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The Cost of Pasteurizing Apple Cider

One case of food poisoning from apple cider is too many, and a death is unthinkable. Yet, there have been cases of food poisoning and even deaths from cider in the last several years due to contamination by *Escherichia coli* O157:H7 (Besser et al., 1993; Whitmore et al., 1996).

E. coli is not a normal contaminant of apples. It is thought that apples and the apple ciders become contaminated through contact with bacteria in fecal material in the soil (McLellan and Splittstoesser, 1996), improper handling, or contamination in the manufacturing process.

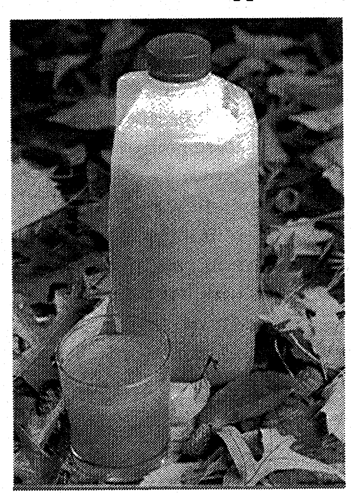
Pasteurization can destroy all disease-producing microorganisms or reduce the number of spoilage microorganisms (Madigan et al., 1997). If all cider were properly pasteurized, there should be no food poisoning by cider. Juices usually are pasteurized or heat treated to kill bacteria, as are frozen concentrates, but only some apple ciders are currently pasteurized.

Aside from such questions as whether it should it be mandatory to pasteurize all apple cider (Neergard et al., 1996) and whether pasteurization will compromise the flavor and quality of the product, there is also the question of whether pasteurization is too costly, especially for the small processor. This article will shed some light on that subject.

Pasteurization

There is no legal or product definition of apple cider. It is a different product in different parts of the country or world. For the purpose of this article, we define apple cider as the juice from freshly squeezed apples separated from the pomace with no further clarification.

A typical medium-sized processing plant pasteurizing cider uses plate-and-frame heat exchangers with heat regeneration. Fig. 1 shows a process for pasteurizing apple cider. In the first stage, the hot cider (87.8°C) leaving the pasteurization process heats the cold (7.2°C), raw incoming cider to 79.4°C. This regeneration step minimizes operating costs by reusing energy from the pasteurized stream. It's like getting energy for free. Regeneration systems commonly recover 85–90% of the energy used in pasteurization.



The heated raw cider enters a second heat exchanger where steam-heated hot water heats the cider to 87.8°C, the pasteurization temperature. A holding tube maintains the cider at 87.8°C for 5 sec to effect pasteurization.

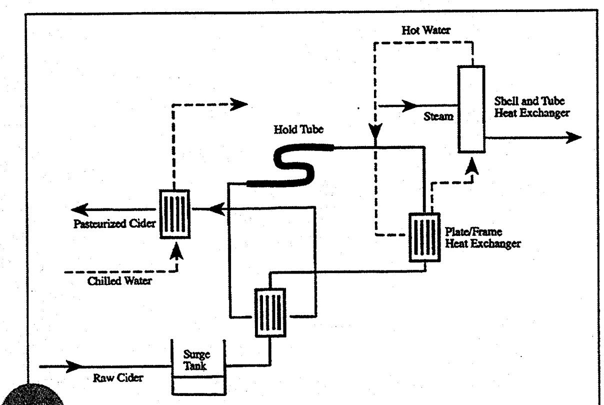


Fig. 1—**Apple cider pasteurization** process with energy regeneration

From the holding tube, the 87.8°C cider goes to the regeneration heat exchanger, where the incoming unpasteurized cider cools the pasteurized cider to 15.6°C. This pasteurized, cool cider then goes to a third heat-transfer section, where 1.1°C chilled water further drops the temperature to 7.2°C.

The pasteurization system includes process pumps, controls, clean-in-place equipment, and instruments to maintain the proper flow conditions and system cleanliness.

Calculating Pasteurization Costs

We based the cost estimate on a medium-sized plant processing 56 million L (14.85 million gal) of apple cider/year with a design capacity of 170 L/min (45 gal/min). The facility processes cider for 22 hr/day, devoting the other 2 hr to sanitizing and maintaining the process equipment. It operates slightly more than 5 days/week, 50 weeks/year, for a total of 5,500 hr of production/year.

Two pasteurization system vendors supplied technical and commercial pricing information, and a producer of pasteurized ap-

Table 1 Estimated capital costs for a pasteurization facility[a]

Equipment	Cost ($)
Raw cider tank	5,000
Plate heat exchanger regeneration section	14,500
Plate heat exchanger heating section	4,000
Plate heat exchanger cooling section	2,700
Holding tube, 5-sec capacity	2,000
Hot water/steam heat exchanger	600
Sanitary centrifugal pumps	10,000
Control system	15,000
Miscellaneous piping	15,000
Engineering and indirect costs	25,000
Subtotal	93,800
Installation costs	91,200
Total installed cost	185,000

[a]Capacity 170.325 L, pasteurization temperature 87.8°C, pasteurization hold time 5 sec, regeneration efficiency 90%

ple cider supplied typical production data. We used a process simulation and costing computer program (Aspen, 1994) to develop capital and operating costs for mid-1997 for a "generic" pasteurization system. The estimate did not include the cost of the apples and other cider processing costs such as crushing, handling, packaging, and storage. Sales and marketing expenses, contingency allowances, and financial charges were also excluded.

