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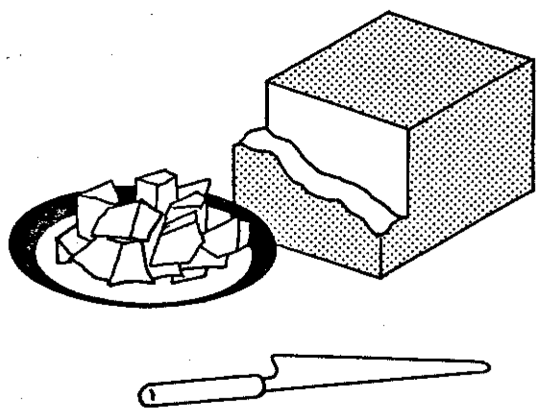
CHEDDAR CHEESE MANUFACTURING COSTS ECONOMIES OF SIZE AND EFFECTS OF DIFFERENT CURRENT TECHNOLOGIES



by
Jens K. Mesa-Dishington
David M. Barbano
Richard D. Aplin

Part 2 of a Research Effort on Cheddar Cheese Manufacturing

Department of Agricultural Economics
Cornell University Agricultural Experiment Station
New York State College of Agriculture and Life Sciences
A Statutory College of the State University
Cornell University, Ithaca, New York, 14853

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PREFACE

Jens K. Mesa-Dishington, David M. Barbano, and Richard D. Aplin are former graduate student, Department of Agricultural Economics; Associate Professor of Food Science; and Professor of Agricultural Economics, College of Agriculture and Life Sciences, Cornell University, respectively.

This publication is the second in a series of publications on Cheddar cheese manufacturing costs. The series of publications will report the results of a major research effort aimed at helping to answer the following questions:

How do aged Cheddar cheese plants in the Northeast differ from plants in Wisconsin, Minnesota and other important cheese-producing states with respect to efficiency and other key factors affecting their economic performance? How much do operational factors, such as number of operating days per week, number of shifts per day, yield potential of milk supplies and recovery of solids at the plant, affect the costs of production? What are the differences in costs among plants using the most modern commercial technologies (e.g., continuous systems) and those using more traditional batch systems for manufacturing Cheddar cheese? How large a cost advantage do large Cheddar cheese plants have over smaller-scale plants?

Subsequent publications will address the following questions: What would be the impact on manufacturing costs of using ultrafiltration or reverse osmosis processes on milk in Cheddar cheese plants? What is the feasibility and what would be the impact on plant costs of using some of the production capacity in Cheddar cheese plants to produce other cheeses including perhaps, some specialty, European-style cheeses? In other words, what are the growth opportunities in the other cheeses for the Cheddar cheese industry as it faces increasing competitive pressures?

This publication reports the results of using the economic-engineering approach to estimate and analyze the production costs of a large variety of Cheddar cheese operations. A major objective was to provide estimates of achievable costs for efficient plants and to assess the cost impacts of different plant sizes, various production schedules and several current manufacturing technologies. An earlier phase of the research involved the study of 11 plants operating in the Northeast and North Central regions. The study of the 11 plants is reported in a companion publication entitled "Economic Performance of 11 Cheddar Cheese Manufacturing Plants in Northeast and North Central Regions." It provided insights and information on Cheddar operations that were valuable in budgeting the costs reported herein.

A second objective of this phase of the study was to provide a basis for determining the cost impacts of adopting new, oncoming technologies, especially reverse osmosis and ultrafiltration, in Cheddar cheese manufacturing. Work has begun to superimpose new milk concentration technologies (i.e., ultrafiltration, reverse osmosis and energy efficient MVR evaporators) on a number of the model plants described in this publication.

Still a third objective was to provide a basis for assessing the feasibility and desirability of using some of the capacity in Cheddar plants to produce speciality cheeses. Work also has been on this phase.

Financial assistance making this project possible was provided from two sources. One was a research agreement with the Agricultural Cooperative Service of the United States Department of Agriculture. The other source was the Agricultural Research and Development Grants Program of the New York State Department of Agriculture and Markets.

Many have contributed importantly to the development and success of this project. Cornell University contracted with Mead & Hunt, Inc., an engineering consulting firm based in Madison, Wisconsin and with broad experience in various industries including cheese, to provide much of the information needed to budget costs. We actually worked with Donald Johnson, Alfred Anderson and Daniel Surfus of Mead & Hunt, Inc. We want to especially thank Don, Al and Dan for doing such a first-rate, professional job.

We also wish to thank several of our colleagues at Cornell. Professor Loren W. Tauer served on the senior author's masters committee and made a number of helpful contributions. Stanley Payson helped structure one of the computer programs needed for the data analysis. John C. Martin made a significant contribution in doing analyses of the model plants. Sandra Basso and Kathy Pierce did an able job in typing and processing the manuscript. Joe Baldwin did the excellent graphics work. We thank them all.

Constructive criticisms of the manuscript were made by K. Charles Ling of the Agricultural Cooperative Service, Andrew Novakovic and Brian Henehan of Cornell's Department of Agricultural Economics, and a number of people in industry.

For copies of this publication, contact:

R. D. Aplin
Department of Agricultural Economics
Cornell University
357 Warren Hall
Ithaca, New York 14853

DIGEST AND HIGHLIGHTS

The principle objectives of this segment of the study were to estimate production costs of cheddar cheese manufacturing and to assess the cost impacts of different plants sizes, various production schedules, and several current manufacturing technologies. A secondary objective was to provide a basis for later phases of work on the probable impacts of adopting new technologies on cheese manufacturing costs, especially reverse osmosis and ultrafiltration, as well as assessing the impacts on plant costs of manufacturing some specialty cheeses in cheddar plants.

Production costs were budgeted for 783 different basic plant designs using the economic-engineering approach. Six plant sizes, nine different production schedules, five cheesemaking technologies and three hooping/packaging systems were used to form the plant combinations needed for the cost estimation. Data from a survey of plants completed in the first phase of the study, an engineering consulting firm, equipment manufacturers, product suppliers, plant managers and other sources of information were used in the plant design and cost estimation procedures.

The average costs calculated in this manner indicate what could be expected with a new plant, engineered according to the specifications of the design and operated according to the assumed, achievable standards. For any given plant design or operating schedule, costs that would be achieved in an actual setting would vary with the quality of management and labor, actual prices paid for fixed or variable inputs, and milk composition and quality factors (which affect cheese yield). The effect on average cost of any of these real-life factors could be very significant; nevertheless, this study demonstrates the importance of scale economies and operating schedules when the vicissitudes of management, milk quality and so on, are neutralized.

RESULTS

Production Costs

Production costs per pound of cheese ranged between 10.7 and 30.1 cents for model plants of different sizes, production schedules and manufacturing technologies.

Economies of Size

Large economies of size were observed in cheddar cheese production regardless of technology or operating schedule. Plant size was by far the most important factor affecting unit costs of production in the model plants. For example, as plant size doubled from 480,000 pounds to 960,000 pounds of daily milk capacity, average production costs per pound of cheese decreased by about 30 percent, everything else staying unchanged. If the plant size were to increase by a factor of five to about 2,400,000 pounds, the reduction in unit cost would be approximately 50 percent over the 480,000 pound plant.

Production Schedules

Production schedules also had an important impact on the average cost of production. As the number of operating days per week or the number of production hours per day increased, the average production costs per pound of cheese decreased because of the higher utilization of plant capacity.

Changes in the daily schedules of production had a relatively larger impact on production costs than similar changes in the weekly schedules. For example, plants were modeled to have the same level of plant utilization (71%) with two different production schedules: 5 (24 hours/day) days per week and 6 (21 hours/day) days per week. The 5-day, 24-hour production organization had a lower cost than the 6-day, 21-hour production organization. Increasing the number of hours of production at the plant from 18 to 24 hours reduced average costs by 15%, while increasing the number of operating days from 5 to 7 days per week reduced the costs by about 6%.

<u>Capacity Utilization</u>

The observed size effects in cheddar cheese manufacturing often offset the expense of operating larger plants at lower levels of plant capacity utilization. In other words, it was generally less costly to produce cheese in a large plant that was underutilized than it was in a small plant running at peak capacity. This was particularly true at lower production levels. For example, a 480,000-pound plant operating 5 days per week and 24 hours per day produces as much cheese per year (12.5 million pounds) as a 720,000-pound plant operating 5 days per week and 18 hours per day. However, the average costs for that 480,000 pound system were approximately 10 percent higher than the costs for the 720,000 pound plant. Likewise, a 960,000-pound plant operating 5 days and 24 hours manufactures the same volume of cheese per year (25 million pounds) as a 1,440,000-pound plant operating 5 days and 18 hours. However, the larger plant had a 4 percent lower cost than the smaller plant. It appears that the relative cost savings are smaller as the size of the operations increase.

The observation that a given volume of production could be produced at a lower cost per pound of cheese in a larger operation than in a smaller one, generates many implications for the industry. It suggests that firms that can market only limited volumes of cheddar cheese and contemplating construction of a plant, perhaps should build a larger plant and operate it at less than capacity instead of building a smaller plant and operating it at capacity. An additional possibility that comes from this situation is that the larger plant might also use the cheddar down days to manufacture other cheese types. In this case, the cheese operation could perhaps take advantage of both the economies of size and the economies of operating a plant at a higher capacity producing relatively smaller volumes of various cheeses.

<u>Technologies</u>

In general, differences in cheesemaking or hooping/packaging technologies had a relatively small impact on the costs of production. The standard cheddaring technology and the regular 40-pound hooping/packaging technology were the highest cost production technologies studied. The other four cheesemaking technologies--the automatic cheddaring, the advanced cheddaring, the standard stirred curd and the advanced stirred curd--resulted in similar costs. As the size of the operation increased, the cost differences among these last four technologies became much smaller or nonexistent. The 40-pound block former and the 640 with conversion to 40 pound blocks also resulted in similar costs for most plant sizes.

Labor was the most important component of the production costs and more important in smaller plants than in larger ones. Labor represented between 42 and 58 percent of the total production costs for the smaller size plants while labor accounted for between 24 and 36 percent of the production costs in the larger size plants. Annual capital costs were lower than labor although they were still significant in cheddar cheese manufacturing. Capital costs represented between 9 and 23 percent of the production costs for all model plants of all sizes. On the other hand, costs of materials represented between 18 and 20 percent in the smaller size plants and as high as 40 percent in the larger operations. Labor, capital and materials accounted for about 80 to 85 percent of the production costs.

For the most part, the different plant relationships observed between systems in the original models did not undergo important changes when different cheese yields, interest rates and wage rates were considered.

TABLE OF CONTENTS

Tables
(Continued)

List of Tables

Tables
(continued) Page

Tables (continued)		Page

Tables
(continued)

Page

Tables
(continued)

Page

List of Figures

CHEDDAR CHEESE MANUFACTURING COSTS
ECONOMIES OF SIZE AND EFFECTS OF DIFFERENT CURRENT TECHNOLOGIES

IMPORTANCE AND CHANGING NATURE OF CHEDDAR CHEESE INDUSTRY

In 1984, twenty-nine percent of the milk received by plants in the United States was processed into cheese. Cheese represented 47 percent of the milk used in manufactured dairy products. During the past 25 years, the production of cheese nearly doubled while the production of butter declined and the production of other manufactured dairy products such as ice cream increased only moderately.

Cheddar Cheese Production

Cheddar cheese has been, and continues to be, the number one cheese variety produced in the United States. Total production has increased more than 136 percent during the last 25 years, from 894 million pounds of cheese in 1960 to 2,113 million pounds in 1984. Currently, Cheddar production accounts for approximately 45 percent of total cheese and 80 percent of American cheese production (Table 1).

