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PROCESSING MAPLE SYRUP WITH A VAPOR COMPRESSION DISTILLER: AN ECONOMIC ANALYSIS

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ABSTRACT

A test of vapor compression distillers for processing maple syrup revealed that: (1) vapor compression equipment tested evaporated 1 pound of water with .047 pounds of steam equivalent (electrical energy); open-pan evaporators of similar capacity required 1.5 pounds of steam equivalent (oil energy) to produce 1 pound of water; (2) vapor compression evaporation produced a syrup equalin quality to that from a conventional open-pan evaporation plant; and (3) a central plant producing 8,000 gallons of syrup per year should yield a return of 16 percent on investment. Increasing annual product output should increase the return on investment.

INTRODUCTION

MAPLE SYRUP is made by boiling down maple sap to remove water. The basic technique has changed little in 200 years. Evaporators have been improved and they are significantly more efficient than the methods used by early colonists, but the basic method of removing water is the same: application of direct heat to an open vessel or, in engineering terms, a single-effect system. This does not mean that the current evaporation method using flue pans is not acceptable; according to existing research and industry technology it is the only acceptable method. But the single-effect open-pan evaporator is only marginally economic. Oil-fired evaporators, the predominant type, require 3 to 4 gallons of oil for each gallon of syrup they produce. Their steam efficiency equivalent is 1.5 : 1; that is, they require 1.5 pounds of steam energy equivalent to evaporate 1 pound of water.

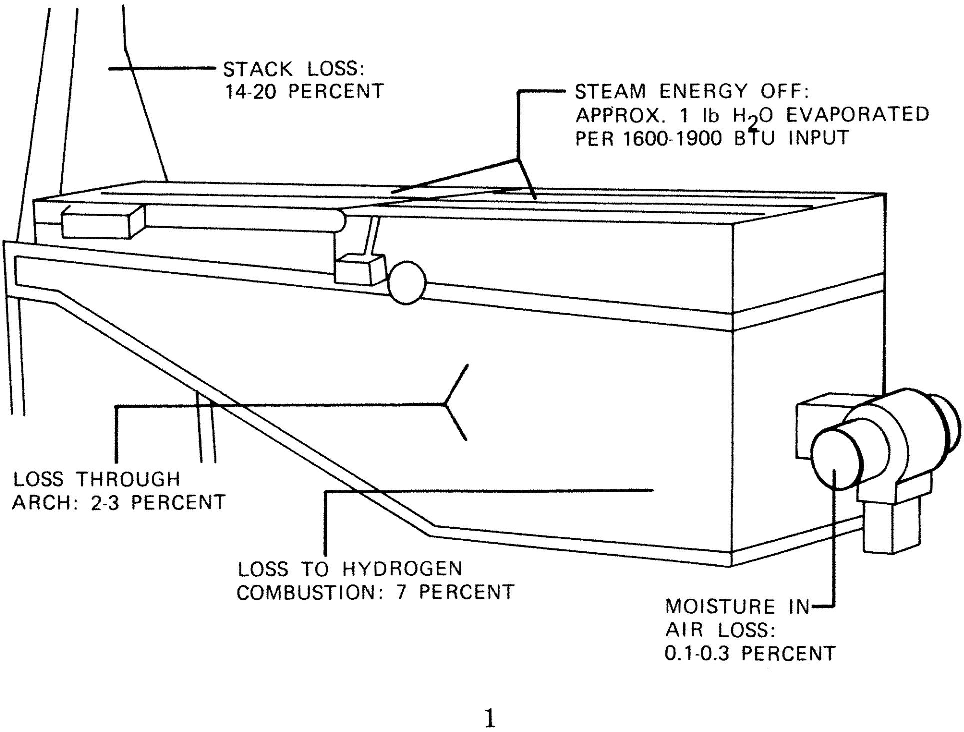
In 1976 the cost of processing a gallon of syrup on an oil-fired open-pan evaporator was approximately $3.60. Our studies indicate that 40 percent of the processing cost is for fuel. And 63 percent is accounted for by a combination of fuel, labor, and miscellaneous direct costs. Only 37 percent is for amortized capital costs, leaving little flexibility for realizing economies of scale with this technology.

Today, there is no commercial maple operation in the United States producing syrup continuously by any method other than open-pan evaporation. Yet, there are other possible ways of concentrating sap to a higher sugar content. These include flash evaporation, thermal evaporation under vacuum, mechanical compression distillation, reverse osmosis, ultrafiltration, and freeze drying.

Mechanical compression distillation has been used for desalinating salt water since World War II, but its potential for processing maple sap has not been previously investigated.

To study that potential, we tested a factory-designed desalination unit, established parameters for redesign, and evaluated a redesigned prototype for processing maple syrup.

Figure 1.—Conventional oil-fired maple syrup evaporator. Evaporator efficiency = 100-[16 + 2.5 + 7.0 + 0.2] 100-25.7 = 74.3.



Comparing processing technology

The engineering and economic efficiency of mechanical compression distillation can best be demonstrated by direct comparison with conventional open-pan evaporation.

