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:heddar Cheese Manufacturing Costs

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The authors acknowledge with appreciation the generous cooperation of dairy plant managers, equipment dealers, engineers, architects, and others in the industry, who supplied the basic data for this study.

Cheddar Cheese Manufacturing Costs

Nicholas B. Lilwall and Jerome W. Hammond *

Developments in the U.S. cheese industry indicate that substantial changes are likely in the next few years. Consumption trends are already rising and a major shift in the geographic pattern of production is in progress. In addition, the basis for significant new capital investment is being established by the development of new equipment and techniques.

The principal aim of this study is the provision of processing cost estimates. Costs are developed, not only for the new technological systems, but also for different sized plants and for plants working under different operational arrangements.

BACKGROUND

On the demand side, per capita cheese consumption has shown a marked upward trend since 1950 (see table 1). Between 1950 and 1968, U.S. per capita consumption increased by 30 percent and now exceeds 10 pounds per year.

Table 1. Per capita U. S. cheese consumption (excluding cottage cheese) 1950-68

Year	American*	Other†	Total
		pounds	
1950	5.5	2.2	7.7
1951-55	5.3	2.5	7.8
1956-60	5.3	2.7	8.0
1961-65	6.0	3.1	9.1
1966	6.2	3.6	9.8
1967	6.4	3.6	10.0
1968	6.6	4.0	10.6

* Includes Cheddar, Colby, washed curd, high and low moisture jack, Monterey, granular, and part skim.
† Includes Swiss, Munster, Brick, Limburger, all Italian types, Cream, Neufchatel, and Blue Mold.
Source: "Dairy Situation," ERS, USDA, May 1969, p. 24.

This per capita increase in cheese consumption, coupled with a rising population, has substantially increased the demand for milk required to produce cheese and lessened the relative demand for milk to produce butter (see table 2). In 1935, 44.5 percent of all market milk was used to produce butter and only 8.4 percent for cheese; in 1968, 21.9 percent was used to produce butter and 15.5 percent for cheese.

Research by Burk on dairy product consumption indicates these trends will continue.[1] By 1980 cheese production will use more milk than butter

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[1] Marguerite C. Burk, *Consumption of Dairy Products: An Analysis of Trends, Variability, and Prospects*. Agr. Exp. Sta. Tech. Bull. 268, Univ. of Minn., 1969.

Table 2. Use of total market supply of milk, U. S., 1935-68

	Use of market milk					Percentage of total market supply			
	Total market supply of milk	Fluid use	Creamery butter	Cheese	Other†	Fluid use	Creamery butter	Cheese	Other
	billion pounds					percent			
1935	75.2	26.7	33.5	6.3	8.7	35.5	44.5	8.4	11.6
1940	86.2	29.5	36.8	7.8	12.1	34.2	42.7	9.0	14.1
1945	98.4	40.5	27.3	11.1	19.5	41.2	27.7	11.3	19.8
1950	98.3	42.4	28.8	11.9	16.2	43.1	28.3	12.1	16.5
1955	108.3	49.4	28.0	13.6	17.3	45.6	25.9	12.6	15.9
1960	113.9	53.0	29.3	13.4	18.2	46.5	25.7	11.8	16.0
1961	117.4	52.6	34.7	14.9	15.2	44.8	29.6	12.7	12.9
1962	118.7	53.3	33.0	14.4	18.0	44.9	27.8	12.1	15.2
1963	118.3	54.3	30.8	14.8	18.4	45.9	26.0	12.5	15.6
1964	120.5	54.9	31.2	15.7	18.7	45.6	25.0	13.0	16.4
1965	118.4	55.4	28.5	15.8	18.7	46.8	24.1	13.3	15.8
1966	115.8	55.4	23.7	16.7	20.0	47.8	20.5	14.4	17.3
1967	114.9	54.0	26.1	17.2	17.6	47.0	22.7	15.0	15.3
1968*	112.8	53.7	24.7	17.5	16.9	47.6	21.9	15.5	15.0

* Preliminary.

† Includes evaporated milk, condensed whole milk, dry whole milk, and frozen dairy products.
Source: *Dairy Statistics*, May 1969, p. 17.

production. Based on past dairy product consumption, the estimated per capita cheese consumption for 1980 will be 16 pounds. This appears quite optimistic, so for purposes of estimating milk use, Burk uses a figure of 14 pounds. This means milk for cheese would increase to 22.5 billion pounds in 1980 or 22 percent of all market milk used. Milk used in butter would fall to 18 billion pounds — 17 percent of all market milk. Thus, some butter manufacturing plants are likely to shift to cheese production.

Geographic shifts in the cheese production areas will require new investment in cheese manufacturing. The East North Central U.S. has traditionally dominated in production. Yet, its percentage of U.S. cheese production declined from 63 percent in 1945 to 53 percent in 1968 (see table 3). The West North Central region gained throughout the period. Minnesota, with only 1.9 percent of U.S. cheese production in 1945, rose to 5.7 percent by 1968. Nebraska, North Dakota, and South Dakota have been developing cheese industries since 1960.

Cheese production's regional shift results principally from a larger consumer demand for fluid milk in the traditional cheese producing areas. Fluid milk has first claim on milk supplies because it returns a higher price. Expansion of fluid markets in and near Wisconsin is likely to further reduce Wisconsin's leadership in the cheese industry. The traditional manufacturing milk areas of Minnesota, Iowa, and possibly the Dakotas and Nebraska will supply these expanding cheese demands.

On the technological side, the cheese manufacturing industry has been characterized by small, often family, operations. Research on economies of size indicates the optimum cheese plant size can be much smaller than most other manufacturing milk operations.[2] But with the development and adoption of new devices and techniques in the last 10 years, cheese making now requires more capital and a larger optimum plant size.

The most important advance has been in the size of the batches which can be processed at one time. For example, vats can now handle 25,000 pound batches in the traditional fashion and over 30,000 pounds when cheddaring takes place away from cooking vats.

In addition, the cheddaring process can now be successfully performed mechanically, and a single machine is available which automatically mills, salts, weighs, and hoops the curd. Both these developments have substantially reduced the labor requirements of cheddar cheese making.

Thus significant changes are taking place in per capita cheese consumption, in the location of cheese production, and in the technological basis of cheese manufacture. It also appears that these changes will continue in their present direction for some time.

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[2] Jerome W. Hammond and Martin K. Christiansen. *Marketing Minnesota's Dairy Products, Characteristics, Problems, and Needs*. Agr. Exp. Sta. Mis. Rpt. 63, Univ. of Minn., 1965, pp. 41, 52-55.

Table 3. Total cheese production (excluding full skim American and cottage cheese) U. S. by regions*

	1945		1950		1955		1960		1968		Percent change
	Million pounds	%	Million pounds	%	Million pounds	%	Million pounds	%	Million pounds	%	1945-68
New England and Middle Atlantic	82	7	110	9	130	10	149	10	189	10	+230
East North Central	706	63	748	63	802	59	830	56	1,029	53	+146
West North Central	126	11	140	12	207	15	236	16	438	22	+348
South Atlantic and South Central	111	10	112	9	137	10	163	11	157	8	+141
Mountain and Pacific	92	8	82	7	86	6	100	7	130	7	+141
United States	1,117	100	1,192	100	1,363	100	1,478	100	1,944	100	+174

* All figures have been rounded to the nearest whole number.

Source: *Production of Manufactured Dairy Products, 1968,* SRS, USDA, Washington, D.C., July 1969.

PROCEDURE

In order to obtain the wide range of costs required by this study, hypothetical plant designs were developed and analyzed. Initially twenty-one alternative technological systems were selected. Each system was then used separately in the construction, on paper, of a range of different sized plants. This allowed processing costs to be related both to technology and to milk volume.