In general, Cheddar cheese production can be classified into two broad categories: block Cheddar cheese, including short-hold and long-hold Cheddar, and barrel Cheddar cheese. The distinction between these two groups is important because the nature of the product, the manufacturing process, and the production economies are somewhat different. Block Cheddar is a high-moisture cheese and a more consumer oriented product. On the other hand, barrel Cheddar is a low-moisture cheese which is used mainly as a raw material in other processes. Unfortunately, most statistics report Cheddar cheese information only as one group and do not make a clear distinction between block Cheddar and barrel Cheddar.

In recent years, Cheddar cheese production has undergone many of the same adjustments observed in the overall cheese industry. The number of plants has decreased, while the average production per plant has increased as new technological advances have been adopted rapidly in many plants.

The reduction in the number of plants has been very important in the cheese industry during the last 25 years (Figure 1). In the United States, the number of cheese plants decreased more than 50 percent, from 1,419 plants in 1960 to 678 in 1984. The reduction in plants was not proportional in all regions. For example, Wisconsin, which traditionally had a large number of small plants, had a reduction of more than 60 percent. The decrease in New York was much closer to the national average, whereas Minnesota did not experience much change in the number of operations.

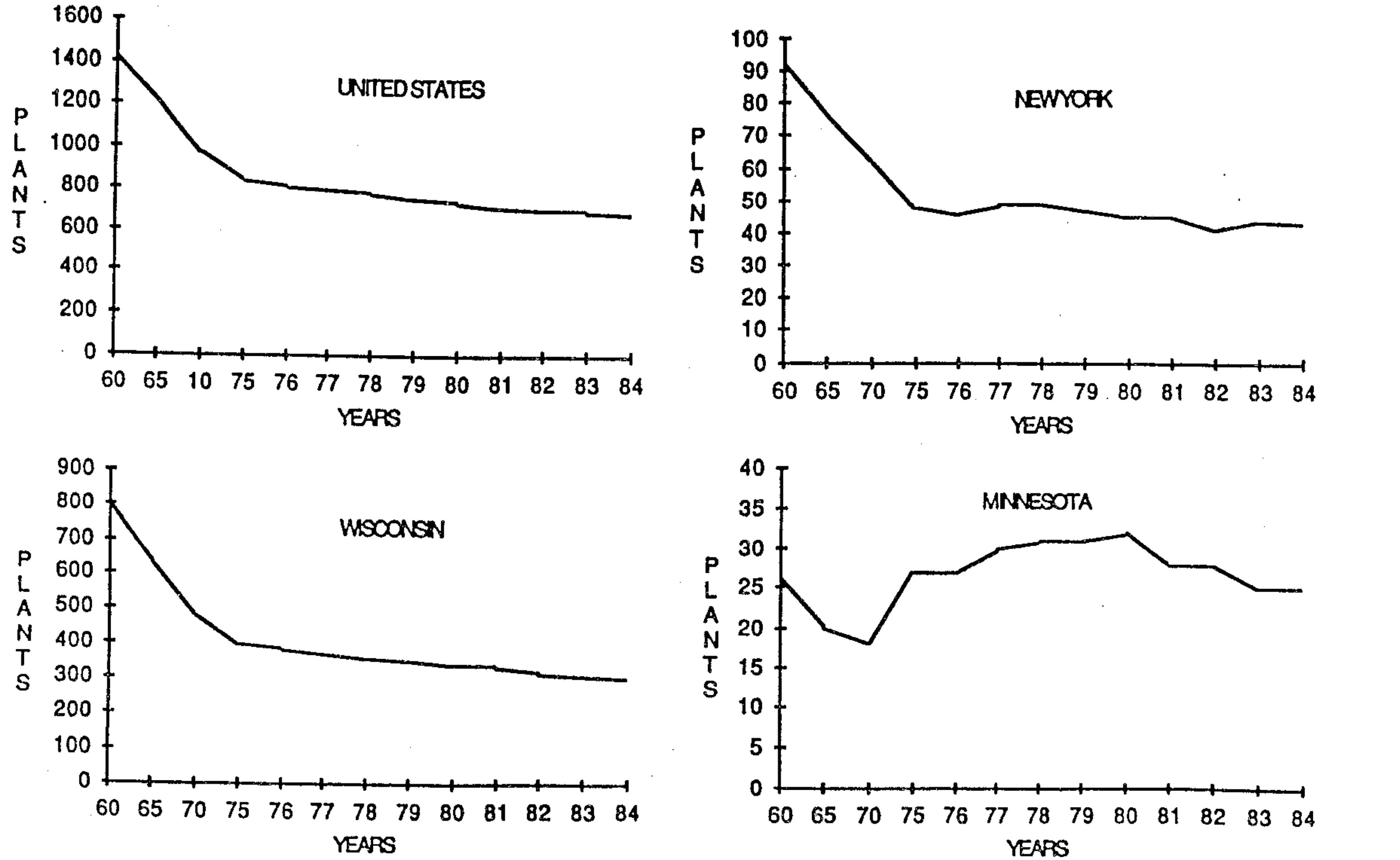
A significant increase in the average production per plant also has taken place during the last two decades (Figure 2). Average production still differs among regions, although the relative increase in production has been somewhat similar. Wisconsin, Minnesota and New York, the three largest cheese producing states, had between a sevenfold and eightfold increase in average plant production between 1960 and 1984. Minnesota continues to have much larger average size operations than Wisconsin or New York. By 1984, Minnesota cheese

Table 1. **Cheddar Cheese Production in the United States, New York, Minnesota, and Wisconsin (Selected Years 1960-1984).**

	United States	New York			Minnesota			Wisconsin		
Year	Production	Production	Share of U.S	U.S. Rank	Production	Share of U.S	U.S. Rank	Production	Share of U.S	U.S. Rank
	(Mil.Pounds)	(Mil.Pounds)	(%)	(#)	(Mil.Pounds)	(%)	(#)	(Mil.Pounds)	(%)	(#)
1960	894.3	38.3	4.3	6	49.6	5.5	4	418.5	46.8	1
1965	1007.8	34.3	3.4	6	63.6	6.3	3	482.0	47.8	1
1970	1182.4	40.4	3.4	6	100.2	8.5	2	569.9	48.2	1
1975	1205.0	52.2	4.3	3	235.1	19.5	2	502.2	41.7	1
1976	1524.1	75.4	4.9	3	276.1	18.1	2	661.5	43.4	1
1977	1517.5	74.5	4.9	3	261.6	17.2	2	692.4	45.6	1
1978	1505.5	77.2	5.1	3	277.0	18.4	2	705.8	46.9	1
1979	1597.3	81.9	5.1	3	308.4	19.3	2	733.3	45.9	1
1980	1750.7	71.1	4.1	3	333.2	19.0	2	809.9	46.3	1
1981	1933.1	68.2	3.5	3	368.5	19.1	2	854.7	44.2	1
1982	2157.5	71.7	3.3	4	389.5	18.1	2	885.8	41.1	1
1983	2351.4	78.5	3.3	4	405.4	17.2	2	951.2	40.5	1
1984	2112.8	70.6	3.3	5	376.6	17.8	2	875.0	41.4	1

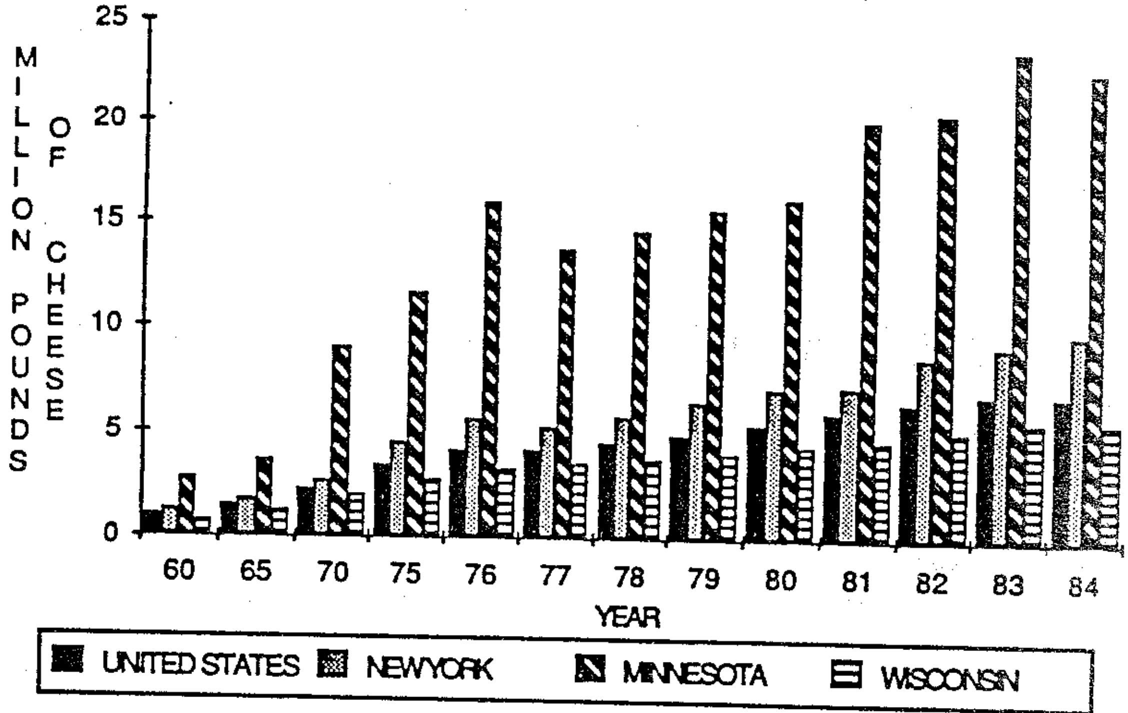
Source: Adapted from U.S. Department of Agriculture. Dairy Products - Annual Summary, Crop Reporting Board, Statistical Reporting Service, (selected issues).

Figure 1. Change in the Number of Cheese Plants in the United States, New York, Minnesota, and Wisconsin (Selected Years 1960-1984).



Source: Adapted from U.S. Department of Agriculture. Dairy Products - Annual Summary, Crop Reporting Board, Statistical Reporting Service (selected issues).

Figure 2. Average Cheese Plant Production in the United States, New York, Minnesota, and Wisconsin (Selected Years 1960-1984).



Source: Adapted from U.S. Department of Agriculture. Dairy Products - Annual Summary, Crop Reporting Board, Statistical Reporting Service (selected issues).

operations produced an average of 22.4 million pounds of cheese per year, while New York plants produced an average of 9.8 million pounds, and Wisconsin plants 5.7 million pounds.

Reduction in the number of plants, regional shifts in production, and changes in the significance of cheese to the dairy industry, also have been accompanied by an increase in mechanization of the cheese operations and rapid adoption of new technologies. Implementation of labor-saving devices, or other cost-saving techniques, and the installation of modern, automated equipment have occurred during the last decade. Larger and highly automated plants have replaced many smaller and older plants. Cheese plants of a size not previously realized are being built or reported to be built in the near future in some regions of the country, specially in the North Central region and California. The increase in the size of the plants and the large investment cost of starting up operations have created a new economic reality for the cheese industry. Are the new, large plants taking advantage of a shift in the relative cost of labor and capital and experiencing larger economies of size than previously perceived? Or, are there other economic justifications?

OBJECTIVES OF STUDY

The primary objectives of this phase of the study were as follows:

(1) To estimate the costs of manufacturing Cheddar cheese in efficient plants in order to measure the cost effects of plant size, various

production technologies in use today, and different operating conditions.

(2) To provide the basis for future work aimed at analyzing new production technologies, especially reverse osmosis and ultra- filtration, as well as assessing the feasibility and probable impacts on plant costs of manufacturing some specialty cheeses in Cheddar plants.

METHODOLOGY

Methodological Considerations

Estimation of plant cost relationships has been done for many different products using different approaches. In general, cost estimation approaches fall into one of three broad categories: 1) descriptive analysis of accounting data, which mainly involves combining point estimates of average costs into various classes for comparative purposes, 2) statistical analysis of accounting data, which attempts to estimate functional relationships by econometric methods, and 3) the economic-engineering approach, which "synthesizes" cost relationships from technical engineering data on factor usages, factor prices and other estimates of the components of the cost functions.

