volume per lamp(s)} \times 3600}{\text{pump rate in gph}} =$$

UV exposure in seconds.

The calculated rise in temperature by exposure of cider to a 36-watt lamp should be 1°F per 18.5 sec. In actual practice, the temperature rise was usually less than this.

RESULTS AND DISCUSSION

Fig. 3 represents the effect of UV irradiation on the microorganisms in fresh, non-clarified cider. This cider was given 6 UV treatments by pumping it 6 times through the 3-lamp system at the rate of 75 gph. The total number of microorganisms was considerably reduced by each UV exposure. Fig. 3 shows that UV sterilization continued at its initial logarithmic rate until 99% of the organisms were killed. When the total number of surviving microorganisms became less than 1%, the UV kill rate was slower than the initial logarithmic rate.

This reduced rate of kill may mean that the surviving organisms represent species that are more resistant to UV irradiation or that they are protected by suspended colloidal particles.

Table 1 shows the effect of flow rate and UV exposure time on the destruction of microorganisms in fresh non-clarified apple cider. At pumping rates

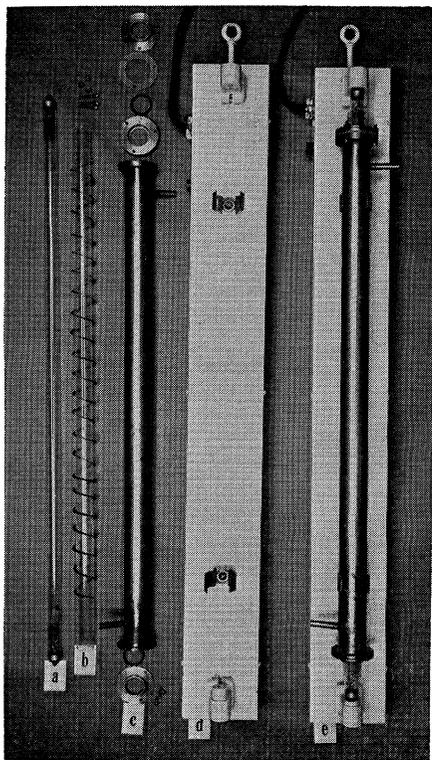


Fig. 1. UV irradiation lamp component parts before and after assembly.

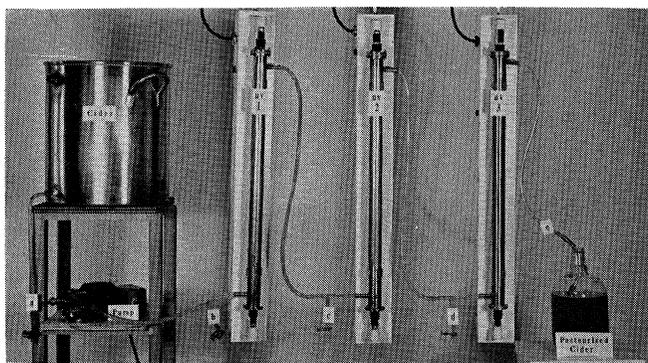


Fig. 2. Operational arrangement of cider irradiation equipment.

Table 1. The effect of pumping rates and UV-irradiation time on the reduction of microbial population in fresh cider.¹

Pump rate gph	Seconds of UV per run	% kill per run	Calculated seconds of UV for 95% kill
86	11.4	55	43
66	15.0	68	40
48	20.7	77	42
23	43.5	88	60

¹ Initial total count 1,100,000/ml.

of 86, 66, and 48 gph, calculations indicate that this cider lot would require an average UV exposure time of 42 sec for a 95% kill, assuming that the kill rate would remain constant. At the slowest pumping rate (23 gph) calculations indicate that a 95% kill would require 60 sec of UV irradiation, indicating that suspended materials, surface renewal, and the cider's UV absorbance are all factors that must be considered in the use of UV for sterilizing fresh apple cider.