The next step was to adjust each plant's volume and design to obtain processing costs for twelve different work routines. These included all combinations of 5, 6, and 7 working days per week, with four different assumptions concerning the number of hours worked per day during the peak period.

There are two advantages to this synthetic approach, over the more traditional dairy plant budget studies. First, plants are more easily compared, since input costs and operational efficiencies can all be established on the same basis, for all plants in a synthetic study. Second, and more important to this study, the synthetic method provides comparable processing cost estimates for a whole range of systems, which are not yet represented in real and operating plants.

Technologies

Over the past few years a number of important engineering advances have been made which reduce labor requirements at certain stages. Some of these new technologies are examined in this study and a total of twenty-one different technological cheese-making systems have been evaluated. These are listed, together with their individual characteristics, in table 4.

For each technological system, seven to 10 different sized plants were constructed on paper to provide a full range of processing rates up to 60,000 pounds of milk hourly. The largest plants, working on a three-shift basis, were able to handle up to 1.3 million pounds of milk daily.

Work routines

Another development, and one likely to become even more important, is the reluctance of employees to work Sundays and night shifts. If the premium required to obtain laborers who are willing to work at these times becomes too great, then alternative work routines must be developed. For plants already operating on a three-shift, 7-day week basis, the change to a 6-day week operation will necessitate expanding the plant size. The capital cost of the operation will therefore be increased and this can be only partly offset by the savings associated with having only six daily cleanup sessions per week instead of seven.

When Sunday is dropped as a workday, a plant must usually be able to process the accumulated day's supply, over the following two days. However, a plant able to do this, could repeat the process with no extra capital cost, if either Wednesday or Thursday were also dropped as workdays. This last adjustment, creating a 5-day week, offers a net savings over

Table 4. Twenty-one selected technological systems used in cheddar cheese manufacturing

System	Vat size (pounds milk) for the 21 systems	Equipment Standard vats	Cooking vats	Automatic cooking machines	Finishing tables	Automatic cheddar-ing machines	Automatic weighing and hooping machines	Automatic milling, salting, weighing, and hooping machines
Standard vat with manual hooping (SV/M)	15,000 20,000 25,000	X X X						
Standard vat with automatic weighing and hooping (SV/AWH)	15,000 20,000 25,000	X X X					X X X	
Standard vat with automatic milling, salting, weighing, and hooping (SV/AMSWH)	15,000 20,000 25,000	X X X						X X X
Two-tier with manual hooping (TT/M)	15,000 20,000 25,000		X X X		X X X			
Two-tier with automatic weighing and hooping (TT/AWH)	20,000 25,000 30,000		X X X		X X X		X X X	
Two-tier with automatic milling, salting, weighing, and hooping (TT/AMSWH)	20,000 25,000 30,000		X X X		X X X			X X X
Automatic cheddaring	30,000		X			X		X
omatic ing	30,000			X	X			X
atic and ng	30,000			X		X		X

the 6-day week system, since only five daily cleanup sessions are required per week, instead of six.

This study produced 12 sets of costs for each plant, to accommodate these important variations in work routine. Thus costs were developed which were specific to each combination of 5-, 6-, and 7-day weeks, with 9, 13, 17, and 21 hours daily operation during the peak milk supply period.[3]

Processing

The flow diagram in chart 1 indicates the various stages included in building up the cost structure for each plant. Raw milk is collected in the receiving center, which was designed in each case to receive both bulk and can supplies. A ratio of 60 percent bulk to 40 percent can was assumed. The raw milk supply was expected to have an average butterfat content of 3.56 percent. In those months where the butterfat content exceeded 3.5 percent, the milk was standardized to 3.5 percent and the excess cream was churned into butter.

The standardized milk then flows through the pasteurizer into the vats in the processing room where the curd is formed. Then the whey is pumped off and the curd is allowed to cheddar, before being milled, salted, weighed, and hooped. The hooped curd is passed to the pressing center where 40-pound blocks are formed. From there, the cheese moves to the packing room and then to the storeroom where it is held for a few days before being shipped out.

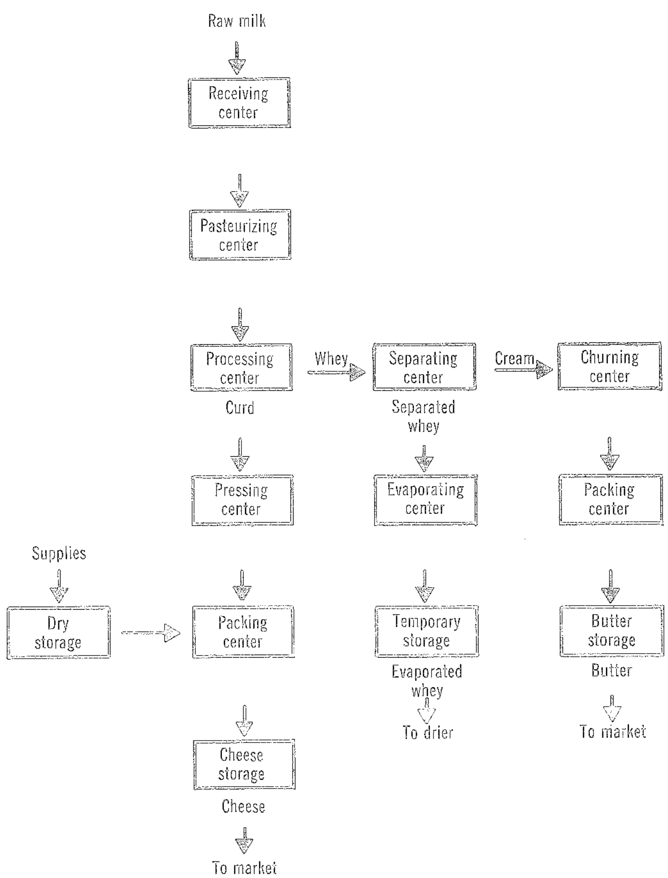
The whey, which was pumped off or which subsequently drained off, is separated into cream and separated whey. The cream is churned to butter while the whey is concentrated to 40 percent solids. It was assumed that the concentrated whey would be shipped out for drying elsewhere or that the drying operation would be costed independently of the cheese enterprise. In either case, only the whey concentrating costs were included in the total processing cost calculated in this study.

For maximum comparability between different systems, certain of the processing times were uniformly fixed. In all systems the period of time between the addition of the rennet and the start of curd milling was 4½ hours. The minimum vat filling time was 30 minutes and all systems were arranged for continuous milk flow throughout the operating period except, of course, for the single vat systems. Thus, when one vat became full, another vat became available for filling, and the pasteurizers were able to operate continuously.

Many plants today have processing times which differ from the 4½ hours used here. Nevertheless, fixing the processing time allows for comparisons of the various types of operations. Changing the processing time is not likely to alter the relative cost results of this analysis.

[3] A maximum of only twenty-one operational hours a day is allowed, to leave 3 hours cleanup time for pasteurizers, condensers, etc.

Chart 1. Plant flow diagram



Costs

Most costs used in this study were those applicable during 1968. Equipment costs were obtained from manufacturers and items were depreciated over 10-20 years. Building costs for each area of the plant were obtained from architects and were depreciated over 35 years. In addition to the depreciation charge, 6.42 percent of the initial cost of equipment and buildings was included in the annual costs to cover interest, insurance, tax, repair and maintenance expenses.[4]

Land requirements were calculated as five times the building area and charged to 20 cents per square foot. This included the cost of leveling,

[4] Interest 3 percent (i.e. 6 percent on the half-life value).
Insurance .29 percent (i.e. .36 percent on 80 percent on initial value).
Taxes 1.63 percent (i.e. 3.26 percent on the half-life value).
Repair and maintenance 1.50 percent.

landscaping, and providing parking facilities. Annual interest and tax were calculated at 9.26 percent of this initial land cost.[5]

Labor costs were based on time studies, where possible. Where some of the more advanced systems have not yet been employed in practice, estimates of the labor needs were made in consultation with the equipment manufacturers. From these itemized labor requirements, an estimate was made of total labor demand during the seasonal peak week. It was then assumed that this labor force would be maintained throughout the year, and that vacations and maintenance work would absorb the excess labor during the nonpeak periods. An overall average labor charge of $3 an hour was made throughout this study, except where otherwise stated. No overtime was required under these arrangements.