Each method has its advantages and disadvantages. The computational procedures involved in the accounting data approach are straight forward and simple. The popularity of the descriptive analysis relies mainly on its use of actual data and the interest among plant operators in comparing their own cost experience to the experience of others. However, there are significant limitations to the accounting data approach. Differences among plants in record keeping and accounting classification, as well as differences in managerial efficiency, scale, production methods, input prices, degree of plant utilization and other conditions, make cross classifications and comparisons of limited value in determining the importance of individual cost-influencing factors.

The statistical analysis uses much of the same data as the descriptive analysis with the difference that the former tries to develop quantitative estimates of cost functions. Some of the weaknesses of the statistical method are: 1) the data limitations and defects which usually lead to biased estimates, 2) its inability to clearly isolate the effects of various cost-influencing factors (e.g. changes in scale or utilization of the plant), and 3) its extreme sensitivity to the functional form chosen for estimation.

The alternative to the descriptive and the statistical analysis of plant accounting data is to synthesize cost functions from engineering input-output specifications. This approach is known as the synthetic or economic-engineering analysis. It focuses exclusively on technical economies since input prices, managerial effectiveness and other factors can be held constant across all plants modeled. The technique allows for comparisons among systems where different physical and operational characteristics are standardized or varied systematically. For this reason, it is appropriate to the estimation of economies of size and the minimum efficient size plant. Moreover, the economic-engineering approach can be used for the analysis of efficient plants or systems that may not actually exist but which are achievable. This is very valuable for evaluating costs of new manufacturing techniques or variations of current operations. Some find objectionable the artificial aspect introduced with the synthetic approach. The probability that operational efficiencies may be influenced by unidentified factors which are not evenly distributed among plants is another shortcoming of this method. The technique is also more sensitive to omitting some costs because they are never identified. This should lead to caution in the use of final results. However, the main strength of the estimates still lies in their comparability.

Given the objectives of this study, especially in determining the effects on costs of different plant sizes with various operational procedures and technologies, the economic-engineering approach was chosen to estimate production costs.

Overview of Research Methodology Used

The major objective of the work reported herein was to estimate the costs of manufacturing Cheddar cheese in efficient plants in order to measure the cost effects of plant size, various production technologies in use today, and several operating conditions. The data and insights obtained in the survey of 11 actual plants[1], together with the input of an engineering consulting firm (Mead & Hunt Inc, Madison, Wisconsin), provided the basis for using the economic-engineering approach. A large number of hypothetical plants were modeled to provide the needed cost budgets and cost comparisons. The model plants also provide the basis for the future work planned in the overall Cheddar cheese production research.

Using the economic-engineering approach, a total of 783 plants were budgeted to determine the production costs of different systems. Five cheesemaking technologies - standard cheddaring, standard stirred curd, automatic cheddaring, advanced stirred curd, and advanced cheddaring - were considered. Also three hooping/packaging technologies--regular 40-pound, 640/40-pound and cutting line, and block former--were studied. These production technologies were integrated into six different plant sizes operating with nine different daily and weekly production schedules.

As applied in this study, the economic-engineering technique consisted of three steps. First, a careful investigation of the production process was done to construct a flow diagram of the operation. The plant was divided into operating centers which are easily identifiable. The selection of a matched group of these operating stages or centers, which in the aggregate form a full-scale

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[1]Jens K. Mesa-Dishington, R. D. Aplin and David M. Barbano, "Economic Performance of 11 Cheddar Cheese Manufacturing Plants in Northeast and North Central Regions", A.E. Res. No. 87-2, Department of Agricultural Economics, Cornell University, Ithaca, NY, January 1987.

cheese plant, was a matter of both logic and convenience, depending on the importance of the individual operations and how they fit into the overall flow of products and materials.

In the second step, the different methods of performing the operations at each center were identified and selected. Then the cost of processing activities for each individual center were estimated. When the functions in one center could be performed in several ways, the cost of each alternative was estimated separately. The cost for each operating center or stage was calculated at different output rates for the whole range of plant sizes considered in the study. At each specified volume, it was then possible to identify the least-cost technology associated with each center.

In the third step, the costs from each center were summed along with certain overall cost components not associated with specific stages. That total, on a per unit of production basis, represents the total average cost for each plant. Selecting the minimum total average cost for processing each specified volume of production provided the data to form the long-run average cost curve for the industry.

OPERATING CENTERS

A flow diagram for the production of Cheddar cheese is presented on a processing center basis in Figure 3. The boxes represent manufacturing centers and the arrows indicate the path followed by the production process. Additional plant operating centers that support the cheese production process were also considered. They include the laboratory, dry storage room, refrigeration, maintenance and boiler room, cleaning (CIP), waste treatment room, water well, offices, lockers and restrooms, and lunch room.

Raw milk arrives at the plant in bulk tank trucks. It is tested, weighed and then held in temporary storage in the milk silos. When milk is needed for processing, it flows from the silos to a treatment area where it passes through the high-temperature, short-time pasteurizer (HTST).

Pasteurized milk is filled into cooking vats in the cheesemaking center. The formal cheesemaking process begins at this point. Two production routines, presented in Figures 4 and 5, indicate the individual steps that are performed sequentially in a timely fashion to manufacture Cheddar cheese. Production procedures are strictly followed, and the duration of each step is very consistent from vat to vat within a plant. Time differences at different stages occur among plants which are determined by technology, specification of equipment used, and manufacturing practices in each cheese operation.

Starter is added to the pasteurized or heat-treated milk soon after the filling of the cheese vat is initiated. Starter culture is added to form lactic acid in the milk which is the first important factor in controlling the moisture in the curd and the texture of the cheese. Shortly after the vat is filled, cheese color and calcium chloride ($CaCl_2$) may be mixed into the vat, and rennet is added to set the milk.

Figure 3. Flow Diagram for the Production of Cheddar Cheese.

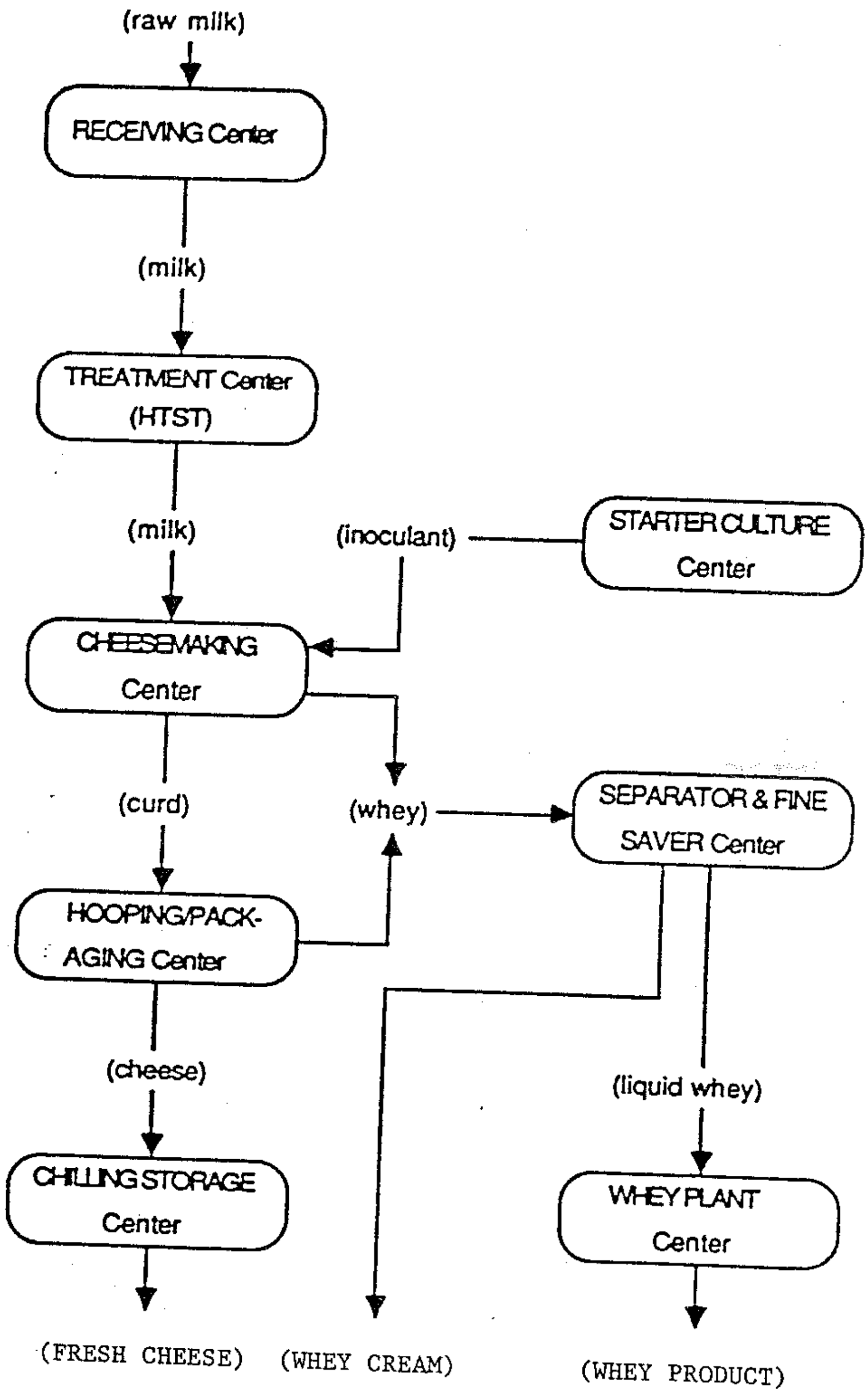
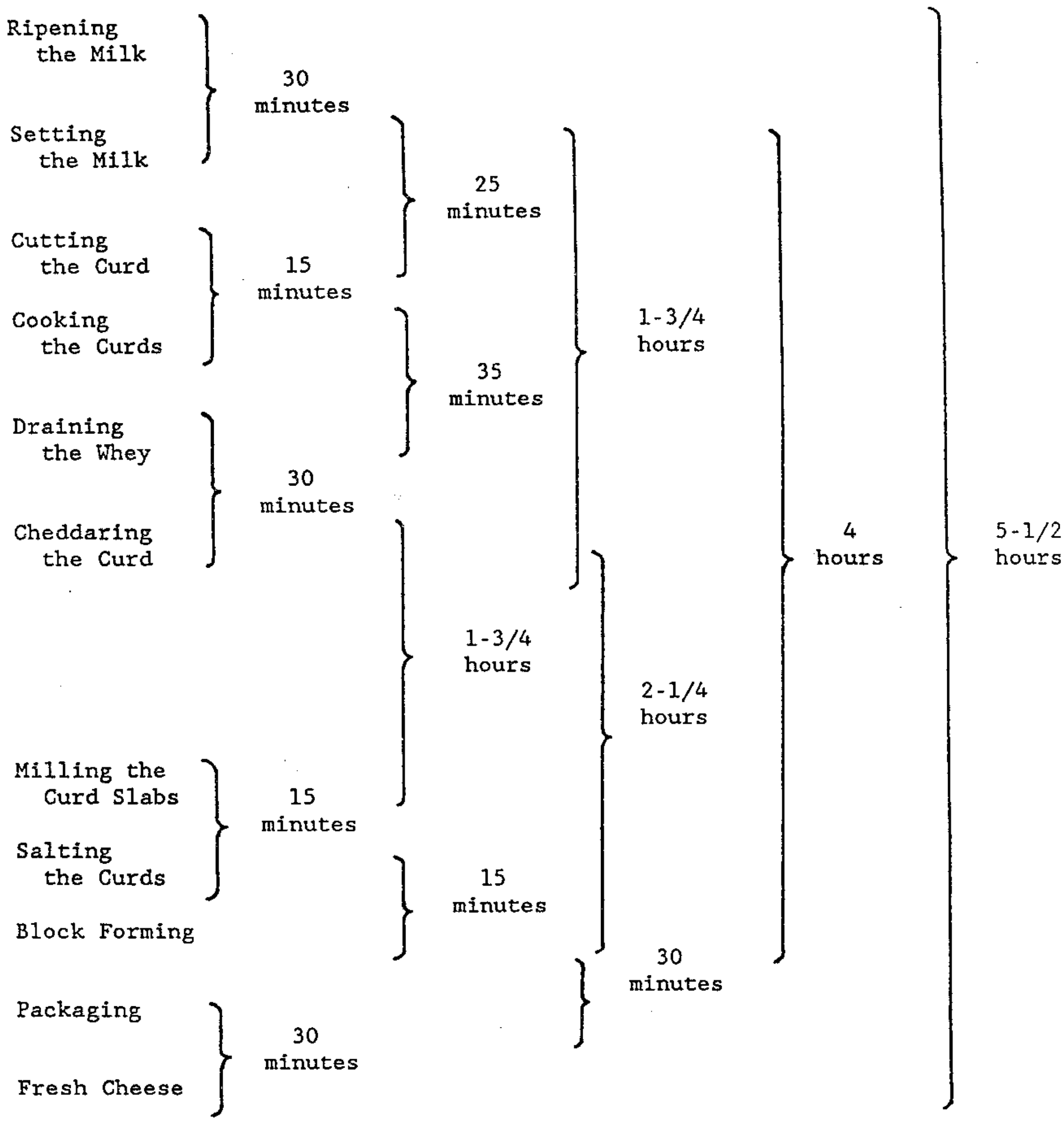
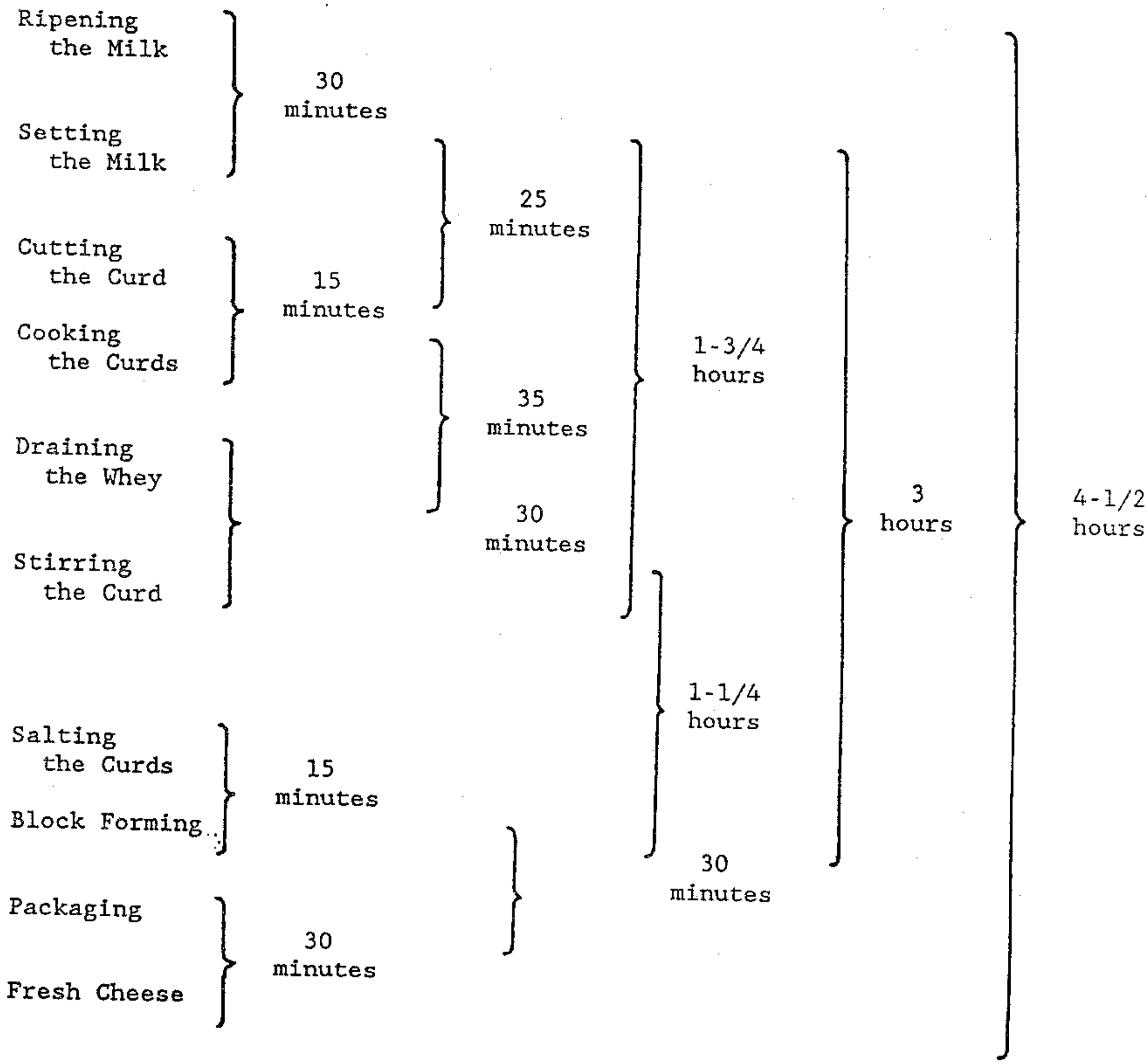