In the open-pan evaporator (Fig. 1), heated gases and steam produced during the process are not recycled or reused. The efficiency of the system cannot exceed 1 : 1—1 pound of steam produces 1 pound of water. In actual field operation it requires 1.3 to 1.5 pounds of steam to produce 1 pound of water.

Mechanical compression distillers differ significantly from conventional maple syrup evaporators in that nearly all the heat energy developed is kept in the equipment.

The sap is preheated in a heat exchanger that absorbs heat from the distillate made in the evaporation chamber (Fig. 2). Sap is fed into the evaporation chamber at 212°F, having approximately 1,100 Btu per pound. The solution is sprayed over a tube bundle with a surface temperature of 228°F. The thin spray on the tubes at that temperature differential creates a flashing effect and allows maximum heat transfer. Flashing vaporizes water molecules, which are pulled from the evaporation chamber at a negative pressure of approximately 1/2 pound per square inch. The vapor passes through a mechanical compressor, increasing its temperature to 228°F and heat yield to 1,150 Btu per pound. The vapors are forced into the tube bundle, and the continuing spray of sap cools the vapors to make distilled water.

The distillate is passed through the plate heat exchanger, releasing its heat to the incoming sap, and passes out of the equipment as water. The syrup passing down through the tube bundle into the sump is also led through the heat exchanger to transfer its heat to incoming sap. If the syrup is not of the desired concentration, it is recirculated with the incoming feed over the tube bundles.

Starting the equipment requires heat for the plate heat exchanger and the tube bundle. This is provided by electric heaters. During operation, the heaters are used only intermittently as heat is needed.

THE STUDY

Test Series 1: Evaluation for redesign

Tests of a standard vapor-compression distiller[1] showed that maple sap can be concentrated to 66°Brix maple syrup of acceptable quality.

[1]Spray-Film® vapor compression distiller (VCD), model S-600 spec-E, bulletin 750-1015, manufactured by Aqua-Chem, Inc., Milwaukee, Wis.

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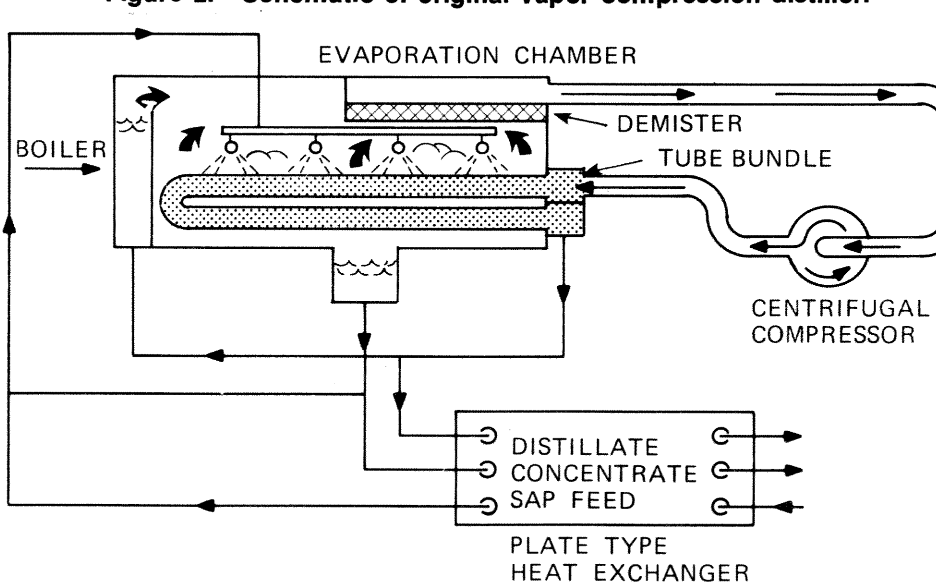
Figure 2.—Schematic of original vapor compression distiller.



Three concentrates were produced from 2.5°Brix sap in Test Series 1: 20°Brix concentrate, 40°Brix concentrate, and 66°Brix syrup. The equipment was operated a total of 80.8 hours, 5.5 hours for the first, 49.8 hours for the second and 25.5 hours for the final 66°Brix concentration.

However, as the equipment tested was specifically designed to produce a constant distillate (5 percent saline solution), the compressor had fixed output capacity. As the viscosity and boiling point of the syrup increased, tube fouling increased and production capacity was reduced.

Tube fouling reduced production capacity most above 40°Brix. At 66°Brix, fouling of the tube bundles decreased the coefficient of heat exchange significantly. Distillate production dropped from 628 gallons per hour at 20°Brix to 523 gallons per hour at 40°Brix. The most significant drop, to 285 gallons per hour, occurred at 66°Brix (Table 1).

The energy required to process maple concentrates with the unmodified mechanical compression evaporator increased significantly with level of concentration. Electric power consumption of 1.4 kWh was required to concentrate 1 gallon of 2.5°Brix solution to 20°Brix. Increasing the concentration increased the power requirements. At 66°Brix, 4.2 kWh were required for each gallon of syrup concentrate produced. At a cost of $.025 per kWh, energy cost $0.04 per gallon to concentrate 20°Brix solution, $0.06 for a 40°Brix concentrate, and $0.125 for a 66°Brix concentrate, or maple syrup.