Fig. 4 shows microbial population reduction by UV irradiation after treatment with 300 ppm of potassium sorbate, or Pectinol, or the combination of both. After these treatments the cider was allowed to settle in the cold room (36°F or 2.2°C) for 24 hr. It was syphoned off from its settlings, plated, then pumped through the 3-UV light series at 24 gph which gave it a

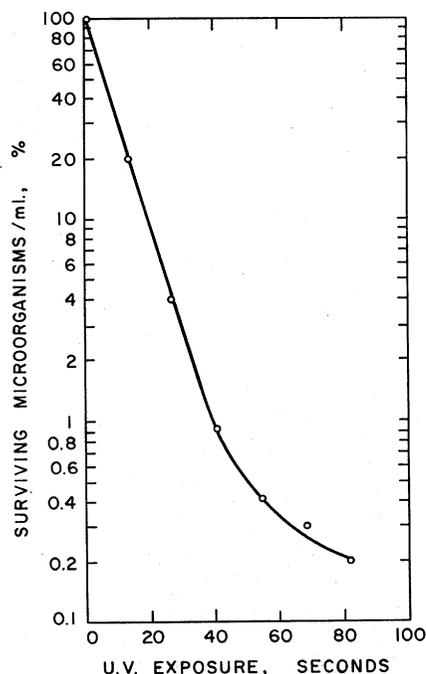


Fig. 3. Effect of UV irradiation on total microorganism count in fresh non-clarified apple cider. Initial count 600×10^8 per ml. For irradiation conditions, see text.

UV exposure of 42 sec. Then it was replated. The total counts of yeast, mold, and bacteria are shown in Fig. 4.

The control's total count was reduced by 6% by settling, then 84% by UV irradiation. The potassium sorbate treated cider's total microbial count was reduced 23% by antiseptic action and settling and 73% more by UV irradiation, a total count reduction of 80%. Potassium sorbate plus Pectinol-treated cider had its total counts reduced 71% during settling and further reduced 79% by UV irradiation, a total microbial kill of 94%. The Pectinol (only)-clarified cider had its total count reduced 65% by settling, then further reduced 99.5% by UV irradiation, an overall count reduction of more than 99.8%. The inhibitory effect of potassium sorbate on yeasts and molds is indicated by total count reduction. Its beneficial effect during storage will not be discussed here. Sorbic acid is very absorbant of UV light. Fig. 4 shows that this absorbance of UV light (blackness to UV) reduces the killing effectiveness of the UV treatments on sorbated ciders whether cloudy or clarified.

Fig. 5 shows the microbial killing effectiveness of UV on fresh apple cider before and after sorbate or Pectinol treatments. The entire lot of fresh cider was given 42 sec of irradiation by pumping it through the 3 UV lights at 24 gph. This reduced the total microbial counts per ml from 585×10^8 to 82×10^8 . This UV-irradiated cider was separated into four portions which were treated as follows: (1) control, no treatment; (2) 300 ppm potassium sorbate; (3) 300 ppm potassium sorbate and Pectinol; (4) Pectinol only. All portions

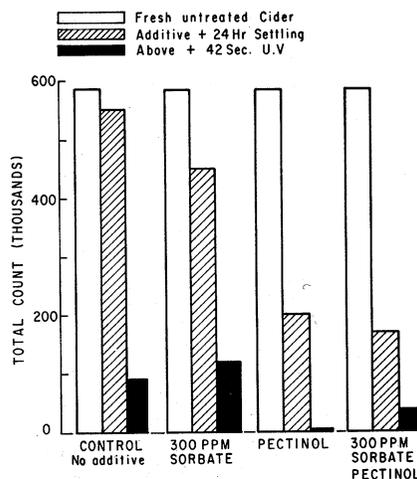


Fig. 4. Effect of different treatments in reducing the microbial populations of fresh cider.

were settled 24 hours in a cold room, 36°F (2.2°C). Then the ciders were decanted (syphoned from their sediment) before plating.

The total counts in Fig. 5 show reduction in viable counts due to the secondary treatments and settling. All the decanted cider portions were again pumped through the lamps and exposed to 42 sec of UV. The effects of both the secondary treatments and the second UV exposure are shown in Fig. 5.

The first UV-irradiation treatment of the fresh, non-clarified cider reduced the microbial count by 86%. The secondary treatments and cold-room settling reduced the total counts by 12% for the potassium sorbate, 67% for the potassium sorbate plus Pectinol, and 57% for Pectinol only.

The second UV irradiation reduced the total viable count of the control by an additional 83%. The nonclarified, sorbated sample count was reduced only 9%. The Pectinol-clarified, sorbated sample had its total count reduced 82% while the Pectinol-clarified cider without potassium sorbate had its viable count reduced by 97%. There was cumulative sterilizing benefit from each successive treatment.

The total count reduction for the two UV-irradiation treatments on the control was 97%; for the nonclarified potassium sorbate-treated ciders the total count reduction was 87%. The ciders that were clarified with Pectinol had a total count reduction of more than 99%. Fig. 5 shows that the sterilizing effect of UV irradiation is reduced by the addition of 300 ppm of potassium sorbate but enhanced by Pectinol clarification.