Figure 4. Time Schedule for Making Cheddar Cheese from Pasteurized and Heat Treated Milks Using a Cheddaring Process.



Source: Adapted from observed current manufacturing practices; Kosikowski, 1982; Lilwall, 1971; and Wilster, 1964.

Figure 5. Time Schedule for Making Cheddar Cheese from Pasteurized and Heat Treated Milks Using a Granular or Stirred Curd Process.



Source: Adapted from observed current manufacturing practices; Kosikowski, 1982; Lilwall, 1971; and Wilster, 1964.

When the curd has the proper consistency or firmness, it is cut to allow the whey to escape from it. The smaller the pieces of curd, the faster the whey escapes. The cutting process is the second important step in controlling the amount of moisture in the curd. After cutting, the curd is allowed to heal and then is gently stirred. Cooking or heating the curd follows to promote whey removal and continues until the cubes become sufficiently firm. When this process is finished, dipping or draining of the whey begins.

Soon after that, the curd and some of the whey are transferred either to enclosed salting finishing vats, open finishing tables or to automatic cheddaring machines. The cooking vats are then rinsed and prepared for another batch. Regardless of the technological system that is used at a particular cheese plant, the manufacturing process always flows at the same pace to allow for a smooth and continuous operation and a consistent product.

If Cheddar cheese is made by the stirred curd process, both the stirring and the salting of the curd are done in end-door finishing vats or in enclosed salting finishing vats (EFVs).[2] If the cheese is manufactured from cheddared curd, the curd is matted, cheddared, and milled using different methods. The milled curd may need to be moved to finishing vats where it is stirred and salted, depending on whether the cheddaring system operates in a two-tier or a three-tier system.

Once the proper acidity has been developed in the curd during either the stirred curd or the cheddaring process, the curd is salted and placed in hoops. Next, the hooped curd is transferred to presses. If the plant uses a block former instead of hoops, the milled and salted curd is pumped to the block former(s) located at the end of the cheese processing line. After the curd is hooped (or formed) and pressed, the blocks of cheese move to the packaging area where they are sealed in plastic bags under high vacuum and placed in rigid cardboard boxes. The cardboard boxes of fresh cheese are placed on pallets and then moved to the chilling storage room so that the cheese can be rapidly cooled. After about ten days, the cheese is moved into warmer refrigerated storage for curing or for shipping to market as fresh Cheddar cheese.

Unseparated whey goes through a fine saver unit and then it can be separated. Whey collected from the manufacturing process is passed through a separating center where fat is removed from the whey as whey cream. Then, the whey cream is pasteurized, cooled, and used in other operations or sold. The finished whey product is determined by the type of whey processing equipment available at the plant and the market conditions for different whey classes.

Several whey processing options are available to manufacturers. The most significant are: condensing to produce condensed whey (40% solids); partially concentrating to produce partially concentrated whey (less than 40% solids); drying to produce powdered whey (grade A and animal feed); and fractionating by ultrafiltration to produce whey protein concentrate and lactose. After the processing of the whey is completed, the product is packaged and stored in readiness for shipment to market.

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[2]EFV is a trademark of Damrow Co.

EQUIPMENT TECHNOLOGIES

Fifteen different technological systems for cheese manufacturing and three processing systems for whey production are considered in the economic-engineering phase of this study. The characteristics of these systems are indicated in Tables 2 and 3. Basically, all cheese plants considered have the same operating centers with variations only in the cheesemaking center and in the hooping or block forming center.

Enclosed cheese or cooking vats are used in all the cheese operations modeled. The plants are assumed to operate smoothly and continuously so that when one cheese vat is full, another becomes ready for filling. This sequence continues all through the day's operation until the last vat is made.

Five different cheesemaking methods - standard cheddaring, standard stirred curd, automatic cheddaring (i.e. DMC), advanced stirred curd (i.e. EFVs), and advanced cheddaring (i.e. Alf-o-matic) - are considered together with three hooping or block forming procedures - regular 40-pound block, 640-pound block with conversion to 40-pound blocks, and continuous block former - to form the total range of systems included in the study (Table 2).

The standard cheddaring system is a two-tier system and a labor intensive cheese production method. The curd is transported from the cooking vats to open tables, where it is cheddared, milled and salted by hand (working over the sides of the tables).

The standard stirred curd system is also a two-tier system. The curd is pumped from the cheese vats to open finishing vats equipped with an overhead traverse and rotating agitators. Curd is stirred continuously instead of cheddared. Salt is then added to the curd when it has developed the proper acidity and both are mixed well.

Automatic cheddaring is a three-tier system and a more automated cheddaring procedure. Curd is placed on a draining matting conveyor machine (DMC)[3] with two moving belts. As the upper belt travels, whey drains off continually through the belt and the curd mat begins to form. When the mat reaches the end of the top belt, it is picked up, upside down, on the lower belt, where the last whey is drained off. During this time, curd temperature is maintained and the starter culture is producing acid. As the mat of curd arrives at the discharge point on the lower belt, it is cut to a desired size in a reciprocating drum type curd mill. The milled curd then is blown to a finishing table to be salted.

An advanced stirred curd system is a two-tier system that uses automated enclosed salting finishing vats (EFVs) rather than open finishing tables. The stirring and salting of the curd is also done in the same vat.

Finally, the advanced cheddaring system is a two-tier continuous production system. Curd is pumped to an Alf-o-matic machine[4] with four conveyors assembled above each other that drain, mat, mill, and salt the curd.

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[3]Trademark of Damrow Co.

[4]Trademark of Alfa-Laval AB.

Table 2. Characteristics of Selected Technological Systems for Model Cheddar Cheese Plants.

System	(#)	Enclosed Cooking Vats	Cheddaring Tables	DMC	Alf-o-matic	Open Finishing Tables	Enclosed Finishing Vats	Hooping
Standard Cheddaring								
	1	x	x					Regular 40#
	2	x	x					640/40# Cut.
	3	x	x					Block Former
Standard Stirred Curd								
	4	x				x		Regular 40#
	5	x				x		640/40# Cut.
	6	x				x		Block Former
Automatic Cheddaring								
	7	x		x		x		Regular 40#
	8	x		x		x		640/40# Cut.
	9	x		x		x		Block Former
Advanced Stirred Curd								
	10	x					x	Regular 40#
	11	x					x	640/40# Cut.
	12	x					x	Block Former
Advanced Cheddaring								
	13	x			x			Regular 40#
	14	x			x			640/40# Cut.
	15	x			x			Block Former

Three methods of hooping or forming the cheese are considered in the economic-engineering phase of the study. In a regular 40-pound block line, a hoop filler is used to place curd in stainless steel hoops which are then put in a press to solidify the cheese and drain the final whey. The blocks of cheese are removed from the hoops, vacuum sealed in plastic bags and placed in cardboard boxes.