Quality

Vapor compression distillers should produce good quality syrup. Concentrate is never exposed to a surface temperature exceeding 228°F, whereas exposure to 500 to 700°F surface temperature is common in a conventional evaporator. Analysis of sap, syrup, and distillate in Test Series 1 revealed that syrup produced from the unmodified VCD was similar in quality to syrup produced from the same sap in an open-pan evaporator. However, because the sap delivered to the research site was of poor quality, the syrup did not exceed "C" grade from either the conventional or VCD unit. Bacteria counts in the sap exceeded 3 million per millimicron; this resulted in high levels of invert sugars, phenols, and amino nitrogen, causing darker color and stronger flavor. (Normal bacteria count of sap at the tap hole is 300 to 1,000 per millimicron.)

Redesign of the VCD

To increase the efficiency of the VCD unit on more viscous solutions, it was redesigned for products ranging from 55°Brix to 65°Brix.

To minimize the effects of the higher boiling point and viscosity of the 66.5°Brix syrup, the redesigned system concentrates the syrup in two steps. The dilute solution entering the system is preheated in a heat exchanger that absorbs the heat from the newly made distillate (Fig. 3). The feed is then introduced into the recirculation loop of the first concentration step, where a part of the liquid is vaporized when it comes in contact with the heating bundle. The

Table 1.—*Performance of 600 gal/h [a] mechanical vapor compression distiller processing 2.5° Brix maple sap to three concentrations.*

°Brix of concentrate	Sap feed rate	Recirculation temperature	Product temperature	Product output		Distillate output	kWh/gal produced
	gal/h	------------ *°F*	------------	*gal/h*	*lb/h*	*gal/h*	
20	735.9	210	58 [b]	107.4	999.6	628.5	1.4
40	558.0	212	211	34.7	347.0	523.3	2.0
66	294.5	217	217	8.6	94.6	285.9	4.2

[a] Rated at 600 gal/h for 0.5% salt solution.
[b] Product initially recirculated through plate heat exchanger to extract heat from solids.

Figure 3.—Schematic of redesigned vapor compression distiller.

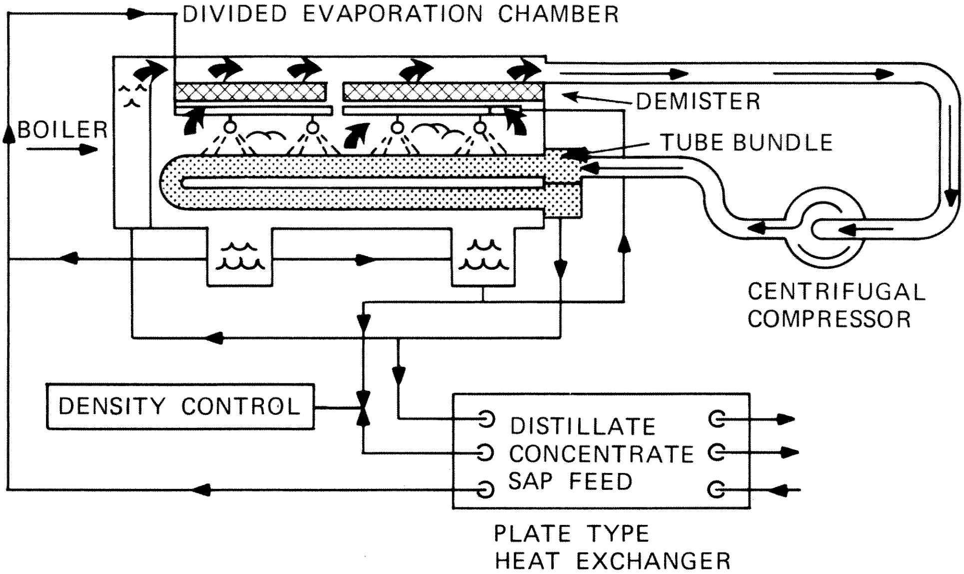
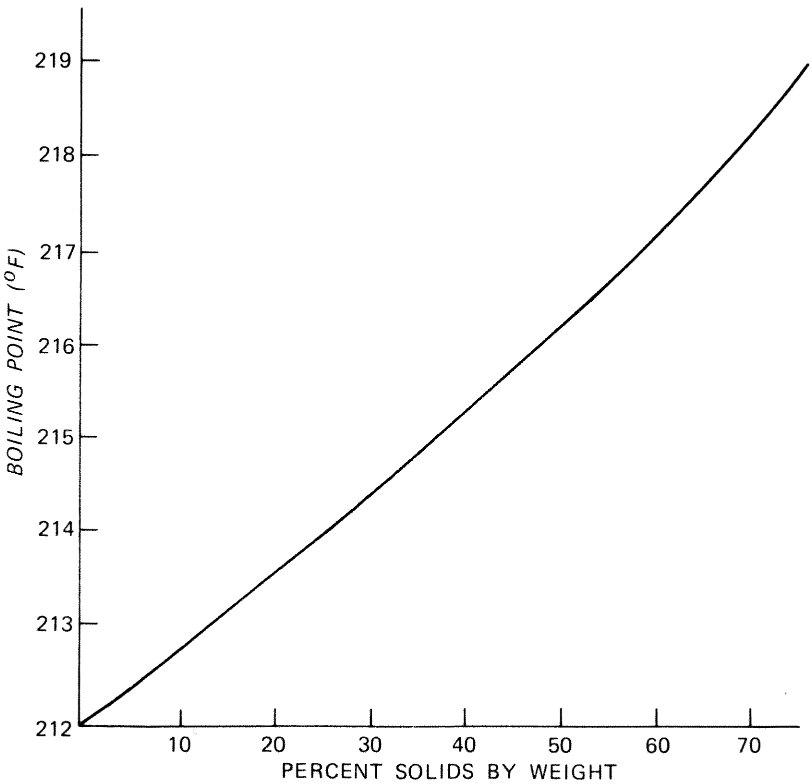