The cost of management and supervision was based on observed salary levels for equivalent sized plants in the Midwest during 1968. For managers, these salaries ranged from $7,000 a year in the smallest plants, up to $20,000 in the largest; for supervisors, the range was from $7,000 to $13,000. In smaller plants, part of the manager's time was allocated to manual work, to conform to current practice.

Electricity was charged at a flat rate of 1.5 cents per kilowatt hour. An interruptible natural gas rate of 37.2 cents per 1,000 cubic feet was used for steam generating and a combined water and sewage cost of 11.0 cents per 1,000 gallons of water used.

The remaining supplies and services, which included salt, rennet, packaging items, office supplies, and cleaning materials, were charged at a rate of $1.511 per thousand pounds of milk processed.

Thus total costs are established on the basis that each plant can just handle a specified peak seasonal supply. This supply is assumed to be 22 percent above the average annual supply. The final cost estimates for cheddar cheese manufacturing are presented in this study as an average annual cost in cents per hundred pounds of milk processed. Appendix A contains some examples of itemized costs for selected plants.

TECHNOLOGICAL OPTIONS

Vat sizes

During the cooking stages of cheese manufacture, labor requirements are more closely related to the number rather than size of batches handled. Thus once the technical problems associated with handling large batches of milk and curd had been overcome, there was a general trend towards larger vats.

Figure 1 illustrates the size of these savings for standard vat systems, when operated on a three-shift, 7-day week basis. The upper curve represents 15,000 pound vat systems; the middle curve, 20,000 pound vat systems; and the lower curve, 25,000 pound vat systems.

[5] Interest 6 percent and tax 3.26 percent.

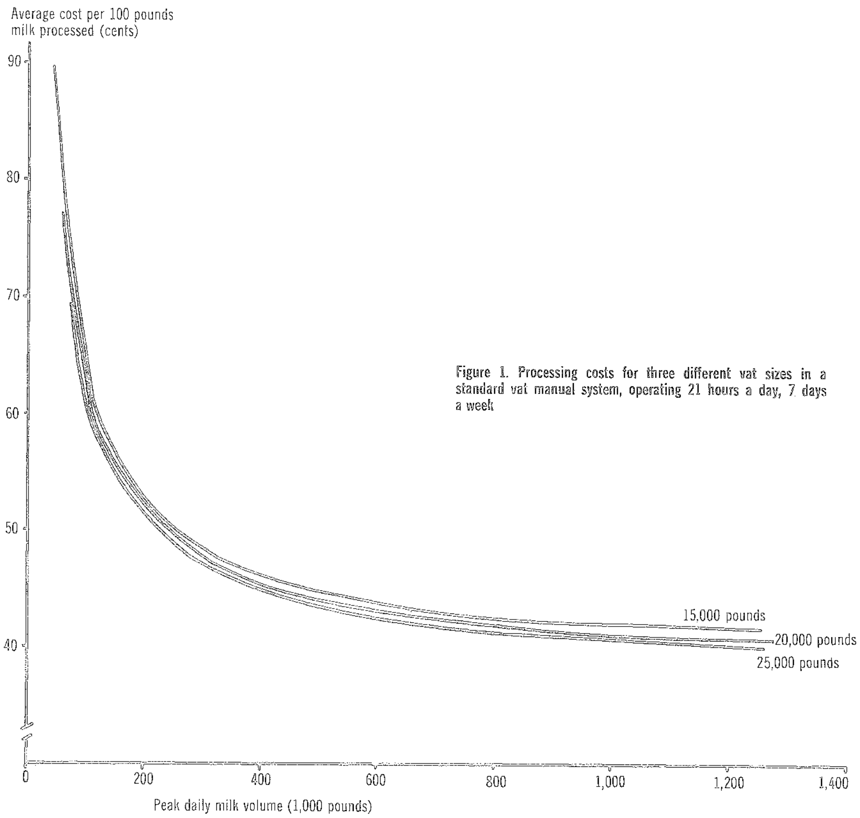


Figure 1. Processing costs for three different vat sizes in a standard vat manual system, operating 21 hours a day, 7 days a week

To make a cost comparison between the different systems, first choose a specific peak daily milk volume along the horizontal axis. If 800,000 pounds a day is chosen, then the processing cost for this size plant, using the 25,000 pound vat system, is 41.4 cents per hundred pounds of milk processed. This cost is read off the vertical axis, at the point on the 25,000 pound vat cost curve corresponding to the peak daily milk volume of 800,000 pounds.

Similarly, for the same peak daily milk volume, the 20,000 pound vat system costs 41.8 cents per 100 pounds of milk processed and the 15,000 pound vat system, 42.6 cents per hundred pounds of milk processed.

Thus for plants using standard vats and having a peak daily milk supply of 800,000 pounds, increasing vat size from 15,000 pounds to 20,000 pounds reduces processing costs by .8 cents per hundred pounds of milk processed. A further increase in vat size, from 20,000 pounds to 25,000 pounds, provides an additional saving of .4 cents per hundred pounds.

A two-tier system saved about 1 cent per hundred pounds of milk processed, by increasing vat size from 20,000 pounds to 25,000 pounds.

A further increase to 30,000 pounds provided an additional saving of about .5 cents per hundred pounds.

For all the standard and two-tier systems, the vat size savings tended to be fairly constant for both variations in work routines and plant sizes.

Standard vat systems

Traditionally, both the cooking and the cheddaring parts of the cheese-making process were carried out in the same vat. In this study, such vats are referred to as standard vats and the systems which employ them are referred to as standard vat systems.

Nine such systems were examined. These were the standard vat with manual hooping, the standard vat with automatic weighing and hooping, and the standard vat with automatic milling, salting, weighing, and hooping. Each of these was constructed using first 15,000 pound vats; then 20,000 pound vats; and finally 25,000 pound vats.

It should be noted that the standard vat systems have an absolute maximum vat size of 25,000 pounds of milk, compared with the arbitrary limit of 30,000 pounds set for the remaining systems. This limitation is necessary so the men can work over the sides of the standard vats, during the cheddaring process. Larger volume vats must be constructed with higher sides, making it too difficult for men to work effectively.

Figure 2 compares the processing costs for the three different 25,000 pound standard vat systems, assuming 7-day week systems, operating three shifts during the peak period.

These charts clearly illustrate two things. First, plants processing less than about 500,000 pounds of milk a day at the peak have a considerable

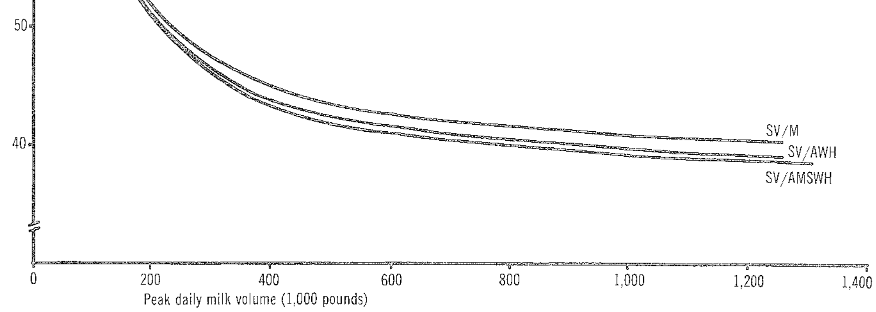


Figure 2. Processing costs for three standard 25,000 pound vat systems, operating 21 hours a day, 7 days a week

cost disadvantage compared with larger plants, regardless of the technology chosen.