In a 640-pound block line, curd is pumped into stainless steel hoops, pressed, placed in a vacuum chamber, inverted and sealed and then moved to a chilling room. Five to ten days later, when the cheese has cooled, it is converted to 40-pound blocks. After being cut into 40-pound blocks, the cheese is moved to an area to be vacuum packaged in plastic bags and placed in cardboard boxes for aging or shipping to market.

With a continuous block forming method, 40-pound blocks are formed without hoops in a 40-pound block forming tower. Curd is drawn by a vacuum to the top of the tower. In the tower the curd begins to fuse under gravity and forms a continuous column of solid cheese. Regular blocks are automatically lowered, guillotined and ejected for the final stages of sealing and packaging. This process is used to reduce labor costs and make very uniform block sizes that reduce trim losses when the cheese is cut down to retail sizes.

Although the costs of whey systems were not budgeted in this study, initial capital investments were budgeted for two different whey plants with three different whey processing methods: condensing, partially concentrating, and drying. Another whey plant with a fractionating by ultrafiltration system (to produce whey protein concentrate and lactose) will be considered. The costs of all three whey systems will be reported in later publications on this research. The first whey plant system produces condensed (40% solids) and partially concentrated whey (less than 40% solids). And the second system has the alternative to produce condensed, partially concentrated, and grade A powder whey.

Table 3. Whey Products Manufactured by Two Model Whey Plant Systems.

Whey Plant System	Condensed Whey	Partially Concentrated Whey	Grade A Powder Whey
System 1	x	x	
System 2	x	x	x

PLANT SIZES

With but one exception, six different plant sizes were considered for each one of the 15 cheese processing systems. The one exception was the advanced stirred curd cheesemaking technology for which only five of the six sizes were considered. The largest size plant studied was not modeled for this particular technology.[5] Thus, a total of 87 different basic cheese plant designs were considered.

The cheese plant sizes selected were: 480,000; 720,000; 960,000; 1,440,000; 1,800,000; and 2,400,000 pounds of milk per day. These volumes represent the capacities of the plants, that is the maximum volume of milk the plant can handle in a 24 hour day with an 18.5 hours fill time. These plant sizes were chosen to satisfy some specifications of the cheese vat rooms of the model plants. Initially, the size and the number of vats in the cheesemaking center were selected to allow a constant number of filling times per vat per day for the different size plants. Later on, some of these characteristics of the vat areas of some plants were altered for different cheesemaking technologies based on recommendations from equipment manufacturers and the consulting engineers to ensure proper plant operation and timing. The plant sizes stayed the same, but the number of filling times per vat per day is not the same across plant sizes with the changes in number and size of the vats for some selected plant systems. As a result, the cheese plants in the study are more realistically modeled than if the original assumptions had been kept, and the processing equipment is integrated in their most efficient way. Differences in the number of filling times per vat per day from one plant to another also were observed in the plant survey reported in the companion publication.

The pasteurizers for the cheese operations have different capacities in the different size plants. The flow rates of the pasteurizers have been selected to process the capacity of each plant in 18.5 hours. Thus, the larger the plant, the faster the filling rate needs to be to meet the daily production goals.

Milk silo holding capacity for the model plants is equal to the daily capacity of the plant (i.e. a cheese operation was assumed to be able to hold milk sufficient for one day's production). This raw milk holding capacity provides enough flexibility for the management to organize its production schedules in accordance with the seasonal changes in the supply of milk. Cheese plants can schedule throughout the day that portion, if any, of milk receipts arriving from milk transfer stations. Also, the cheese operations eventually can transfer to other plants some milk that is not needed for cheese processing.

The model cheese plants provide cheese storage capacity in the chilling room for ten full production days. This is assumed to be sufficient for a cheese plant operating under normal conditions. <u>Any additional required storage space is considered to be part of the marketing function rather than</u>

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[5]At the time of their study, enclosed salting finishing vats (EFVs) were manufactured in one capacity, 4,000 pounds. This technical constraint limited the number of alternatives available for the cheese vats to be combined with this system. The maximum recommended capacity for the cheese vats in stirred curd plants using EFVs is 40,000 pounds of milk. Thus, the largest size plant considered in this study, 2,400,000 pounds of milk per day, was not appropriate for this processing technology. Today, EFVs are available that can handle more than 4,000 pounds of curd.

the cheese production operation. Therefore it is not considered in this study of manufacturing costs. Cheese aging, retail cutting and packaging, or special sales arrangements with some customers (e.g. the CCC) are viewed as marketing activities. To have a clear comparison of plants, these marketing expenses, determined by specific conditions at each plant, need to be kept separate from the production costs.

The laboratory facilities in the model cheese plants can perform all the testing required for good control of the manufacturing operation. Milk, whey, and cheese are tested for every vat manufactured at the plant. Additionally, producer milk testing and waste treatment water testing are assumed to be done periodically at the model cheese plants.

PRODUCTION SCHEDULES

Nine different production schedules were considered for each plant design. These were obtained by combining three different days-per-week sched- ules with three different hours-per-day schedules.

The three different weekly production schedules were 7-day, 6-day, and 5-day. The three daily production options were 24-hour, 21-hour, and 18-hour. None of the selected production schedules required changes in the specifications of the modeled plants. It was assumed that shorter work weeks or shorter days are imposed by a shorter supply of milk or lack of sufficient market for cheese. Cheese operations are designed to hold, without any problem, the peak supply of milk reaching the plant during the year. When there is a reduction in the milk available, the plant can adjust manufacturing by reducing the number of days per week or the number of hours per day of operation, so that both the weekly and the daily production schedules repeat very similarly for a period of time. In general, these types of adjustments are made at cheese plants periodically and for a certain number of weeks, in order to adequately schedule and plan labor requirements.

During periods of shorter milk supplies, usually some production capacity remains idle at most plants. If a cheese plant were to continue running long days, it needs to compensate for that with a down-day(s) during the week. In that way, it can spread the volume of milk received during the down-day throughout the following operating days. If the plant needs to have a second down-day during the week, the two down-days are not likely to be consecutive days. Separating the down-days more evenly distributes the milk receipts and the uses of milk at the plant.

Plants working a 24-hour day schedule have a total milk filling time of about 18.5 hours. This allows for sufficient time to finish up the last vat of cheese for the day and to do an adequate cleaning job at the plant. Similarly, the total milk filling time in a 21-hour day and in a 18-hour day schedule is approximately 15.4 hours and 12.3 hours, respectively, with a fixed time used for cleaning in all plants.

COST ESTIMATION

Introduction

The money costs involved in processing Cheddar cheese are a function of the physical quantities of the resources used and the prices which must be paid to obtain these production factors. A successful application of the economic-engineering or synthetic cost estimating technique needs specific and detailed information on the technical input-output relationships of production and on the prices of the resources used in the manufacturing process.

Assumptions on the raw material, the process, and the final product used in modeling the Cheddar cheese manufacturing operations are presented in this section. These assumptions were required to make the production cost estimates comparable among different systems and size plants. The sources of information used in the cost estimation procedure also are identified. Later, each one of the Cheddar cheese production cost components are described with some of the resource requirements and their cost calculations.

Assumptions

This study, among other things, estimates Cheddar cheese production costs and compares the costs for different systems and plant sizes. For this reason, some assumptions that apply to all the model plants must be made in order to allow for comparability of the final results.

Milk received at the cheese plants is assumed to be of good quality and with the same composition for all plants so that initial production conditions for cheese manufacturing are the same for the model plants. Any seasonal variation in milk composition affects the components of the milk received at the plants similarly.

Actual plants can usually stretch normal production practices in periods of excess supply by slightly shortening the cheese making time or running more hours at the expense of cleaning time. None of those situations is considered here. The model plants in the study operate with consistent making and cleaning times for any production schedule or external conditions affecting the cheese operations.

Cheesemaking performance as regards fat recovery, yield efficiency, and product characteristics is assumed to be similar for all technological systems and size plants. No significant plant-to-plant differences in Cheddar cheese fat recovery or Cheddar cheese yield efficiency exists among the model plants. The finished, fresh cheese produced by all plants is 40-pound block, high-moisture (37-38%) Cheddar cheese, and its quality and composition are the same regardless of the volume of production or the technology used.

Whey cream is sold in bulk and moved out of the plant periodically. Although whey cream is an important source of additional revenue to the plant, no value is credited to the cheese production process in order to identify the total magnitude of Cheddar cheese net production costs. In the case of the model plants it would be constant because the same milk composition and cheese fat recovery is assumed in all plants. Likewise, separated liquid whey is transferred without cost to a whey plant for further processing.

For the analysis, the costs of processing separated whey are not considered. Whey processing is viewed as a separate operation and no revenues are credited or costs charged to the cheese manufacturing process. However, the initial investment required by two whey plant systems are determined and reported.

Each of the model plants has storage capacity equivalent to 10 days' production. This 10-day chilling storage is to provide for rapid cooling of the cheese immediately after manufacture. Storage capacity for aging of the cheese is not provided in the model plants. The aging of cheese is viewed in this study as part of the marketing function--not as part of the production function. As illustrated later, the provision for an aging cooler would add significantly to the construction costs of the plants.

The office center in each model plant contains only those offices and related areas that are necessary for the management and supervision of the operation of the plant. The terms conservative and functional may best describe the interior and exterior decoration of the office space provided in the models. In reality, the expenditure of millions of dollars for a new facility will, in general, attract corporate level offices with their higher construction costs. As these costs can significantly increase the cost of the total structure, but have no effect on production efficiency, they are not reflected in the plants modeled.

Data Sources

The necessary data to estimate the processing costs were obtained from various sources. Mead & Hunt Inc. of Madison, Wisconsin, an engineering consulting firm with extensive experience in the Cheddar cheese industry, provided technical coefficients and some specific price information on land, building structure, production equipment, labor requirements, utility demands, and other expenses in Cheddar cheese plants. Prices and specifications on major equipment were obtained by the consultant engineers from equipment manufacturers. These were used by the consulting firm to make some of their recommendations for the model plants.

Information collected from the 11 actual Cheddar cheese plants studied in the earlier phase of the research was used to prepare general plant specifications, to determine several cost assumptions, and to assess the reasonableness of the labor and other cost estimates for the model plants. One of the junior authors estimated the production and laboratory materials for the model plants. The technical and price information obtained from the engineering consulting firm was reinforced by closely monitoring and discussing the results with the engineers and comparing their design and cost information to that actually observed in the cheese plant survey. Industry suppliers provided prices on production materials and on other expenses (e.g. cleaning) at cheese plants. Finally, plant managers also made a contribution in this phase of the study, providing miscellaneous information on various aspects of the manufacturing process. By and large, the technical coefficients and cost information used in costing Cheddar cheese production were newly developed for this research.

Land, Building, and Equipment Costs

Land requirement factors for each size model plant were estimated based on the building areas and the car parking, truck parking, and turn-around areas of average operations. Since land requirements in actual cheese operations usually do not change proportionally to the building area or the size of the plant, separate land factor estimates were calculated for each size plant. Land for a waste treatment facility operated by the cheese plant was not considered in these factors. The land estimates in square feet were converted to acres and divided by the building area to obtain land input factors per 10,000 square feet of plant building area. The estimated input factors used in computing the land requirements for the different selected model plants are given in Table 4. Land purchase costs were assumed at $30,000 per acre or about $0.69 per square foot. An additional cost of $29,800 per acre of land was considered for rough and finish grading, paving, landscaping and the underground electrical, plumbing, gas, sewer utilities, and engineering fees required at the cheese plant site.