Figure 4.—Effect of syrup density on boiling point of maple syrup.



syrup then passes by gravity to the second concentration step, where it reaches the desired concentration. The concentration is discharged from the system by a pump.

The water vapor generated from the two sections is combined and passed through a wire mesh demister to remove any entrained droplets. The vapor is then compressed and piped to the inside of the heat tubes. In the heating bundle the hot vapor is condensed by the cooler concentrate on the outside of the tubes, thus giving up its latent heat of vaporization and most of the energy required to evaporate an equivalent amount of feed solution. The condensed vapors are collected as distillate and pumped to the heat exchanger. Heat is transferred to incoming sap as the distillate leaves the system.

Heat lost to the environment by radiation and convection, and incomplete heat exchange, require that a small amount of heat be continually added to the system to prevent a vacuum from forming in the shell. This heat is added by electric heaters located in a boiler that reboils a small portion of the distillate. Since the boiler is directly connected to the steam chest, the small amount of vapor produced is at the same pressure as the vapor inside the tube bundle (about 3 to 4 lb/in^{2}g). The boiler contains four heaters, all of which are used in starting. During normal operation a pressure switch on the shell turns one heater on and off to maintain the correct pressure.

Not only does the boiling point increase as the sap is concentrated, requiring more heat and thus lowering efficiency (Fig. 4), but also less steam is produced per unit volume of liquid passing over the tube bundle, reducing total heat transfer per unit volume.

These problems were solved in the redesigned equipment by dividing the tube bundle into two evaporating surfaces. The first surface, 60 percent of tube bundle, handled concentrates up to 40 percent solids, creating sufficient steam volume to maintain a high heat transfer for the higher concentrations being sprayed over the remaining 40 percent of the surface. Two larger sumps replaced the original one (Fig. 3).

The evaporation efficiency of the redesigned VCD is 21.0 when concentrating to 66°Brix. Evaporating efficiency is not affected by changes in the sugar content of incoming sap concentrate. That is, a change of 1.5 to 3.0°Brix changes the sap-to-syrup ratio but has an insignificant effect on distillate flow and Btu requirements (Table 2). This improvement significantly increased operating efficiency over that of the standard design.

Changing syrup concentration from 50°Brix to 66°Brix reduces evaporating efficiency (Table 3). Less heat energy is used per hour (240 versus 248 Btu), but there is a drop in distillate production from 5,675 to 5,050 lb/h, a 13-percent reduction that outweighs the 8-Btu energy saving and reduces evaporating efficiency from 22.9 to 21.0.

The drop in evaporation is caused primarily by increased concentration and reduced boil-off per unit flow. Each unit of boil-off requires more Btu, but the reduced rate actually lowers the total kWh requirement.

The drop in evaporating efficiency at higher viscosities also reduces hourly syrup production from 29.1 gallons (from 2.5°Brix sap) at 50°Brix concentration to 18.8 gallons (from 2.5°Brix sap) at 66.5°Brix concentration. This demonstrates the capability of the equipment to increase production significantly during maximum sap flows. A more stable partial concentrate (i.e. 40 to 50°Brix) can be produced at times of peak flow and stored for final processing later.

Table 2.—*Operating characteristics of redesigned vapor compression distiller at various sap concentrations.*

Sap concentration	Sap input	Syrup output at 66.5°Brix		Total processing cost per gallon of syrup
°Brix	------*gal/h*------		*lb/h*	
1.5	5167	10.6	117	$5.17
2.0	5216	15.1	166	3.64
2.5	5259	18.9	209	2.44
3.0	5303	23.0	253	2.38

Distillate output: 5050 lb/h; heat equivalent: 240 Btu/h; evaporating efficiency: 21.0.