Second, the optimum choice of technology depends on the plant size required. Below 125,000 pounds a day at the peak, the least-cost technology is the standard manual system. Between 125,000 and 270,000 pounds a day at the peak, the least-cost technology is the standard vat system modified with automatic weighing and hooping equipment. And above 270,000 pounds, the automatic milling, salting, weighing, and hooping equipment assures the lowest costs for the standard vat system. These are about 42 cents per hundred pounds of milk processed, for plants handling 500,000 pounds a day at the peak, and fall to about 38 cents a hundred pounds for plants handling a peak daily supply of 1,300,000 pounds.

Two-tier systems

As already mentioned, the largest practical vat size which can be used in a standard vat system is 25,000 pounds. If further economies are desired, through the use of even larger vats, then some method such as the two-tier system, must be developed to allow cheddaring outside the deep cooking vats. In this system the milk is heated in deep cooking vats, but instead of draining off the whey and completing the cheddaring in these vats, only half the whey is drained off and the remainder, with the curd, is transferred to shallow cheddaring tables. Here the rest of the whey is drained off and the cheddaring process proceeds.

This arrangement has two additional advantages, apart from the easier cheddaring situation. First, two-tier systems can save on equipment costs because the deep vats, which are more expensive than cheddaring tables, can then be used more intensively for cooking, meaning fewer are required to process a given volume of milk. Second, saving occurs in connection with the automatic weighing and hooping system. This involves modifying the end of each vat which contains milled curd. The number of modifications required in a two-tier system is roughly half that required in the standard system. This is because only the cheddaring tables need be modified — and approximately one cooking vat plus one cheddaring table replace two standard vats.

Figure 3 compares the processing costs for three two-tier systems, each

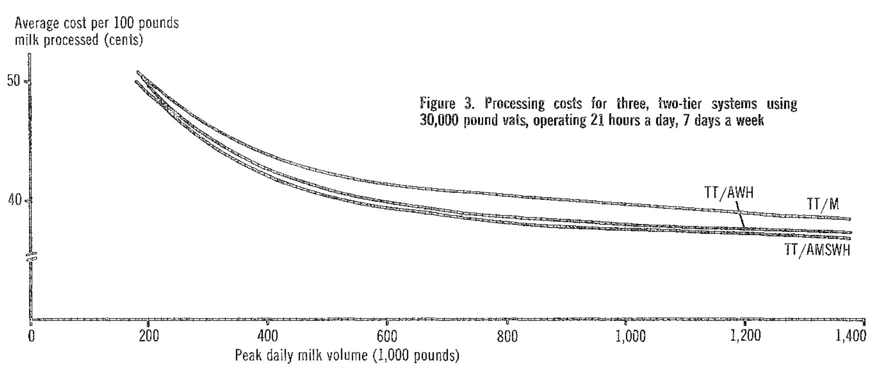


Figure 3. Processing costs for three, two-tier systems using 30,000 pound vats, operating 21 hours a day, 7 days a week

operating with 30,000-pound vats. One system is completely manual, the second has automatic weighing and hooping, and the third has automatic milling, salting, weighing, and hooping.

Again the charts illustrate that plants processing less than 500,000 pounds of milk a day at the peak, are at a considerable cost disadvantage compared with larger plants, regardless of the technology chosen.

For plants designed to operate 7-day weeks, three shifts a day at the peak, the chart indicates that at no stage does the completely manual system offer the lowest costs. The automatic weighing and hooping system offers the lowest costs up to 300,000 pounds a day at the peak. Beyond this the automatic milling, salting, weighing, and hooping systems offer a saving of about .5 cents a hundred pounds of milk processed over the automatic weighing and hooping system, and up to 2 cents a hundred pounds over the manual system.

Automated systems

Automation is being introduced into the cheese industry. Automatic vertical cooking vats can control the cooking phase; automatic cheddaring machines can handle the cheddaring process; and finally a single automatic milling, salting, weighing, and hooping machine can take the curd up to the pressing stage.

Three systems, which incorporated at least two of these innovations, were examined in this study. They all included the automatic milling, salting, weighing, and hooping machine. The first used 30,000-pound cooking vats in conjunction with automatic cheddaring machines. The second used 30,000-pound vertical cooking vats in conjunction with matching cheddaring tables. And the third system was fully automated, using 30,000-pound vertical vats with automatic cheddaring machines.

Figure 4 illustrates that the fully automated system has a small cost advantage over the partially automated systems. However, at no point does this advantage exceed 1 cent per hundred pounds of milk processed.

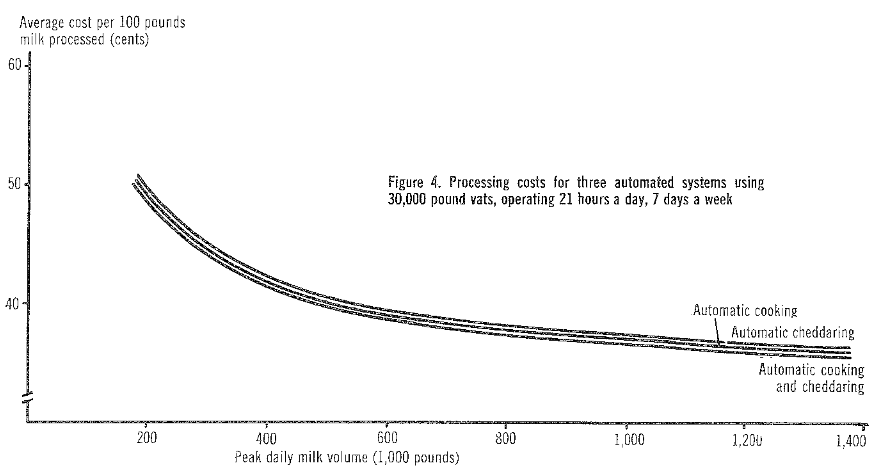


Figure 4. Processing costs for three automated systems using 30,000 pound vats, operating 21 hours a day, 7 days a week

OPERATIONAL OPTIONS

Variations in operating days per week

For all practical purposes, the choice lies between 5-, 6-, or 7-day week operations. Seven-day a week systems are usually the most efficient where labor is readily available for Sunday work. By working 7 days, the equipment is utilized most intensively and raw milk storage costs are kept to a minimum.

A 6-day week system is the least efficient because the plant processing rate must be increased by one-third, compared with the 7-day week system processing the same annual volume. Thus the plant size must be sufficient to handle Sunday's milk, as well as the regular daily supply, during Monday and Tuesday. In addition, raw milk storage capacity must be increased to handle the extra day's accumulation.

Five-day week systems, which leave Sunday and Wednesday or Thursday idle, can operate with the same amount of equipment and storage capacity as 6-day week systems handling the same annual volume. This is because the 6-day week system generally takes only 2 days to digest Sunday's supply. By Wednesday, therefore, the equipment is ready to process another idle day's supply. No extra equipment is required, but a further saving is associated with the elimination of another cleanup period in the week.