Table 4. Land Requirement Factors for Model Cheddar Cheese Plants of Different Sizes.

Plant Size	Land Factor[a]
(Pounds of Milk per Day)	
480,000	1.813
720,000	1.577
960,000	1.557
1,440,000	1.431
1,800,000	1.403
2,400,000	1.298

[a] Land acres per 10,000 square feet of building area.

Building areas were calculated by the consulting engineers based on the size of the equipment in each center and on other specifications from equipment manufacturers.

The building areas of some selected model Cheddar cheese plants are presented in Table 5. Building costs were based on floor-space require- ments. The costs included engineering fees, electrical, plumbing, pneumatic, refrigeration, structural, and ventilation aspects of each center. Construc- tion costs and ceiling heights for each operating center are given in Appendix Table A1.

All of the plants modeled for this study used the following structural materials. Insulated concrete blocks were used for the exterior walls; concrete block for the interior walls; reinforced concrete foundation and floor slabs, and pre-cast flatslab and prestressed concrete double-tee's for ceilings and roof surfaces with structural steel beams and columns for support as required. Floor brick set in acid resistant grout bed, and glazed tile wall covering were used for the process areas. The roof used was a ballasted EPDM (rubberized) roofing system installed over rigid insulation. Epoxy painting for washable wall finish was used throughout except where glazed tile wall coverings were used or in unpainted mechanical rooms.

A list of major and minor equipment was prepared for every center and every technology considered in the study. The selected equipment was integrated in the most efficient way for each model plant according to equipment manufacturers' and consulting engineers' recommendations. Some of these equipment specifications are listed in Table 6. All plants were modeled using modern, present-day automation, where needed.

The process controls included in the model plants were based on the use of programmable controllers. A control system based on programmable controllers had a level of sophistication that was applicable to all model sizes being studied, and was modular which allowed the cost to be more accurately assigned to the proper centers within each model plant. With this type of system in place within the model plants it would be possible to unify the modules of control under the direction of a computerized system, with little or no change in the existing equipment.

Although the hardware cost for computer systems can vary, there is an even greater variance in the degree of complexity in the software packages that can be used in identical systems, which makes generalizing the costs extremely difficult. The additional costs for computerizing a plant depend on what other tasks, in addition to process control, the computer would be required to accomplish. No superautomation (e.g. remote control) was considered in the cheese operations and all the controls could be overridden manually.

Equipment costs reflect fall 1985 prices and they included engineering fees, equipment delivery and installation costs. No allowance was made for special discounts. A summary of the equipment investment cost by center is provided in Appendix Table A2.

Capital Investment Costs. The initial capital investments for a group of selected model Cheddar cheese plants are presented in Table 7. As described earlier, the investment costs include those in land, building and equipment for production only. Although provision is made for 10 days of chilling storage, storage for aging is not provided, as aging was considered to be part of marketing. As illustrated in Table 8, the provision for an aging cooler would add from 25% to 50% to investment costs.

The investment costs in Table 7 do not include the investment required for whey operations. Nor do the cheese production costs reported in this publication reflect whey operations. However, the investments for different whey systems are reported in Table 9 to illustrate the potential overall investment in cheese and food grade whey operations. These costs are also large, equalling 41% to 52% of cheese processing investment for the whey condensing operation and 78% to 92% for condensing and powdering. The amount whey processing adds relative to total investment declines with plant size.

Table 5. Building Areas for a Selected Group of Model Cheddar Cheese Plants of Different Sizes[a].

Plant Type	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Square Feet)					
Standard Cheddaring with Reg. 40# Hooping	19,624	24,905	27,795	37,461	42,223	52,125
Standard Stirred Curd with Block Former	19,222	24,152	27,108	36,211	41,043	50,082
Automatic Cheddaring with 640/40# Cutting	25,632	32,172	35,530	45,509	51,399	60,842
Advanced Stirred Curd with Block Former	19,233	23,811	26,633	35,856	41,802	n.a.
Advanced Cheddaring with Block Former	19,415	24,393	27,483	35,668	40,947	49,369

[a] Do not include whey operation.

n.a. = not applicable

Table 6. Selected Equipment Specifications for Various Technological Systems Used in Model Cheddar Cheese Plants of Different Sizes.

	Plant Size (Pounds of Milk per Day)					
Technology and Equipment	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
Cheesemaking:						
a) Standard Cheddaring:						
Enclosed Cheese Vats[a]	4/30,000	4/40,000	4/50,000	6/45,000	6/50,000	8/50,000
Open Finishing Vats[b]	4/3,000	4/4,000	4/5,000	6/4,500	6/5,000	8/5,000
b) Standard Stirred Curd:						
Enclosed Cheese Vats[a]	4/30,000	4/40,000	4/50,000	6/45,000	6/50,000	8/50,000
Open Finishing Vats[b]	4/3,000	4/4,000	4/5,000	6/4,500	6/5,000	8/5,000
c) Automatic Cheddaring:						
Enclosed Cheese Vats[a]	4/30,000	4/40,000	4/50,000	6/45,000	6/50,000	8/50,000
DMC[c]	44'/76'	56'/100'	68'/124'	64'/117'	68'/124'	68'/124'
Open Finishing Vats[b]	2/3,000	2/4,000	2/5,000	3/4,500	3/5,000	4/5,000
d) Advanced Stirred Curd:						
Enclosed Cheese Vats[a]	4/30,000	4/40,000	4/40,000	6/40,000	8/40,000	n.a.
Enclosed Salting Finishing Vats[b]	3/4,000	3/4,000	3/4,000	5/4,000	6/4,000	n.a.
e) Advanced Cheddaring:						
Enclosed Cheese Vats[a]	6/20,000	6/26,000	6/35,000	6/50,000	7/50,000	8/50,000
Alf-o-matic[d]	3,000	4,000	5,500	8,500	10,000	13,500
Hooping/Packaging:						
a) Regular 40# Hooping:						
40# Hoops[e]	350	525	700	1050	1325	1750
b) 640/40# & Cutting Line:						
640# Hoops[e]	426	636	850	1272	1590	2118
c) Block Former:						
Wincanton Towers[e]	2	3	4	6	7	9

a Number of vats/size of each vat in pounds of milk.
b Number of vats/size of each vat in pounds of curd.
c Equipment length/belt length.
d Pounds of curd per hour.
e Number of units.
n.a. = not applicable

Table 7. Total Initial Capital Investment for a Selected Group of Model Cheddar Cheese Plants of Different Sizes.

Note: Includes investment in land, building and equipment for production only. Does not include investment in storage for aging, whey operation or organizational office space (just production office space).

Plant Type	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Dollars)					
Standard Cheddaring with Reg. 40# Hooping	4,095,000	4,758,000	5,326,000	6,867,000	7,748,000	9,474,000
Standard Stirred Curd with Block Former	4,248,000	5,028,000	5,708,000	7,384,000	8,396,000	10,183,000
Automatic Cheddaring with 640/40# Cutting	5,486,000	6,367,000	7,150,000	8,895,000	10,174,000	12,213,000
Advanced Stirred Curd with Block Former	4,423,000	5,118,000	5,760,000	7,559,000	8,905,000	n.a.
Advanced Cheddaring with Block Former	5,049,000	5,776,000	6,542,000	8,019,000	9,198,000	10,884,000

Table 8. Total Initial Capital Investment for Provision for Six Months of Aging Storage in Model Plants[a]

Note: These costs for aged storage are not included in model plants or in cost estimates reported in this publication.

Cheese Plant Size (Pounds of Milk Per Day)	Investment Required For 6-Months Aging Storage (Dollars)
480,000	$1,068,000
720,000	1,603,000
960,000	2,137,000
1,440,000	3,205,000
1,800,000	4,007,000
2,400,000	5,342,000

[a] Assuming 10% cheese yield.

In considering the model cheese plant investment costs, also recall the following. The plant is constructed to be economically functional for the long term, yet not plush. Functional plant production office space is provided, but not space for an organization's headquarters. The control system is rather highly automated, but not superautomated (e.g. remote control). A metering/monitoring manhole is provided for BOD tests, suspended solids tests and flow measurement to verify discharge volumes. However, no provision for the pretreatment of sewage is included in the modeled plants.

An annual charge was made on the initial capital investments at each model cheese plant to account for depreciation and capital costs. Three different categories of capital investment were considered in calculating these costs: land, building, and equipment. The cost of capital that would be tied up in constructing the plants also was considered. In this regard, the following assumptions were made: the land would be purchased two years before the plants would be operational; 30 percent of the sitework and structure costs would be incurred 18 months and 70 percent one year before plant opening; and the equipment would be purchased six months before the plants became operational.

Annual land cost was assumed equal to the opportunity cost of the money needed to purchase the land. The opportunity cost of money was estimated using a 6 percent real interest rate. No appreciation or depreciation of the land value was considered during the life of the investment.

Table 9. Total Initial Capital Investment for Selected Whey Processing Plants Modeled to Match Cheddar Cheese Plants of Different Sizes.[a]

Note: These costs for whey plants are <u>not</u> included in model plants or in cost estimates reported in this publication.

Whey Plant System	Cheese Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Dollars)					
Condensed Whey	2,442,000	2,817,000	3,050,000	3,526,000	3,863,000	4,382,000
Condensed and Grade A Powdered Whey	4,273,000	4,912,000	5,413,000	6,220,000	7,017,000	8,295,000

[a] Includes investment in land, building, and equipment. The model operations are to process food grade whey products.

The initial investment for the building and the costs of the work on the plant site were annualized over the operating life of the building, using present value techniques and assuming a 6 percent real interest rate. This procedure captures the expected economic depreciation of the assets and the cost of the money tied to that investment. The useful life of the building for a plant operating at 100 percent capacity was assumed to be 25 years with no salvage value. The operating life of the building was allowed to change with the utilization of the plant so that the expected life increased with lower plant utilizations. A maximum of 35 years was permitted on the useful life of the building to allow for the likelihood of obsolescence. An example of the various operating lives of the building and equipment for different levels of lant utilization is given in Table 10.

Table 10. Expected Life of Building and Equipment of Model Cheddar Cheese Plants for Selected Levels of Plant Utilization.

Assets	Plant Capacity Utilization 100%	80%	60%	40%
	(Years)			
Building	25	30	35	35[a]
Equipment:				
Group 1	5	6	7	8
Group 2	10	12	14	15[a]
Group 3	15	15[a]	15[a]	15[a]

[a] Assumed maximum expected life to allow for obsolescence.

Repair and Maintenance. Repair and maintenance expenditures in manufacturing operations vary according to the intensity of use, policies of individual firms toward maintenance, the original quality of the building or equipment and other factors. Repair and maintenance costs were estimated by the consulting engineers for the building and equipment of the model Cheddar cheese plants separately. The consultants determined factors for each piece of equipment and the building area in each center.

Data on actual structural maintenance costs were gathered by the consulting engineering firm from a significant number of cheese operations of sizes approximating the ones used in this study. The estimated average cost for building and maintenance was $0.6033 per square foot per year. This cost was broken into a fixed and a variable element to make the maintenance cost calculations for the model plants.

Equipment maintenance costs were estimated based on the cost and the useful life of the equipment. Although they differed for each piece of equipment, the maintenance costs for the equipment were all considered variable with the volume of milk processed at the plant. An example of building and equipment repair and maintenance costs for a selected group of plants are presented in Appendix Table A3.

Insurance. The insurance for the model cheese plants includes fire insurance and extended coverage on building and equipment. The insurance costs per year were estimated using an average rate of $4.60 per $1,000 of building and equipment values. The building and equipment values were considered to be 85 percent of the initial capital investments in these assets.

Property Taxes. Rates for property taxes vary by city, township, and state. An average rate of $35 per $1,000 of market value of land, building, and equipment was used in determining the annual property taxes for each plant. The market values for the land and the buildings were obtained taking 100 percent of the initial investment costs, while the market value considered for the equipment was only 50 percent of that cost.