Although UV treatment is more ef-

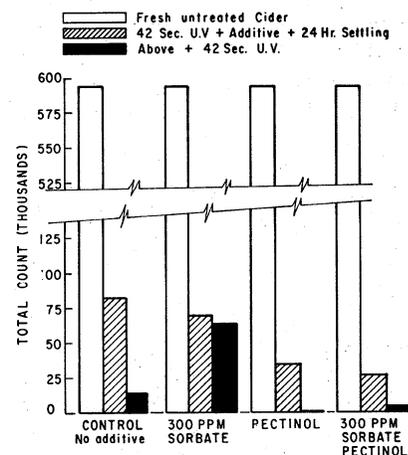


Fig. 5. Effectiveness of initial and final UV irradiation on the microbial population of fresh cider.

fective following Pectinol clarification, there would be an advantage in applying UV immediately after pressing in situations where the initial microbial count is high and there is not adequate refrigeration.

Table 2 indicates the benefits of UV irradiation on the storage life of fresh nonclarified apple cider. The total microorganism count was reduced and the cider's cold storage life was extended. In this experiment portions of cider were pumped at a rate of 73 gph through the 3 UV lamp series 1, 2, 3, or 4 times. Each UV treatment reduced the total viable microbial counts by about 80%. After each UV treatment, samples were taken for storage. The initial total microbial counts were made immediately after the UV exposures and again after 20 or 35 days of storage at 36°F (2.2°C). There was no visible fermentation in any of the samples at 20 days of storage. The control and the 13.5-sec UV treatment samples were actively fermenting after 35 days in cold storage. The total count of the longer UV-treated ciders increased but no off-flavors or other changes were noted.

Most stored ciders with a total microbial count approaching a million per ml were usually in an active state of fermentation or had developed off-flavors characteristic of mold or bacterial spoilage.

Table 3 shows the results of a taste panel test for flavor difference between UV-irradiated fresh cider and two non-irradiated controls.

A single lot of fresh cider, 3 hr after

Table 2. Growth of microorganisms in UV-irradiated apple cider stored at 36°F (2.2°C).

Exposure time (seconds)	Storage time		
	None	20 days	35 days
None	658 ¹	492	5,000 ²
13.5	132	135	1,100 ²
27	17	45	125
40.5	5	7	27
54.0	1.4	3.5	11

¹ All counts in thousands.

² Fermented.

Table 3. Taste panel flavor comparisons between UV irradiated, non-irradiated and fresh cider.*

Test replications	Number of tasters	Average scores ¹		
		No treatment control	UV-irradiated 120 seconds	Nonirradiated control
1	45	7.20	7.38	6.82
2	38	7.74	7.45	7.24
3	45	7.07	7.36	7.44

¹ A 9-point hedonic scale; the higher the score the better the sample.

* No significant difference between the irradiated samples and the other two controls at the 5% level.

pressing, was divided into 3 portions. One portion (control) was given no treatment. A second portion was UV-irradiated by pumping it through the lighted UV irradiation system 3 times at the rate of 25 gph. This exposed the cider to 40 sec of UV per pass or a total of 120 seconds. This is approximately 3 times the usual exposure.

A third portion, the nonirradiated control, was pumped through the equipment in the same manner except that the UV lamps were not turned on. All 3 treatments were bottled and stored at 36°F (2.2°C). Samples were removed from storage over a 7-day period for taste evaluation as needed.

A standard 9-point hedonic test was used with three replications on different days. The results are shown in Table 3. By analysis of variance, there was no significant difference at the 5% level of probability between the irradiated samples and the two controls.

It is not immediately evident why these results on flavor differ so markedly from those of Mack *et al.* (1959). It seems likely that the UV exposure they used was greatly in excess of that used here, but it is not possible to make direct comparisons of intensity and UV exposure from their data.

Assuming that fresh apple juice as it comes from the press is at its peak of quality, and since no changes were observed in apple cider attributable to UV except for the reduction of microbial contamination, this treatment should help maintain the quality of fresh apple juice as it comes from the press.

The UV-irradiation equipment described here was effective in reducing the microbial count of apple cider without changing the flavor. The increase in storage life of the product would be an advantage in the manufacture and sale of fresh apple cider.

UV irradiation should not be used as a substitute for poor sanitary practices or the use of low quality fruit. UV destroys most of the spoilage microorganisms in freshly pressed cider but it cannot restore quality once it is lost.

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