Figure 5 illustrates how 6-day week working increases costs by about 5 cents per hundred pounds of milk processed over the 7-day week operation. The 5-day week increases costs by only half that amount. These cost increases are almost independent of the capacity of the plant. More detailed information concerning different technologies and capacities is pro-

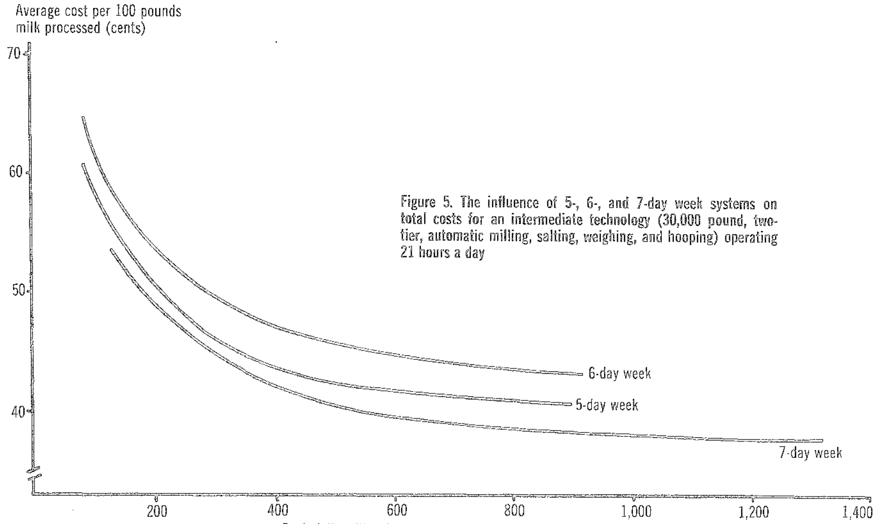


Figure 5. The influence of 5-, 6-, and 7-day week systems on total costs for an intermediate technology (30,000 pound, two-tier, automatic milling, salting, weighing, and hooping) operating 21 hours a day

vided in appendix B, but these merely confirm the general applicability of these estimates.

Variations in operating hours per day

A plant designed to handle a given volume of milk on a round-the-clock basis can usually offer some saving over plants handling the same volume on a one- or two-shift a day basis. The main reason for this is that a round-the-clock system enables a given volume of milk to be processed by a smaller plant than would be required with less intensive systems.

Some of the cost implications of building and operating a plant to handle a given peak milk supply in less than three shifts per day are illustrated in figure 6. About a ½ cent per hundred pounds of milk processed is lost by building a plant which handles a given volume of milk in 17 instead of 21 operational hours a day. Another 1 cent per hundred pounds is lost by reducing the work time from 17 to 13 hours per day, and a further 1½ cents is lost by operating only 9 hours a day.

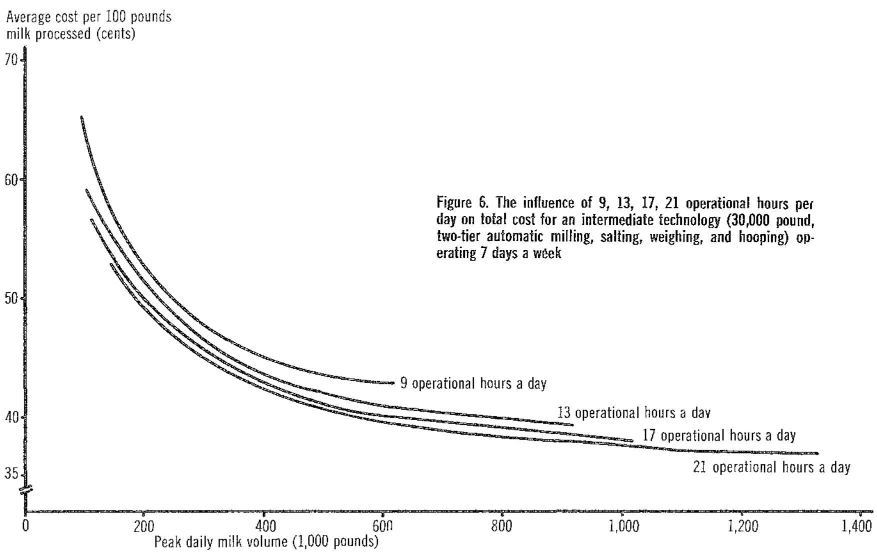


Figure 6. The influence of 9, 13, 17, 21 operational hours per day on total cost for an intermediate technology (30,000 pound, two-tier automatic milling, salting, weighing, and hooping) operating 7 days a week

Further calculations showed that neither the size of the plant nor the technology employed greatly affects these estimates.

Variations in wage rate

Labor costs represent a significant proportion of total costs in cheese making. However, the exact proportion depends on two principal factors — the size of the plant and the technology employed. Therefore, it may be important to management, when designing a new plant, to have some idea of how total processing costs are influenced by alternative wage rates.

Figure 7 illustrates how various wage rate changes can affect total processing costs, for different plant sizes, and for different technologies used in manufacturing. The labor intensive, standard vat system, shows total costs rising by about 4 cents per hundred pounds of milk processed, for every 50 cent rise in labor cost, in the small 200,000 pound plants. This compares with a rise of only 3 cents per hundred pounds of milk processed, for every 50 cent rise in labor cost, in larger 1,000,000 pound plants. On the other hand, the automated system shows a cost increase of 3 cents per hundred pounds processed in the small plants and only 2 cents in the large plants for every 50 cent rise in labor costs.

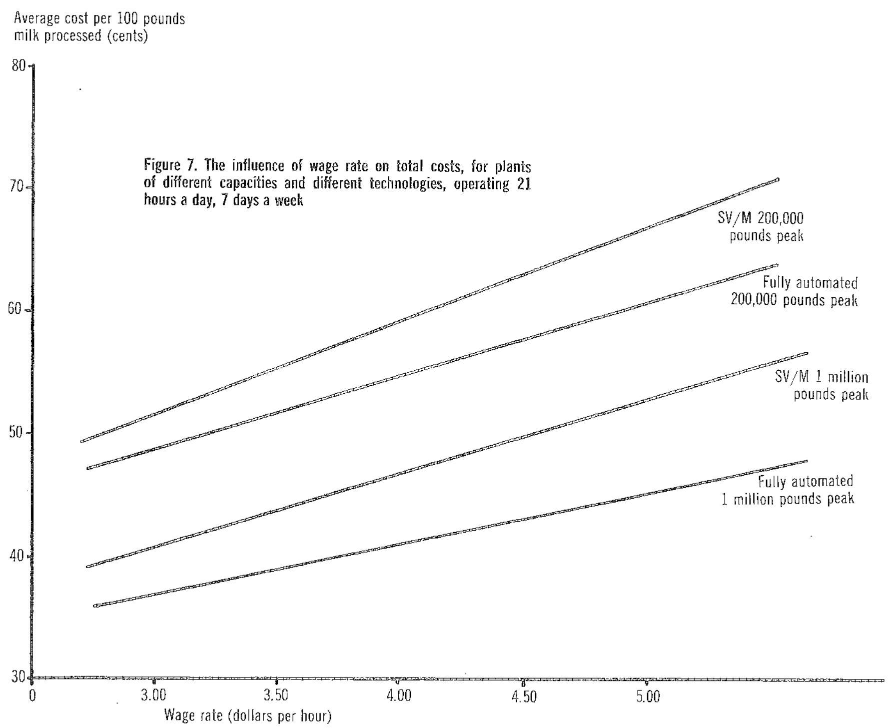


Figure 7. The influence of wage rate on total costs, for plants of different capacities and different technologies, operating 21 hours a day, 7 days a week

Thus any planning, which involves plant construction intended to last many years, must consider possible rising labor costs and their implications for the initial choice of plant size and technology. If it is anticipated, on the basis of current trends, that the average wage rate over the life of a plant will be $5 an hour, then clearly the choice of a least-cost plant design should be based on this estimate, rather than current wage rates.