Salaries, Wages, and Labor Costs

Labor requirements in Cheddar cheese plants vary considerable depending on cheesemaking technology, plant layout, labor management practices, and other factors. Very little detailed labor information on Cheddar cheese plants is published. Labor requirements for the model plants in this study were determined based on production times, making schedules, and other activities performed in each center of the plant. These labor estimates were established and evaluated by discussion with consulting engineers and a comparison with actual labor information provided by 11 Cheddar cheese plants surveyed in an earlier part of this study.[6]

Cheese plants have different policies on labor management. Some plants operate with a permanent amount of overtime and a smaller labor force, while others prefer to hire additional people to avoid overtime charges. Even though the physical labor requirements during the production process remain the same, these decisions have an impact on the number of employees needed at the plant. In general, the labor forces in cheese plants are flexible. Management can adjust fairly easily the number of people hired and their working schedules. Many plants also can layoff people most any time that is required. Full-time seasonal labor, part-time permanent and seasonal labor, longer and shorter work-weeks (e.g. 50-hour weeks vs. 40-hour weeks), are some of the choices available to the management of cheese plants to select and hire their labor.

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[6]Jens K. Mesa-Dishington, Richard D. Aplin, and David M. Barbano, "Economic Performance of 11 Cheddar Cheese Manufacturing Plants in Northeast and North Central Regions", A.E. Res. No. 87-2, January 1987, Dept. of Agricultural Economics, Cornell University.

Labor requirements at the model plants were budgeted on the basis of two major categories: supervisory labor and direct labor. Because this study only considered 18, 21, and 24-hour day production schedules, supervisory labor was assumed fixed per operating day. Supervisory labor includes the plant manager and one assistant per additional shift. Direct labor was estimated to have a fixed and a variable component. Direct fixed labor requirements were constant on a daily basis. It included the labor used in cleaning and setting the equipment as well as the labor for other activities that normally need to be done at the plant regardless of the volume of production. On the other hand, direct variable labor included all the other production and support labor in all the operating centers at the plant that were not classified either as supervisory labor or direct fixed labor. The variable labor was assumed to change proportionally with the volume of milk processed at the model plants. The labor requirements for a selected group of operations are given in Table 11.

This study assumed that the labor used and paid in the model cheese plants was equal to the actual labor requirements for those operations. No additional costs are charged for labor that is not needed and used at the plants. Also, any management decision on reorganizing or adjusting the labor force (e.g. increasing the length of the work-week instead of hiring additional employees) is assumed to have no effect on the average labor cost per hour. A flat wage rate of $9.00 per hour was used for all direct labor, which represents an average for the different wage categories and night and holiday premiums at the model cheese plants. In addition to the wage cost, it was assumed that the cheese plants had fringe benefit costs equal to 32 percent of the wages. Some of the direct fringe benefits and provisions included in this allowance are welfare fund, retirement fund, social security, life insurance, medical and dental expenses, unemployment insurance, sick leave, and paid vacation time. On average, supervisory labor cost was assumed to be 30 percent higher than direct labor costs plus an adjustment for plant size. The adjustment used was $0.20 per hour for every 100,000 pounds of daily milk capacity at the plant. Examples of average typical supervisory salaries for the model plants in the study are provided in Table 12.

Utility Costs

The principal utilities considered in the model Cheddar cheese plants were electricity, natural gas, water and sewage. Gas and electrical power requirements for each piece of equipment were determined by the consulting engineers from product data bulletins supplied by equipment manufactures. Where steam was used, the natural gas component of that steam production was included in the gas requirements for that center. Water consumption was calculated from known equipment flow rates and estimated usage rates. The data presented are for utility costs for the cheese plant only and do not include the whey plant.

Electricity. The electricity requirements for the model plants included a fixed and a variable component. The number of kilowatt hours of electricity were estimated per operating hour or per million pounds of milk for each operating center in each size plant. Electricity was charged at a flat rate of $0.06 per KWH. This unit cost estimate reflects an average cost for the 11 Cheddar cheese plants surveyed and commercial rates charged in New York. Using

Table 11. Daily Labor Hour Requirements for a Selected Group of Model Cheddar Cheese Plants of Different Sizes Operating with a 24-Hour Production Schedule.

Plant Type	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Hours Per Day)					
Standard Cheddaring with Reg. 40# Hooping	596	628	696	792	818	852
Standard Stirred Curd with Block Former	428	460	504	576	596	660
Automatic Cheddaring with 640/40# Cutting	428	436	480	516	560	588
Advanced Stirred Curd with Block Former	404	436	480	540	572	n.a.
Advanced Cheddaring with Block Former	416	448	492	552	572	612

n.a. = not applicable

Table 12. Average Salaries for Supervisory Labor in Model Cheddar Cheese Plants of Different Sizes.

Plant Size	Average Supervisory Salary
(Pounds of Milk per Day)	($/Year)
480,000	30,400
720,000	31,500
960,000	32,700
1,440,000	35,000
1,800,000	36,700
2,400,000	39,600

the flat rate to cover both the demand charge and the energy charge facilitates the summation of energy costs among operating centers. Also, using a flat rate avoids the question of which centers should pay the higher initial energy rates and which ones should pay the less expensive subsequent rates. A summary of the electricity requirements for a selected group of model plants is provided in Appendix Table A4.

Natural Gas. Natural gas was selected as the fuel for the model plants. Natural gas requirements were provided by center, when needed, as therms per operating day or therms per million pounds of milk. A flat rate charge of $0.50 per therm was made. This unit cost estimate was based on average costs for the 11 Cheddar cheese plants visited earlier in the study and on commercial rates charged in New York. Natural gas requirements for various Cheddar cheese plants are given in Appendix Table A5.

Water and Sewage. Water and sewage requirements were considered fixed on a daily basis for each center in every size plant. For the most part, water was used for cleaning the building and equipment at the plant every operating day regardless of the length of the processing day. The model plants were designed with their own water wells and no direct charge was made for water used. The capital investment costs and the operating expenses for the water well were included in other cost categories. On the other hand, a flat rate of $1.50 per 1,000 gallons of fluid disposed in the sewage system was made. This rate was determined based on average sewage costs of Cheddar cheese plants with new sewage contracts or with old sewage contracts that had been revised recently by the local municipalities.

Supply and Other Service Costs. Supply and other service costs include production, packaging, laboratory, and cleaning supplies as well as other expenses that together represent a significant fraction of the total Cheddar production costs.

Production Supplies. The production supplies for Cheddar cheese manufacturing considered in this study include calcium chloride, color, rennet, salt, and starter culture. The quantities of these materials used in estimating the total production costs were determined from standard acceptable manufacturing requirements. The estimated costs of the production supplies reflect 1985 prices and a shipping charge, but no allowance for special discounts. These costs were obtained from product suppliers and cheese plants located in the Northeast and North Central regions. A combined cost of production materials of $2.90 per 1,000 pounds of milk processed at the plant was used for budgeting costs. A breakdown of the production materials and their cost is provided in Appendix Table A6.

Packaging Supplies. The cheese blocks manufactured at the model plants are wrapped and sealed in plastic bags and then placed in corrugated cardboard boxes. The cost of these packaging supplies was estimated at $0.50 per 40-pound block of cheese. Additionally, the cost of the disposable cloth used to press the cheese in a regular 40-pound or 640-pound hooping system also was included as part of the packaging materials for the plants using those technologies. The estimated cost of the disposable press cloth was $0.08 per 40-pound block and $0.27 per 640-pound block of cheese.

Laboratory Supplies. Laboratory testing practices are variable among cheese plants. This study assumes plants with good manufacturing practices performing all the standard control and quality tests recommended in cheese operations. The model plants test for antibiotics, bacteria count, milk fat, milk protein, pH, whey protein, fat in unseparated whey, fat in separated whey, fat in whey cream, cheese moisture, cheese fat, and cheese salt. Laboratory tests are done on each load of raw milk arriving at the plant and on every vat of cheese manufactured. Laboratory tests performed at cheese plants are related more to the number of vats manufactured than to the total milk processed at the plant. The model cheese plants also keep laboratory records on the BOD tests of the fluids that are disposed in the sewage system. A separate factor to estimate the cost of the laboratory supplies was determined for every size plant. The estimated laboratory supply costs for the model plants are reported in Appendix Table A7.

Cleaning Supplies. The cost of cleaning supplies for the model plants was determined by the consulting engineers from information provided by suppliers based on costs for actual cheese plants. When cleaning supplies were needed in a center, the cleaning costs were determined for each center using the flow rate and the number of operating hours of the CIP system in each size plant. Cleaning costs were considered fixed on a per operating day basis assuming that all the equipment in the plants is used and cleaned each operating day. An example of the cleaning costs for some selected systems and plant sizes is provided in Appendix Table A8.

Other Expenses. The expenses in this group include accounting and office supplies, communications and travel, laundry, telephone, and other services. The cost estimates for the model plants were developed based on interviews with managers of actual cheese plants and adjusted for the different size plants. These costs were assumed fixed per year for each size model Cheddar cheese plant (Appendix Table A9).

Production Inventory Costs. A ten-day production inventory cost is considered in this study. This cost reflects a capital expense, or an opportunity cost, for the period between the moment when the resources are used in production and the time when the fresh product is moved out of production. The inventory cost was determined using a 6 percent annual cost on the value of the resources that comprise the variable costs of production. The cost of the milk used in production was calculated using an average price of $11.60 per hundred pounds of milk with 3.7% fat.

RESULTS
PRODUCTION COSTS, ECONOMIES OF SIZE AND EFFECTS OF TECHNOLOGY, AND STABILITY OF THE RESULTS

Introduction

The major objective of the economic-engineering phase of the study was to measure the cost effects of plant size, various production technologies and various operating conditions. To obtain the cost budgets and comparisons needed to do this, production costs were estimated for 87 basic Cheddar plants operating with nine different production schedules for a total of 783 different plant combinations. The estimated costs included only the costs associated with plant production, that is from the raw milk receiving room through and including the cheese chilling room. The production costs did not include the cost of raw milk, milk assembly, whey handling, cheese aging, cheese marketing, or any management or administration except direct plant management. Likewise, no credit or charge was considered for the whey cream sold and the liquid whey processed at the plants.

The budgeted costs reflect production costs in new Cheddar cheese operations using the technologies studied and facing the factor costs described earlier. The cost estimates do not necessarily reflect the production costs of current Cheddar cheese operations that have been in operation for a period of time. Many older plants, among other things, still use assets that are largely, or perhaps fully, depreciated.

This section provides comparisons between plants with different weekly and daily production schedules, various production technologies, and different plant sizes. The cost impacts of changes in cheese yield, wage rates, and interest rates also are considered. This sensitivity analysis enhances the value of the results calculated initially and minimizes whatever limitations they may have as a result of fixing the performance and costs of some of the production factors.

Production Cost Estimates

Variability in Costs. Estimated Cheddar cheese manufacturing costs varied widely among plants with different technologies, different production schedules, and different plant sizes. Each of these variables had a distinct impact on the absolute level and the relative composition of the production costs.

The large variability in the production cost estimates for the various plants studied make single estimates of Cheddar cheese production costs of limited use. Given cost estimates are valid only under very qualified scenarios (e.g. a given technology, production schedule and plant size). For this reason, much more attention should be given to the cost relationships between plants with different characteristics. Appendix Tables A10-A23 report production costs per pound of cheese for a selected group of plant combinations studied.

To illustrate the range of cost estimates obtained and the composition of costs, Table 13 reports the average production costs per pound of cheese for five selected Cheddar cheese plants thought to represent existing technological systems. Additionally, a range of the costs obtained for plants with the same technologies but with different production schedules and of different sizes is provided to indicate the magnitude of the cost variability. When the five plants selected were organized to process approximately 25 million pounds of cheese per year in operations with 960,000 pounds of daily milk plant capacity, the average production cost was 16.7 cents per pound of cheese. On the other hand, the production costs varied between 27.4 and 11.0 cents per pound of cheese when the plants were producing about 8.3 and 87.4 million pounds of cheese per year in a 480,000 and 2,400,000-pound plant, respectively.