• **Capital Costs.** Commercial pasteurization units include heat exchangers to provide heating and cooling, a holding tube to maintain the process material at the pasteurization temperature for the required time, control devices, pumps, and interconnecting piping. Pasteurization units with three or four heat exchangers are common. One exchanger heats the incoming fluid, a second exchanger cools the fluid, and a third exchanger (for regeneration) recovers some of the energy used. A fourth heat exchanger, steam/hot water, controls the temperature of the hot water.

The estimated costs of the pasteurization facility include the costs of the pasteurization equipment, the building to house this equipment, and all necessary materials, labor, and technical support required to ensure proper operation. The suppliers' quotations for the pasteurization systems include the cost for all the materials and technology necessary for a functioning unit but do not include the costs of installing this unit in the apple cider facilities. The installed cost is approximately two times the price of the pasteurization equipment. Table 1 shows a breakdown of the capital costs for this facility.

• **Plant Operator Wages.** Modern pasteurizing systems are automated, and while they require only a minimum amount of a plant operator's time, they do require attention for monitoring, adjusting, and handling of plant upsets. About one-tenth of a plant operator's time per shift is allocated to the pasteurization facilities. We assigned $15.00/hr plus 35% for fringe benefits for plant operator wages.

• **Utilities and Other Operating Costs.** The major utilities are steam, electric power, and chilled water. Since steam and chilled water may also be required for other portions of an apple cider plant, we used typical unit prices rather than specific utility generating equipment such as boilers and ice makers. Table 2 presents the utility costs.

The maintenance costs are 3% of the plant's capital cost for labor and 2% for supplies. General and administrative charges are 6 % of capital costs. Property taxes and insurance are 3% of capital costs.

The installed equipment cost for the base case is $185,000 (Table 1). The cost to pasteurize apple cider in the base case with 90% regeneration is $0.0017/L ($0.0063/gal), as shown in Table 2.

Factors Affecting Cost

Several factors can alter the cost significantly, e.g., the extent of energy regeneration, the size of the plant (a large plant will have economy of size), and the utility costs. We therefore made cost estimates for similar facilities with different operating parameters to determine the sensitivity of pasteurization costs to different design and operating variables.

• **Regeneration.** Process energy recovery systems (regeneration systems) reduce overall pasteurization costs by recovering the energy from the hot outgoing stream and transferring it to the cool incoming unpasteurized stream. For the base case without regeneration, the installed equipment cost decreased by about 12% from $185,000 to $163,000, but the cost of pasteurizing cider increased from $0.0017/L to $0.0051/L.

To heat a 170-L/min stream from 79°C to 87.8°C requires 204 kg/hr of 414-kPa steam or 0.0024 kg of steam/°C-L of cider processed. Without regeneration, the steam requirement increases to 1,838 kg/hr. The amount of ice water required to cool this stream from 15.5°C to 7.2°C is approximately 11,340 kg/hr or 0.133 kg/°C-L of cider processed. Without regeneration, the ice water requirement increases to 102,146 kg/hr. However, regeneration has only a minor impact on the overall capital costs because the savings are offset by the reduction in duty and heat-transfer areas of the other heat exchangers in the system.

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Table 2 Annual and unit operating costs for pasteurizing 56,207,000 L/year

Item[a]	Annual cost ($)	Unit cost ($/L)
Utilities		
Steam	15,000	
Ice water	12,000	
Electricity	3,000	
Subtotal	30,000	0.00053
Labor		
Operating labor[b]	9,000	
Maintenance labor	5,000	
Supervision	3,000	
Fringe benefits	7,000	
Subtotal	24,000	0.00043
Supplies		
Operating supplies	1,000	
Maintenance supplies	4,000	
Subtotal	5,000	0.00009
General works		
General and administrative	11,000	
Property tax	4,000	
Property insurance	1,000	
Subtotal	16,000	0.00028
Depreciation[c]	18,000	0.00032
Total cost	93,000	0.0017

[a]Raw material (apple cider) costs not included
[b]0.1 of operator's time
[c]Capital cost of $185,000 divided by economic life of 10 years, rounded off

Table 3 Heat exchangers comparison

Equipment	Duty (cal/sec)	LMTD (°C)	Heat transfer area (m^2)	Installed cost ($)
With regeneration				
Regeneration	204,157	8.9257	33.73	28,600
Heating	25,500	3.3377	9.3887	7,900
Cooling	25,500	6.3476	6.236	5,300
Steam/hot water	25,500	65.6345	1.4323	1,200
Total			50.787	43,000
Without regeneration				
Heating	229,657	12.8515	21.9605	10,800
Cooling	229,657	28.129	12.6736	6,900
Steam/hot water	229,657	81.3694	10.4054	2,600
Total			45.0395	20,300

Table 3 demonstrates the difference in the heat exchangers and their capital costs for the two systems. Fig. 2 illustrates the relationship of pasteurization costs to regeneration efficiency.