The results of this analysis indicate that if rising wages are assumed, it will enhance the potential cost advantage enjoyed by larger capacity and more highly automated plants.

TECHNOLOGICAL AND OPERATIONAL SELECTIONS

In this study 252 systems are examined and described in terms of their technological and operational compositions. Each of these systems was in turn costed over a range of seven to 10 sizes. Thus three sorts of information are now available. First, for any specified volume, the appropriate least-cost system can be given. Second, if work routine constraints are introduced, the appropriate least-cost technology can be indicated. Finally, for existing plant managers, with fixed technologies, the costs associated with different work routines are shown.

Day per week constraints

Six and 5-day week constraints were examined and figures 8 and 9 illustrate which systems entered into the respective longrun planning curves. These longrun planning curves indicate the lowest processing cost associated with each volume of milk received, over the entire range of possible plant sizes. Since only the days per week are held constant in these examples, we can expect to see both the optimal technologies and the optimal

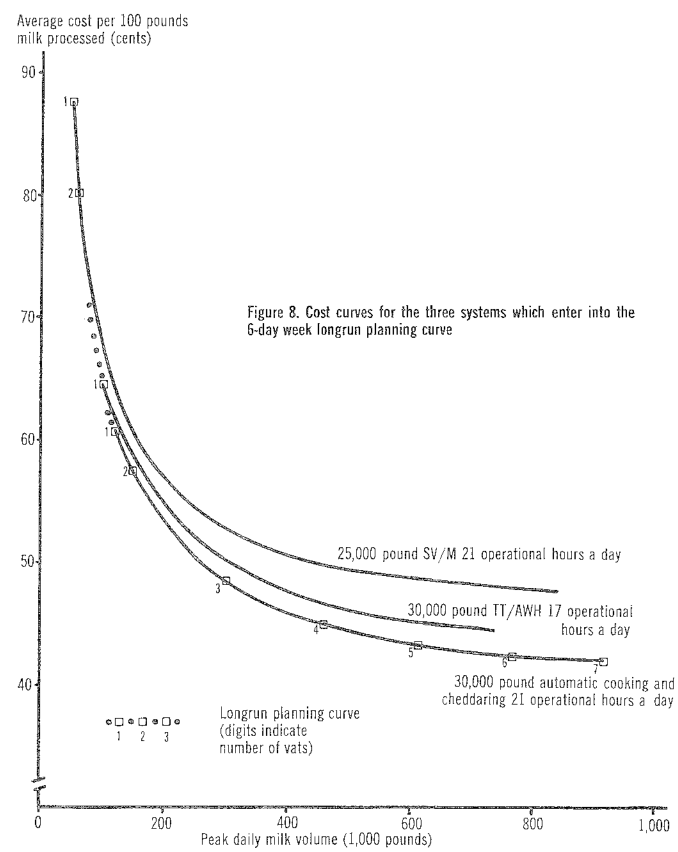


Figure 8. Cost curves for the three systems which enter into the 6-day week longrun planning curve

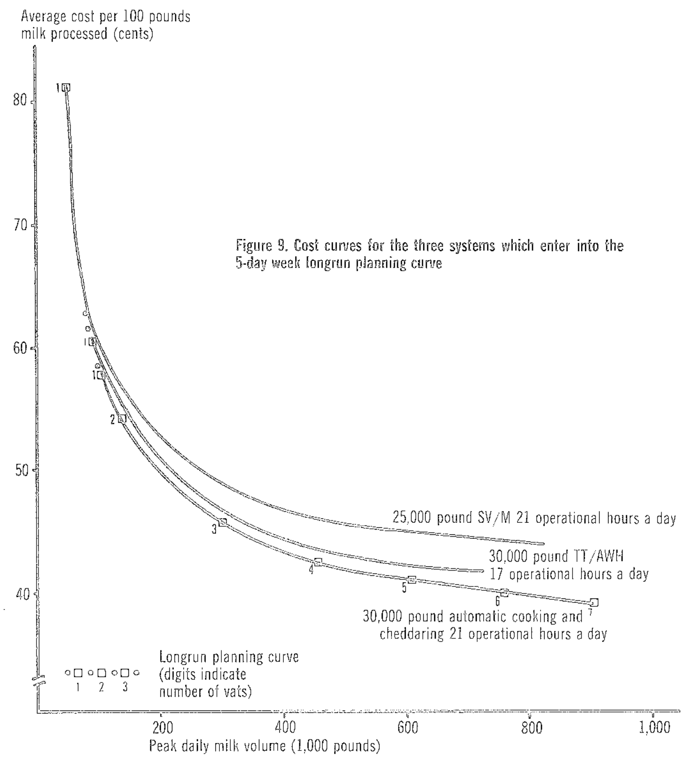


Figure 9. Cost curves for the three systems which enter into the 5-day week longrun planning curve

hours per day changing, as we move around the planning curves from small to large plant sizes.

In these two cases examined here, three systems entered into the planning curves. For the smallest plants the least-cost system used the standard vats with manual hooping, operating three shifts a day at the peak. With 100,000 pounds per day peak supply, it paid to change to a two-tier automatic weighing and hooping system, operating 17 hours a day. And with 120,000 pounds a day, and above, it paid to switch to a fully automated system, operating on a three-shift basis.

A comparison of these two planning curves again emphasizes that, once the decision has been made to eliminate Sunday work, there is a strong economic incentive to eliminate a midweek day also, and operate only 5 day weeks.

Night shift constraint

If a two-shift constraint is imposed, only two systems enter into the longrun planning curve. These are illustrated in figure 10 and show that the least-cost system, for plants receiving a peak supply of less than 120,000 pounds a day, is the standard vat system with manual hooping, operating 7 day weeks. For 120,000 pounds a day peak milk supply and above, it pays to switch to the fully automated system, operating 7 day weeks.

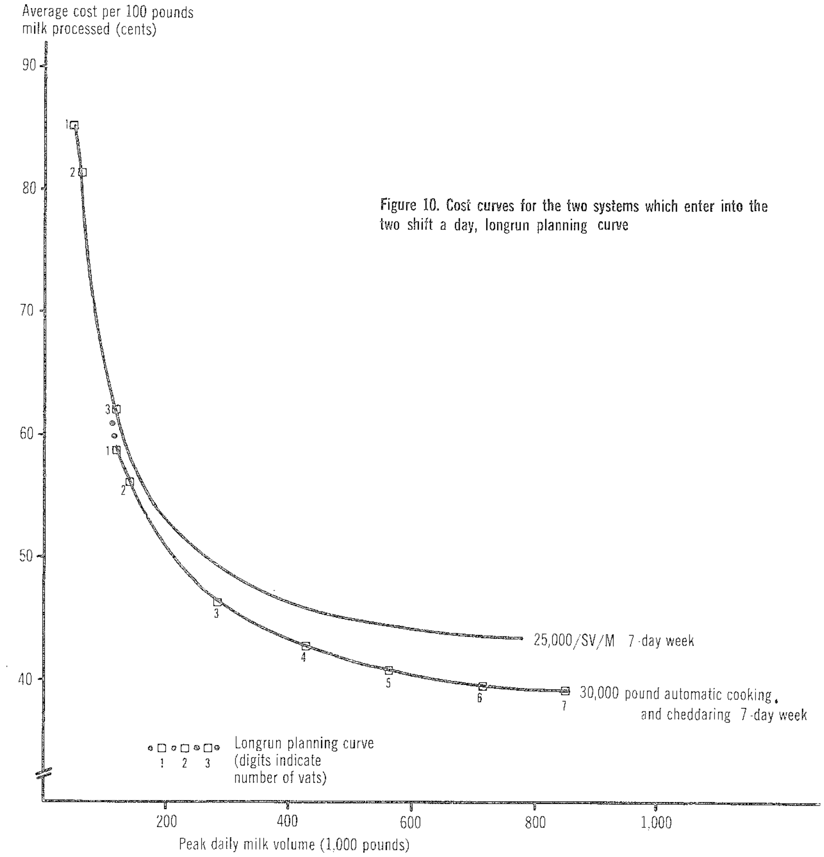


Figure 10. Cost curves for the two systems which enter into the two shift a day, longrun planning curve

Unconstrained planning curve

This is the cost curve which a firm would be interested in, if it were free to choose among all combinations of technological and operational systems.