Table 3.—*Evaporating efficiency of redesigned vapor compression distiller producing various maple syrup concentrates.* [a]

Product concentration	Sap input concentration	Flow rates: Sap	Flow rates: Distillate	Flow rates: Syrup at 60°F		Annual syrup production (in 360 h)	Electric power input: Compressor at motor	Heaters	Pumps at motors	Total	Equivalent heat input	Evaporating efficiency
------ °*Brix* -----		-------- *lb/h* -----			*gal/h*	*gal*	---------------- *kW* ----------------				*Btu/h*	
50	1.5	5851	5675	176	17.1	6,160	43.4	23.7	5.7	72.8	248	22.9
	2.0	5911	5675	236	23.0	8,280						
	2.5	5974	5675	299	29.1	10,500						
	3.0	6037	5675	362	35.2	12,700						
55	1.5	5680	5525	155	14.7	5,290	42.7	23.7	5.7	72.1	246	22.5
	2.0	5733	5525	208	19.7	7,090						
	2.5	5778	5525	263	25.0	9,000						
	3.0	5844	5525	319	30.3	10,900						
60	1.5	5487	5350	137	12.7	4,570	42.0	23.7	5.7	71.4	244	21.9
	2.0	5534	5350	184	17.1	6,160						
	2.5	5583	5350	233	21.7	7,810						
	3.0	5632	5350	282	26.2	9,430						
66	1.5	5167	5050	117	10.5	3,780	41.0	23.7	5.7	70.4	240	21.0
	2.0	5216	5050	166	14.9	5,360						
	2.5	5259	5050	209	18.8	6,770						
	3.0	5303	5050	253	22.8	8,210						

[a] Assumptions: Heat transfer coefficient: 80%; Sap entering heat exchanger at 40°F; Evaporation rate independent of feed concentration; Compressor and pump motors have 91% efficiency; Syrup product does not pass through heat exchanger; Heaters rated at 23.7 kW.

There is little change in power consumption with changes in flow. As related, decreasing the density of syrup from 66.5 to 50°Brix decreases power consumption by only 2.4 kWh (72.8 to 70.4). The electric motors and heaters that drive the system are not designed for variable power usage, so running at lower concentrations changes flow but has little effect on energy requirements.

The redesigned VCD prototype required only 0.047 pounds of steam equivalent per pound of distillate produced. This compares to 1.5 pounds of steam in a conventional maple syrup evaporator and 1.1 pounds in the most efficient single-effect boilers. Based on these data, the evaporating efficiency of the vapor compression system tested was $21 \frac{1.000}{0.047}$, as compared to $.65 \frac{1.0}{1.5}$ for the conventional open-pan evaporator. In other words, the evaporating efficiency of vapor compression is 32 times that of the conventional open-pan evaporator.

Product Quality

Maple syrup from test runs of the redesigned VCD unit was similar in quality to syrup from a conventional evaporator. Tables 4 through 6 include statistics on sap, syrup, and distillate samples from the redesigned prototype.

Syrups produced by the redesigned VCD unit were rated good to excellent in flavor and "B" in color. Analyses showed some differences between these samples and a random sample of "B" syrups produced by conventional evaporators (Table 5) but these differences do not indicate major differences in the product. The syrups are similar in sucrose level and pH. The higher average of invert sugars in syrups from the conventional evaporator relates to the higher phenol count. Although the amounts of metal salts differ in the two syrups, both are well within FDA acceptable levels. In short, the syrups produced by the VCD and conventional evaporator are of similar quality.

Table 4 presents analyses of the sap used to make the syrup samples in the VCD unit. The sap was 46 hours old and had a temperature of 62°F when processed into syrup. Time, temperature, and numerous transfers of the sap could have contributed to the high phenol and amino nitrogen counts, which contribute to the darker color and stronger flavor of "B" grade syrups (University of Vermont 1973).

Table 4.—*Analysis of sap processed into maple syrup concentrates in redesigned vapor compression distiller (six samples).*

Statistic	Metal salts: Fe	Pb	Cu	Zn	pH	Sucrose	Invert sugar	Phenol	Amino nitrogen
	p/m	p/m	p/m	p/m		%	%	p/m	p/m
Mean	0.578	0	0.198	1.150	6.330	2.370	0.400	18.180	1.600
Standard deviation	.749	0	1.76	0.055	.197	0.234	.089	1.863	0.447
Variance	.561	0	.031	.003	.039	.055	.008	3.470	.200

Table 5.—*Comparison of syrup samples produced from conventional evaporator and vapor compression distiller.*

Statistic	Metal salts: Fe	Pb	Cu	Zn	pH	Sucrose	Invert sugar	Phenol	Amino nitrogen	Syrup grade
	p/m	p/m	p/m	p/m		%	%	p/m	p/m	
					CONVENTIONAL EVAPORATOR [a]					
Mean	16.03	.34	1.68	24.26	6.66	61.23	6.08	1,096.23	325.11	B
Standard deviation	8.50	.54	1.25	8.97	.25	3.25	4.32	176.44	41.23	B
Variance	72.25	.29	1.56	80.57	.06	10.50	18.68	31,131.00	1,699.91	B
					VAPOR COMPRESSION DISTILLER [b]					
Mean	2.20	5.50	2.44	10.30	6.63	61.77	2.01	1,010.41	255.00	B
Standard deviation	0.37	0.70	0.52	2.50	0.19	4.45	0.41	168.33	47.67	B
Variance	0.14	0.49	0.27	6.26	0.04	19.78	0.17	28,335.35	2,272.58	B

[a] 13 samples
[b] 13 samples

Table 6.—*Analysis of five distillate samples from maple sap processed in redesigned vapor compression distiller (in parts per million).*

Statistic	Mineral salts: Na	K	Ca	Mg	Metal salts: Cu	pH	Phenol	Amino nitrogen
Mean	.10800	.02600	.1160	.01800	.08800	5.660	3.28	.178
Standard deviation	.01300	.00500	.0170	.00400	.00400	0.114	1.06	.083
Variance	.00017	.00003	.0003	.00002	.00002	0.013	1.13	.007

All values 0 for Fe, Mn, Zn, Pb, Sn, ed, sucrose, and invert sugar.