• **Plant Size.** As the throughput of a facility increases, the utility requirements increase proportionallly. The capital cost of the facility, however, increases only slightly compared to the capacity increase, and the requirements for plant operators to monitor an automated facility are independent of the facility's capacity. For instance, the pasteurization cost is $0.0064/L for a plant with a capacity of 30.3 L/min, compared to $0.0017/L for 170 L/min. Fig. 3 shows the relationship between pasteurization costs and production rate. Below about 150 L/min, the plant unit costs increase sharply.

The number of days per year the plant is in operation also affects the costs, as shown in Fig. 4. At about 120 days of operation/year, competitiveness improves sharply.

• **Post-Pasteurization Handling.** Post-pasteurization chilling of the apple cider is not always required. Some producers package the apple cider while it is still warm rather than hold it in storage tanks in a chilled state. As discussed above, it requires 0.133 kg of ice water/°C-L of cider processed to lower the cider from 15.5°C to 7.2°C, for a utility cost reduction of $0.00022/L. Capital costs are about $5,000 less.

• **Temperature and Holding Time.** The pasteurization process in the base case was 87.8°C for 5 sec. Pasteurizing at 75°C for 15 sec reduced steam and ice water consumption, thus requiring smaller heat-exchanger areas and an increase in the holding tube size. As a result, the capital cost decreased from $93,000 to $88,000, and the unit operating cost decreased from $0.0017/L to $0.0016/L.

• **Utility Cost.** Steam costs make up about 15% of the pasteurization costs, and refrigeration charges in the form of ice water make up an additional 13%.

The relationship of pasteurization costs to steam costs is:

Pasteurization cost in $/L = 0.00139 + 0.0000233 ($/1,000 kg of steam)

The relationship of pasteurization costs to ice water costs is:

Pasteurization cost in $/L = 0.0014 + 0.001115 ($/1,000 kg of ice water)

Should All Cider Be Pasteurized?

The approximate retail price for apple cider is $1.00/L. For a mid-sized plant processing 107 L/min, a price increase for pasteurization of $0.0017/L should be economically feasible. Even for a small plant processing 30 L/min, a price increase of $0.0064/L should not be prohibitive.

On strictly a cost basis, we think pasteurization with regeneration is a sound investment in safety of the product. However, these are cold, hard numbers. There are considerations other than cost, e.g., taste, market acceptance, or regulatory requirements, which bear on a decision as to whether all apple cider should be pasteurized.

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The authors thank M.H. Zeigler & Sons, Inc., Lansdale, Pa., for their complete cooperation and specifically W. McFarlane, who supplied much of the plant data and technical consulting. Thanks also go to Peggy Greb for the apple cider photo. Mention of a brand or firm name does not constitute an endorsement by the U.S. Dept. of Agriculture over others of a similar nature not mentioned.

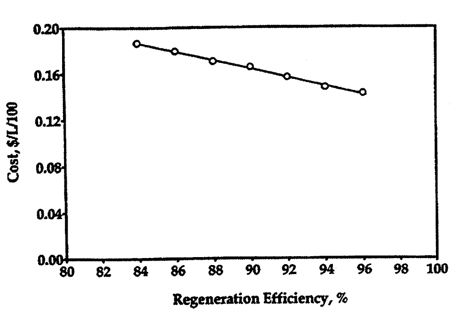

Fig. 2—**Pasteurization cost** vs regeneration efficiency

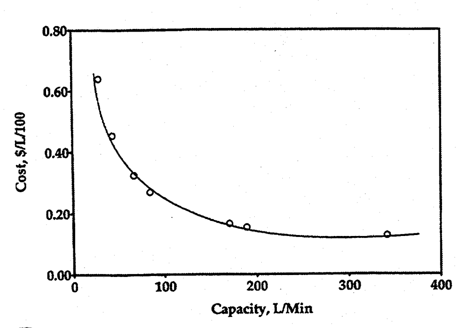

Fig. 3—**Pasteurization cost** vs hourly production rate

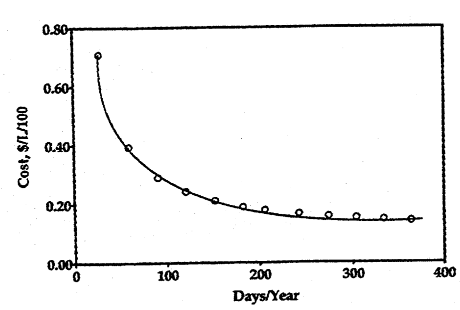

Fig. 4—**Pasteurization cost** vs days of processing