When all the systems considered in this study were compared, only four could be selected as offering the lowest processing costs at some point in the range of supply volumes considered. The complete cost curves for these four systems are found in figure 11. The longrun planning curve for the industry is then given by the minimum cost envelope of these four systems.

For small plants, receiving less than 100,000 pounds peak daily milk supply, the least-cost system employs the standard vat with manual hooping, on a three-shift, 5-day week basis.

The least-cost system for peak daily volumes between 100,000 and 150,000 pounds involves the use of two-tier vats with automatic weighing and hooping, operating 17 hours a day, 5 days a week. For volumes between 150,000 and 180,000, the same two-tier technology, with automatic

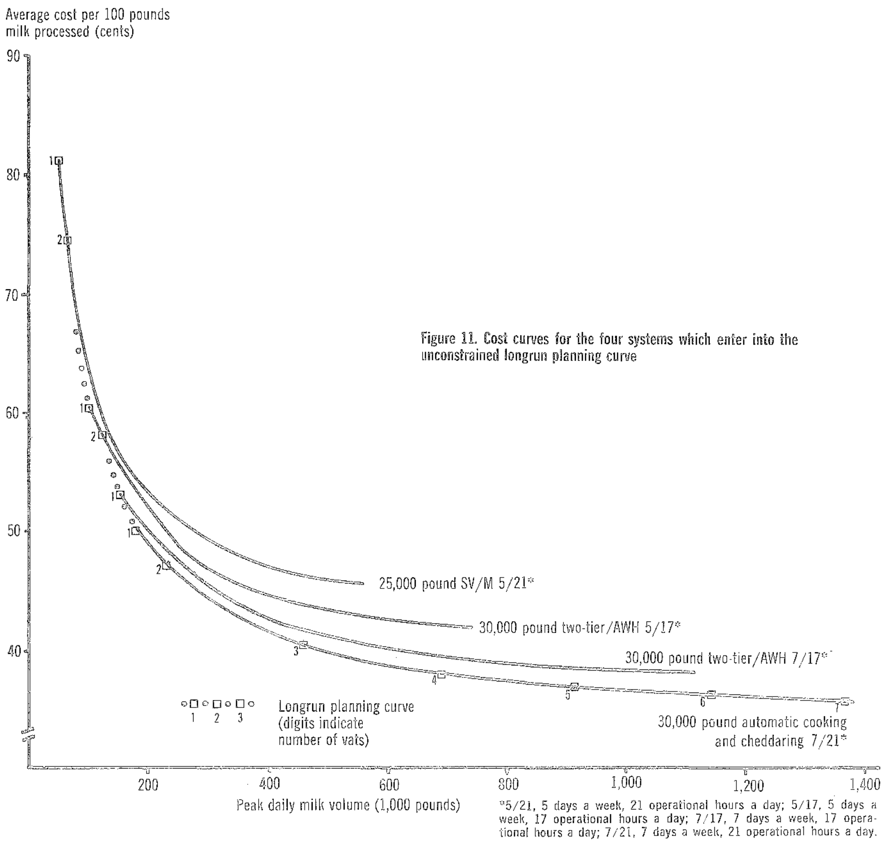


Figure 11. Cost curves for the four systems which enter into the unconstrained longrun planning curve

weighing and hooping, is used. It is still operated 17 hour days, but a 7-day week organization is now required, compared with 5 day weeks for the smaller volumes.

Least-cost plants processing a peak daily volume of 180,000 pounds or more, use automatic cooking and cheddaring equipment on a three-shift, 7-day week basis.

SUMMARY AND CONCLUSIONS

This study measured the effect of different combinations of technologies, work routines, and wage levels, on cheddar cheese manufacturing costs. Each of these combinations was further examined for variations in plant size, up to a maximum of about 1.3 million pounds a day peak milk supply. The principal findings were:

1) For plants with a peak daily milk supply of a quarter of a million pounds, the addition of a further 100,000 pounds can cut costs by about 5 cents per hundred pounds of milk processed. This economy to size diminishes rapidly once the peak daily supply is in excess of 500,000 pounds.

2) The choice of a least-cost technology depended mainly on the available milk supply. For plants processing a peak milk supply of less than 100,000 pounds a day, a standard vat system with manual hooping was best. Between 100,000 and 180,000 pounds peak supply, a two-tier system with automatic hooping gave the least-cost solution. And for plants receiving 180,000 pounds or more a day, the fully automated system was best. It may be added, however, that any of the 30,000 pound vat systems, which offered automatic hooping, had costs within 1 or 2 cents per hundred pounds of the fully automated system.

3) The elimination of Sunday work added about 5 cents per hundred pounds, for any given technology, to the processing cost. This was because the plant size had to be increased by about one-third, in order to handle the accumulated supply, during the following 2 days. The elimination of both Sunday and a midweek day reduced this extra cost to 2.5 cents per hundred pounds, because these 5-day week plants use no extra equipment compared with 6-day week plants, yet they save an extra cleanup session each week.

4) The cost of eliminating the night shift is about 1.5 cents per hundred pounds of milk processed. This is fairly constant for all technologies and plant sizes.

5) Wage rate increases affected costs differently for different plant sizes using the same technology, and for identical plant sizes using different technologies. Thus a 50-cent an hour increase in labor costs raises processing costs in a small standard manual plant by 4 cents per hundred pounds of milk processed. This compares with only a 3-cent rise in similar plants processing over 1 million pounds a day. Comparative figures for the fully automated system were 3 cents and 2 cents, for small and large plants, respectively.

6) Finally, if a plant were specifically designed to operate 5-day weeks on a two-shift basis, compared with 7-day weeks with three shifts, the extra cost per hundred pounds of milk processed would be about 5 cents. This is equivalent to a dollar an hour wage differential. In other words, only when the premium necessary to attract labor to 7-day week, three-shift systems exceeds a dollar an hour, on all hours worked, does it become profitable to switch to a 5-day week, two-shift system.

Thus the main conclusion of this study is that the cheddar cheese making industry will continue to find it profitable to adopt new equipment and techniques. Many of these innovations, however, are most profitable when used in large scale operations. This means that plants operating with less than 250,000 pounds of milk a day will find themselves at an increasing cost disadvantage when compared with larger plants.