It is not possible to compare the characteristics of syrup produced by the VCD unit with a standard because no standard exists. All the characteristics studied varied widely in a cross section of syrups from conventional evaporators, and the VCD syrup was well within the limits of these values. We believe that with a higher quality sap the VCD unit would produce a higher quality syrup.

The other product of the VCD is distilled water. Analysis of samples showed it to be of high quality. None of the metal or mineral salts exceeded 0.1 ppm and a low phenol count indicated minimal contamination.

Economic effectiveness

The economics of vapor compression processing and its level of application are affected by several production factors unique to the maple industry:

- Maple sap is high in unit weight (8.5 lb/gal) but low in unit value ($0.104/gal).
- Maple sap is geographically dispersed so that its transfer cost increases significantly as the distance from tree to plant increases. As the processing plant gets larger, the procurement zone becomes larger, increasing the unit cost of sap.
- The volume ratio of raw material (sap) to product (syrup) is 36 to 1. Consequently, costs are incurred for 97 percent of the resource volume which is later discarded.
- The production period is limited to 8 to 12 weeks, or only 15 to 20 percent of the annual production period available for many processed foods. This forces a large plant to increase output per hour to provide a production base over which to spread larger capital costs.
- Maple syrup processing requires considerable energy for water evaporation and the development of color and flavor. Energy is fast becoming the highest cost input in food processing.

The availability of maple sap in a plant's procurement zone may fluctuate as much as 30 percent from one year to another because of weather alone. This is crucial for plants that require heavy capital investments and, therefore, high annual amortization. Even taking into account all of the above constraints, a vapor compression plant affords greater return on invested capital than the conventional maple syrup processing system. The reason is its significantly lower processing cost per unit of production.

Tables 7 and 8 show estimated annual operating costs for a vapor compression plant and a conventional plant. The estimated annual cost for the VCD plant is $2.44 per gallon of syrup produced; significantly lower than the annual cost of $3.60 per gallon for the conventional system.

These economic evaluations of the two plant designs treat all future costs as though they were incurred today. They do not consider the time value of money. Yet they do give a realistic economic evaluation of the two investment opportunities. All capital investment is amortized at 10 percent for the time periods indicated. Operating costs are current expected costs of operating the plants. With conventional evaporation, approximately 63 percent of the processing costs are operating or direct costs—energy, labor, and materials. Only 37 percent are capital or fixed costs (Table 8). Consequently, increasing production has little effect on unit costs.

The opposite is true of a vapor compression plant: The physical plant is costly but efficient. Capital costs are 87 percent of total processing costs, whereas operating costs are only 13 percent (Table 7). Therefore the greater the production, the lower the unit cost of production.

The main costs of a VCD plant are capital costs; the plant will incur these costs regardless of production level. Potential investors should be aware that decreases in production due to weather or plant failure will increase unit cost.

A VCD plant designed for 7,000 to 9,000 gallons annual production can sustain a production cut of 35 percent and still produce syrup at a processing cost comparable to that of a conventional plant. A 66°Brix maple syrup can be produced for $2.38/gallon at a production level of 8,210 gallons (Table 1). Reducing the production level 18 percent to 6,770 gallons increases unit cost to $2.88. A reduction of 35 percent to 5,360 gallons will increase unit cost to $3.64, or approximately that of a conventional evaporator.

Table 7.—*Total annual costs for a vapor compression maple syrup processing plant producing an average of 8,000 gallons per year.*

Cost item	Cost	Useful life	Annual cost	Percent of total
Capital costs [a]				
Building	$ 6,798	20	$ 744.38	
Sap storage (32,000 gal @ $.60/gal)	19,200	20	2,102.40	
Syrup storage (7,000 gal @ $2/gal)	14,000	20	1,533.00	
PCVC 850	106,000	20	11,607.00	
Equipment	9,900		1,084.05	
Total	$155,898		$17,070.83	87
Operating costs				
Electricity— 70.4 kW x 403 h @ $.05/kWh			$1,418.56	
Operating and routine maintenance— 114 h @ $3/h			342.00	
Cleaning chemicals— $60/wash x 3 washes season			180.00	
Annual maintenance supplies			448.00	
Annual preparation and maintenance labor— 27 h @ $3/h			81.00	
Total			$ 2,469.56	13
Total annual costs			$19,540.39	100
Annual processing cost/gallon				$2.44

[a] Capital costs amortized at 10 percent.