Appendix A. Itemized costs for four sample plants

	Technological system			
	Standard vat with manual hooping	Two-tier automatic weighing and hooping	Automatic cooking and cheddaring	Automatic cooking and cheddaring
Vat number	2	2	2	7
Vat size	25,000 pounds	30,000 pounds	30,000 pounds	30,000 pounds
Operational system	7 day/week; 3 shifts	7 day/week; 3 shifts	7 day/week; 3 shifts	7 day/week; 3 shifts
Processing rate	4,500 pounds/hour	10,900 pounds/hour	10,900 pounds/hour	65,400 pounds/hour
Peak daily capacity	94,500 pounds	228,900 pounds	228,900 pounds	1,373,400 pounds
Annual volume processed	28.3 million pounds	68.5 million pounds	68.5 million pounds	411.1 million pounds
Total initial capital cost	$199,849	$296,055	$395,779	$1,190,557
	dollars			
Annual costs				
Equipment depreciation	16,951	24,624	31,125	95,627
Equipment, interest, insurance tax, repair, and maintenance	12,830	19,007	25,409	76,434
Building and land, depreciation, interest, insurance, tax, repair, and maintenance	16,764	23,343	19,407	46,798
Labor and management	79,003	135,898	120,485	540,259
Supplies and other expenses	56,428	126,321	126,321	710,524
Total annual costs	181,976	329,193	322,747	1,469,642
	cents			
Cost per 100 pounds milk processed	64.34	48.05	47.11	35.75

Appendix B. System processing costs for different supply volumes

Technology (including vat size)	Organization (peak period)	Peak daily volume (1,000 pounds) 50	100	150	200	400	600	800	1,000	1,200
		cents per 100 pounds milk processed								
Standard vat with manual hooping (25,000 pounds)	7 day/week; 3 shift	...	61.9	55.1	51.5	44.8	42.6	41.4	40.9	40.4
	6 day/week; 3 shift	87.5	68.1	60.7	57.1	50.6	48.6	47.9	...	...
	5 day/week; 3 shift	81.3	62.8	56.3	52.9	46.9	45.0	44.2	...	...
Standard vat with automatic weighing and hooping (25,000 pounds)	7 day/week; 3 shift	...	62.8	54.8	50.3	43.8	41.4	40.2	39.8	39.2
	6 day/week; 3 shift	88.4	67.1	60.1	56.3	49.3	46.9	46.1	...	...
	5 day/week; 3 shift	82.5	63.4	55.7	52.4	45.7	43.5	42.8	...	...
Standard vat with automatic milling, salting, weighing, and hooping (25,000 pounds)	7 day/week; 3 shift	...	62.8	55.8	51.1	43.5	41.2	40.0	39.1	38.5
	6 day/week; 3 shift	...	69.5	60.2	55.6	49.9	46.7	45.4	...	...
	5 day/week; 3 shift	...	65.3	56.4	51.9	45.7	43.4	42.4	...	...
Two-tier with manual hooping (30,000 pounds)	7 day/week; 3 shift	...	...	...	49.9	43.9	41.2	40.3	39.7	38.9
	6 day/week; 3 shift	...	...	59.4	56.0	48.9	46.7	45.6	...	...
	5 day/week; 3 shift	...	...	55.5	52.5	45.4	43.5	42.1	...	...
Two-tier with automatic weighing and hooping (30,000 pounds)	7 day/week; 3 shift	...	...	...	49.1	42.7	40.1	38.7	38.2	37.3
	6 day/week; 3 shift	...	...	58.6	55.0	47.4	45.1	43.9	...	...
	5 day/week; 3 shift	...	...	54.7	51.7	45.6	42.4	40.9	...	...
Two-tier with automatic milling, salting, weighing, and hooping (30,000 pounds)	7 day/week; 3 shift	...	...	...	49.7	42.5	39.8	38.4	37.4	37.0
	6 day/week; 3 shift	...	...	58.7	54.8	47.3	45.0	43.7	...	...
	5 day/week; 3 shift	...	...	54.8	51.6	44.0	42.1	40.8	...	...
Automatic cheddaring (30,000 pounds)	7 day/week; 3 shift	...	...	...	49.2	42.0	39.7	38.2	37.4	36.7
	6 day/week; 3 shift	...	...	58.5	54.1	46.8	44.8	43.3	...	...
	5 day/week; 3 shift	...	...	54.9	50.8	44.1	42.0	40.7	...	...
Automatic cooking (30,000 pounds)	7 day/week; 3 shift	...	...	...	48.9	41.7	39.2	37.9	37.1	36.4
	6 day/week; 3 shift	...	...	57.9	53.5	45.7	44.2	42.8	...	...
	5 day/week; 3 shift	...	...	54.5	50.7	43.4	41.3	40.1	...	...
Automatic cooking and cheddaring (30,000 pounds)	7 day/week; 3 shift	...	...	...	48.7	41.3	38.9	37.5	36.8	36.2
	6 day/week; 3 shift	...	...	57.8	53.2	46.2	43.4	42.2	...	...
	5 day/week; 3 shift	...	...	54.4	50.0	43.4	41.0	49.7	...	...

Appendix B. (continued) System processing costs for different supply volumes

Technology (including vat size)	Organization (peak period)	Peak daily volume (1,000 pounds) 50	100	150	200	400	600	800	1,000	1,200
		................cents per 100 pounds milk processed................								
Standard vat with	7 day/week; 2 shift	85.2	64.3	56.7	52.9	46.3	44.2	43.4	...	...
manual hooping	6 day/week; 2 shift	95.3	70.2	63.0	59.3	53.2	...	...	...	...
(25,000 pounds)	5 day/week; 2 shift	90.0	65.6	58.7	55.2	49.3	...	...	...	...
Standard vat with	7 day/week; 2 shift	86.4	64.7	56.6	52.3	45.5	43.3	42.1	...	...
automatic weighing and	6 day/week; 2 shift	93.8	69.7	62.4	58.5	51.9	...	...	...	...
hooping (25,000 pounds)	5 day/week; 2 shift	90.0	66.3	58.3	54.6	48.3	...	...	...	...
Standard vat with automatic	7 day/week; 2 shift	...	65.0	57.3	52.7	45.2	42.4	41.8	...	...
milling, salting, weighing, and	6 day/week; 2 shift	92.1	70.6	62.7	58.2	51.1	...	...	...	...
hooping (25,000 pounds)	5 day/week; 2 shift	86.2	66.0	58.6	54.5	47.4	...	...	...	...
Two-tier with	7 day/week; 2 shift	...	...	56.2	52.1	44.8	42.6	41.6	...	...
manual hooping	6 day/week; 2 shift	...	69.9	62.2	57.8	51.0	...	...	...	...
(30,000 pounds)	5 day/week; 2 shift	...	65.3	57.9	53.8	46.7	...	...	...	...
Two-tier with automatic	7 day/week; 2 shift	...	...	55.6	51.7	43.7	41.4	40.3	...	...
weighing and hooping	6 day/week; 2 shift	...	69.1	61.2	56.6	49.7	...	...	...	...
(30,000 pounds)	5 day/week; 2 shift	...	64.9	57.5	53.0	46.6	...	...	...	...
Two-tier with automatic	7 day/week; 2 shift	...	...	55.7	51.6	43.6	41.2	39.9	...	...
milling, salting, weighing and	6 day/week; 2 shift	...	69.0	61.3	56.4	49.3	...	...	...	...
hooping (30,000 pounds)	5 day/week; 2 shift	...	65.0	57.4	53.0	46.3	...	...	...	...
Automatic	7 day/week; 2 shift	...	...	56.0	51.2	43.8	41.2	40.1	...	...
cheddaring	6 day/week; 2 shift	...	69.7	61.4	56.7	49.7	...	...	...	...
(30,000 pounds)	5 day/week; 2 shift	...	66.0	58.0	53.4	46.8	...	...	...	...
Automatic	7 day/week; 2 shift	...	...	55.6	51.1	43.1	40.5	39.4	...	...
cooking	6 day/week; 2 shift	...	69.0	60.9	56.0	48.7	...	...	...	...
(30,000 pounds)	5 day/week; 2 shift	...	65.2	57.6	52.8	45.7	...	...	...	...
Automatic cooking	7 day/week; 2 shift	...	...	55.5	51.1	43.1	40.2	39.2	...	...
and cheddaring	6 day/week; 2 shift	...	68.8	61.0	56.3	48.7	...	...	...	...
(30,000 pounds)	5 day/week; 2 shift	...	65.3	57.8	53.2	46.2	...	...	...	...