Table 8.—*Annual capital and operating costs for conventional open-pan evaporator plant producing an average of 750 gallons per year.*

Cost item	Cost	Useful life	Annual cost	Percent of total
Capital costs				
Building	$1,820	25	$ 151.16	
Plant equipment	6,738	20	791.72	
Total	$8,558		$ 942.88	37
Operating costs				
Labor (hired) @ $3/h.			$ 400.00	
Fuel (oil and gas) @ 43c/h			1,128.75	
Electricity and miscellaneous			50.00	
Total			$1,578.75	63
Total annual costs			$2,521.63	100
Annual processing cost/gallon				$3.36

Return on investment

A study by Huyler of 14 conventional plants in the Northeast revealed that they return 10 to 14 percent on invested capital.[2] Producers studied did not approach the size of the plant studied here. However, studies by Kearl (1970), Acker and others (1970), and Pasto and Taylor (1962) indicate that the cost structure of the conventional plant permits little reduction in unit cost with increased size.

To evaluate return on investment for a VCD plant, a series of cash flows were developed to represent expected annual costs and returns. The data were developed to compare the expected returns from a VCD plant selling its product wholesale with those of a plant selling at retail (Figs. 5 and 6). The ROI analysis is based on a capital plant investment of $150,000, which includes equipment, buildings, storage tanks, and installation costs. Syrup production ranges from 6,770 gallons in year 1 to 9,000 gallons in year 20 for both analyses. Sap prices start at $.10 per gallon in year 1 and go to $.25 per gallon in year 20. All operating costs such as management, labor, fuel, materials, etc. are subject to an inflation rate of 5 percent per year. Also, each analysis contains an expensed investment for land in year 1.

Revenue cash flows for the two investments differ. Revenues for the plant that wholesales its product are based on a wholesale price ranging from $0.60 to $0.70 per pound in year 1. The plant that retails its product receives from $0.90 to $1.09 in year 1. However, to obtain that higher revenue, the plant is assessed a marketing cost equivalent to 20 or 30 percent of its gross revenues. Net revenues from both plants are further reduced by a 50 percent tax on net income.

Depreciation of capital investment is computed by the sum of year digits method (Parks 1973). This method was selected to reduce the impact of income tax liability in the early years of the investment. Ten years was selected as the length of the depreciation schedule to accommodate IRS regulations concerning agriculture equipment.

The analysis did not include investment credit on new equipment purchases. That credit would improve the return, but it is not equally available in all maple-producing regions.

The most critical factors in the analysis are the production period and the size of the operation. Twenty-five thousand taps are necessary to supply sufficient raw material to the plant, requiring a 60,000-gallon storage capacity at peak periods. Sap costs are computed f.o.b. the plant at $0.10, $0.11, and $0.12 per gallon of 2.5°Brix solution.

Maximum holding time for sap was set at 72 hours to minimize degrade. This limitation, applied to a probability distribution of small and large runs during an 8-week season, reduces the potential operating period. To compensate for the probability of bad seasons during the early years of operation, the plant is scheduled to produce only between 6,700 and 7,200 gallons, or operate only 360 hours per year. The run is expected to increase from 15 days (360 hours) the first year to 20 days (480 hours) in year 20.

Returns to the plant owner who wishes to wholesale his product (Fig. 5) will be less than if he retailed the product at a higher price (Fig. 6); he will receive a return on invested capital of from 10 percent at $0.60/lb. to 16 percent at $0.70/lb.

A plant owner who decides to retail can expect to invest $150,000 today and earn 12 to 18 percent interest over the next 20 years (Fig. 6). If he can borrow capital at a rate of 8 to 10 percent, he can expect to return 4 to 8 percent to management. The wholesaler will obviously earn less return (Fig. 5) but his venture should return 2 to 6 percent to management.

CONCLUSIONS

Several conclusions can be drawn from these analyses:

- Vapor compression distillation can produce maple syrup of the same quality as that produced by a conventional evaporator. Both metal and mineral salts are within the concentrations expected in syrups from open-pan evaporators.
- VCD equipment will also produce a distilled water that exceeds pharmaceutical quality standards for certain grades.
- The VCD equipment tested was 32 times as efficient as conventional open-pan evaporators. Whereas 1.5 pounds of steam equivalent are

[2]Huyler, Neil K. 1976. Cost and return estimates for maple syrup operations. Unpublished report on file at George D. Aiken Sugar Maple Laboratory, Burlington, Vt.

Figure 5.—Analysis of economic return on VCD plant investment at various levels of wholesale syrup price and sap cost.

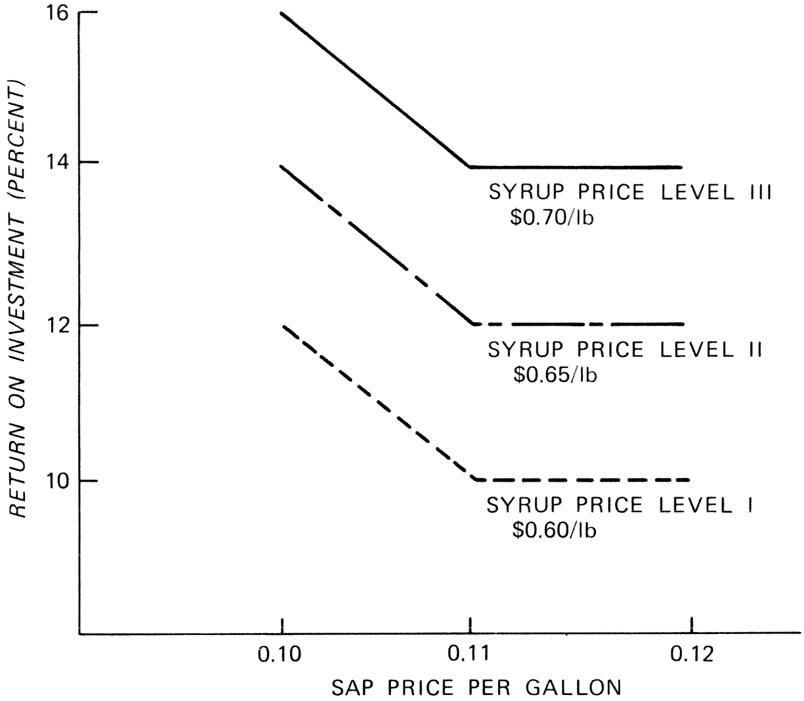
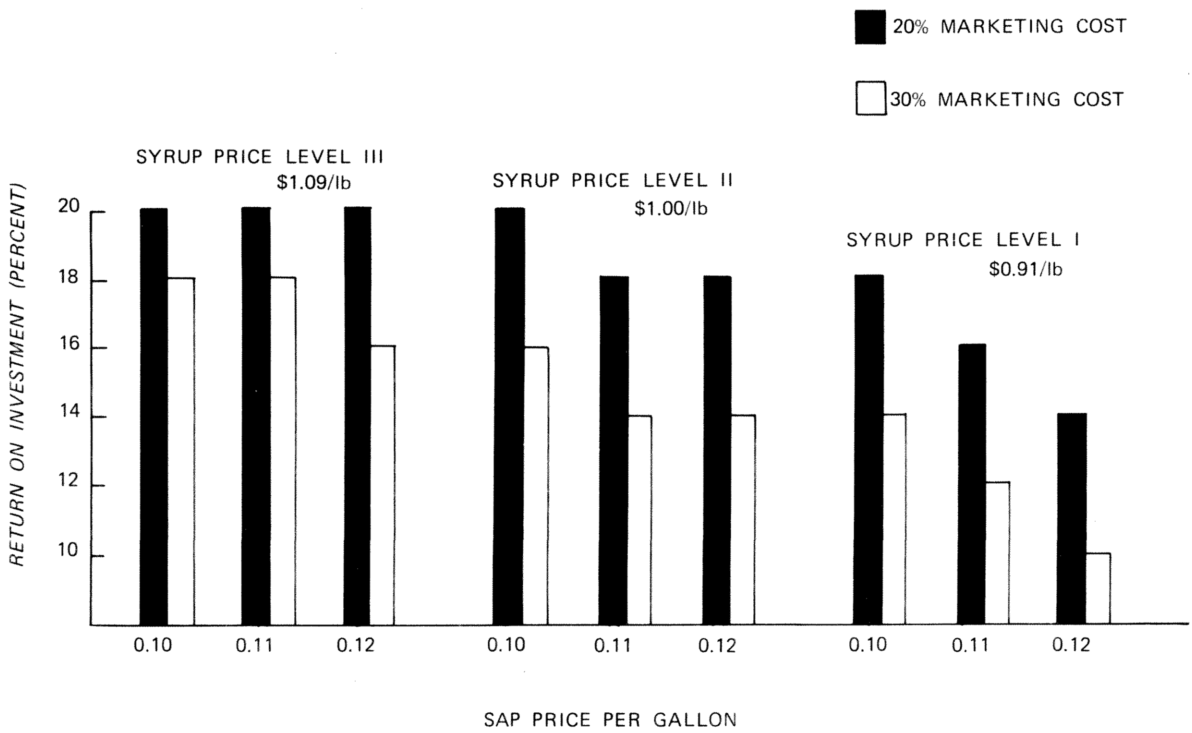


Figure 6.—Analysis of economic return on VCD plant investment at various levels of retail syrup price, sap price, and marketing cost.



required to evaporate 1 pound of water in an open-pan evaporator, only .047 pounds are required to evaporate 1 pound of water in a VCD plant.

- The estimated cost of processing 35 gallons of 2.5°Brix sap to 1 gallon of 66°Brix syrup in a VCD plant is $2.44, compared to $3.60 in a conventional plant. A VCD plant operating 35 percent below capacity produces syrup for $3.64 per gallon, approximately the same cost as a conventional plant.
- A VCD plant capable of processing 7,000 to 9,000 gallons of syrup during an 8-week season can realize a 10 to 18 percent return to the investor. The return and its associated risks must be weighed against those of other investments.

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