Labor was the single most important component of the production costs for the Cheddar cheese plants. Moreover, labor costs varied the most of any cost factor from plant to plant. Labor represented between 42 and 58 percent of the total production cost for small plants (i.e. plants with 480,000 pounds of daily milk capacity) with different technologies and production schedules. On the other hand, labor only represented between 24 and 37 percent of the production costs for the large plants (i.e. plants with 2,400,000 pounds of daily milk capacity). The large variability in labor cost per pound, especially among plants with different sizes, resulted from wide differences in labor productivity. Table 14 reports labor productivity for six different size plants with five selected technologies. Labor productivity for those selected plants ranged between 81 and 408 pounds of cheese per hour of labor. Except for the standard cheddaring process with regular 40-pound hooping, the labor productivities in plants with these various technologies were fairly similar for a given size plant.

Annual capital costs were lower than labor costs although they were significant in Cheddar cheese manufacturing and varied widely from one plant to another (Table 13). Capital costs represented between 9 and 23 percent of the production costs in the 783 model plants. The relative importance of capital costs on a pound of cheese basis was influenced more by the technology used and the level of plant capacity utilization than by the size of the operation.

Cost of materials, such as production ingredients (e.g. rennet, starter) and packaging supplies, are very important in Cheddar manufacturing. Materials represented between 18 and 20 percent of the production costs in small plants and as much as 40 percent of the cost in larger operations. Since materials generally are utilized in fixed proportions to the milk processed or to the cheese produced at the plant, the use of most materials changes proportionally with the volume of production. With the productivity of labor and capital increasing with the size of the operation and with relatively little economies of size in materials cost, materials represent a higher percentage of total costs in larger operations than in smaller ones.

Labor, capital, and materials together accounted for about 80 or 85 percent of the production costs. The remaining costs are utilities, property taxes and insurance, repair and maintenance, inventory costs, and other expenses. Utilities alone account for about half of these remaining costs.

Table 13. Average Production Costs for a Selected Group of Five Model Cheddar Cheese Plants[a].

Cost Item	Cost per Pound of Cheese[b]	Percentage of Total Costs	Cost Range for Different Plant Systems[c]
	(Cents)	(%)	(Cents/Pound)
Labor			
Supervisory	0.5	3.0	(0.2 - 1.3)
Direct Fixed	0.6	3.6	(0.3 - 1.4)
Direct Variable	5.8	34.7	(3.0 - 9.7)
Total Labor	6.9	41.3	(3.5 - 12.4)
Capital Costs			
Depreciation & Interest	2.3	13.8	(1.2 - 5.2)
Utilities			
Electricity	0.2	1.2	(0.1 - 0.3)
Fuel	1.2	7.2	(1.0 - 1.6)
Water & Sewage	0.1	0.6	(0.1 - 0.2)
Total Utilities	1.5	9.0	(1.2 - 2.1)
Materials			
Laboratory	0.1	0.6	(0.1 - 0.1)
Production	2.9	17.3	(2.9 - 2.9)
Packaging	1.2	7.2	(1.2 - 1.2)
Cleaning	0.5	3.0	(0.2 - 1.0)
Total Materials	4.7	28.1	(4.4 - 5.2)
Repair & Maintenance	0.2	1.2	(0.1 - 0.3)
Property Tax & Insurance	0.7	4.2	(0.3 - 1.6)
Production Inventory	0.2	1.2	(0.2 - 0.2)
Other Expenses	0.2	1.2	(0.1 - 0.4)
TOTAL	16.7	100.0	(11.0 - 27.4)
Pounds of Cheese per Year	25.0 Million		(87.4 - 8.3)

a The five model plants selected had the following technological systems: standard cheddaring with regular 40-pound hooping; standard stirred curd with block former; automatic cheddaring with 640/40-pound & cutting line; advanced stirred curd with block former; and advanced cheddaring with block former. Individual costs for these different systems are reported in Tables A10-A23 in the appendix..

b The average cost per pound corresponds to plants with a capacity of 960,000 pounds of milk per day, operating 21 hours per day, and 6 days per week.

c The lower and upper ranges correspond to the average costs of the same five systems with a capacity of 480,000 pounds of milk per day, operating 18 hours per day, and 5 days per week and 2,400,000 pounds of milk per day, operating 24 hours per day, and 7 days per week, respectively. The average for the upper cost range excludes the advanced stirred curd system not modeled for that size plant.

Table 14. Labor Productivity for a Selected Group of Model Cheddar Cheese Plants of Different Sizes Operating with a 24-Hour Production Schedule.

Plant Type	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Pounds of Cheese/Hour of Labor)					
Standard Cheddaring with Reg. 40# Hooping	81	115	138	182	222	282
Standard Stirred Curd with Block Former	112	157	190	250	302	364
Automatic Cheddaring with 640/40# Cutting	112	165	200	279	321	408
Advanced Stirred Curd with Block Former	119	165	200	267	315	n.a.
Advanced Cheddaring with Block Former	115	161	195	261	315	392

n.a. = not applicable

Size of Plant. The size of the plant was, by far, the most important factor affecting the unit costs of the model Cheddar cheese plants. For example, as plants increased the daily milk processing capacity from 480,000 to 2,400,000 pounds, the production costs per pound of cheese decreased by approximately 50 percent for the whole range of technologies and organizations of production considered.

Production Schedules. The daily and weekly production schedules also had a significant impact on the production costs. As the number of operating hours per day and/or the number of operating days per week increased for any size plant, the unit production costs decreased. In other words, the higher the plant capacity utilization, the lower the cost per unit of production in a selected plant size.

Production Technologies. The cost per pound of cheese differed somewhat, but not significantly, between different production technologies. For the most part, the cost of the cheesemaking and hooping/packaging technologies studied ranked consistently for all plant sizes (Tables 15A & B and 16A & B). That is to say, when any two technologies, say A and B, were compared for one size plant and A had a lower cost per pound of cheese than B, technology A also had a lower cost than, or at least the same cost as, technology B for the other plant sizes.

For plants up to about one million pounds of milk processing capacity per day, there were clear cost differences in the cheesemaking technologies studied: standard cheddaring, automatic cheddaring, advanced cheddaring, standard stirred curd, and advanced stirred curd. For the larger size plants the differences in costs due to technology were smaller than for smaller size plants on a cents per pound basis (Table 15B). However, the differences in costs due to technology were about the same in all plant sizes when viewed as a percentage of total costs. Except for the standard cheddaring system, the cheesemaking technologies resulted in essentially similar costs in the various larger plants.

For all plant sizes, the standard cheddaring technology had much higher average production costs than any other cheesemaking technology studied (Table 15A). The standard cheddaring technology was followed by the automatic cheddaring, the advanced cheddaring, the standard stirred curd, and the advanced stirred curd technologies. The two granular cheesemaking technologies, the standard stirred curd and the advanced stirred curd, showed some cost advantages over the cheddaring technologies particularly in the smaller plants (i.e. under one million pounds of milk per day). However, for plants larger than one million pounds of milk processing capacity per day, cost differences between the automatic cheddaring, the advanced cheddaring, the standard stirred curd, and the advanced stirred curd technologies were much less important than in the smaller plants. For the larger plants, these four cheesemaking technologies competed very closely cost wise and their cost differences were either small or nonexistent (Table 15B).

Hooping/Packaging Technologies. Of the three hooping/packaging technologies studied--regular 40-pound, 640/40-pound & cutting line, and block former--the regular 40-pound technology had the highest cost per pound of cheese produced in all size plants (Table 16A). The plant size had an important impact on the cost difference between the regular 40-pound and the other two hooping/packaging

Table 15A. Costs for Various Cheesemaking Technologies, Different Size Model Cheddar Cheese Plants Operating at 100 Percent Capacity with Regular 40-Pound Hooping.

Plant Size[a]	Standard Ched-daring	Automatic Ched-daring	Advanced Ched-daring	Standard Stirred Curd	Advanced Stirred Curd
	Cheesemaking Technology				
	(Cents per Pound of Cheese)				
480,000	25.5	24.3	24.2	23.7	23.3
720,000	19.8	18.7	18.4	18.2	17.9
960,000	17.3	16.2	16.0	15.8	15.6
1,440,000	14.7	13.6	13.5	13.5	13.3
1,800,000	13.2	12.4	12.3	12.2	12.2
2,400,000	11.8	11.1	11.0	11.1	n.a.

Table 15B. Cost Savings of Various Cheesemaking Technologies Over Standard Cheddaring System, Different Size Model Cheddar Plants Operating at 100 Percent Capacity with Regular 40-Pound Hooping

Plant Size[a]	Automatic Cheddaring		Advanced Cheddaring		Standard Stirred Curd		Advanced Stirred Curd	
	¢/lb.	% Saving	¢/lb.	% Saving	¢/lb.	% Saving	¢/lb.	% Saving
480,000	1.2	4.7	1.3	5.0	1.8	7.1	2.2	8.6
720,000	1.1	5.5	1.4	7.0	1.6	8.1	1.9	9.6
960,000	1.1	6.4	1.3	7.5	1.5	8.7	1.7	9.8
1,440,000	1.1	7.5	1.2	8.2	1.2	8.2	1.4	9.5
1,800,000	0.8	6.0	0.9	6.8	1.0	7.6	1.0	7.6
2,400,000	0.7	6.0	0.8	6.8	0.7	6.0	n.a.	

[a] Pounds of milk per day.
n.a. = not applicable.

technologies considered. The cost disadvantage of the regular 40-pound hooping method dropped from more than two cents per pound of cheese in the 480,000 pound size plant to about 0.3 cents per pound in the 2,400,000 pound size plant (Table 16B). For the most part, the block former and the 640/40-pound and cutting line technologies compared similarly in their cost per unit of production for all plant sizes.

Table 16A. Costs for Various Hooping/Packaging Technologies, Different Size Model Cheddar Cheese Plants Operating at 100 Percent Capacity and Using Standard Cheddaring Technology.

	Hooping/Packaging Technology		
Plant Size[a]	Regular 40-Pound	Block Former	640/40-Pound & Cutting Line
	(Cents per Pound of Cheese)		
480,000	25.5	23.1	23.7
720,000	19.8	18.6	18.5
960,000	17.3	16.5	16.4
1,440,000	14.7	14.1	13.9
1,800,000	13.2	12.7	12.8
2,400,000	11.8	11.5	11.5

Table 16B. Cost Savings of Various Hooping/Packaging Technologies Over Regular 40-Pound Hooping System, Different Size Model Cheddar Cheese Plants Operating at 100 Percent Capacity and Using Standard Cheddaring Technology.

	Hooping/Packaging Technology			
Plant Size[a]	Block Former Saving Over Reg. 40-Pound Hooping		640/40-Pound & Cutting Line Saving Over Reg. 40-Pound Hooping	
	Cents/lb.	Percentage	Cents/lb.	Percentage
480,000	2.4	9.4	1.8	7.0
720,000	1.2	6.0	1.3	6.6
960,000	0.8	4.6	0.9	5.2
1,440,000	0.6	4.1	0.8	5.4
1,800,000	0.5	3.8	0.4	3.0
2,400,000	0.3	2.5	0.3	2.5

[a] Pounds of milk per day.

Production Schedules and Levels of Capacity Utilization. The managements of cheese plants have several options for organizing production in the short-run. The number of production hours per day or the number of operating days per week can be adjusted to meet changes in the milk supply, the demand for cheese, or other variables affecting the cheese operation. The various alternatives for adjusting production have different impacts on the production costs per pound of cheese. The options available to the managements of cheese plants in the short-run were evaluated to determine the minimum cost alternatives for different volumes of production that also form the short-run cost curve.

Three daily production schedules, 24-, 21-, and 18-hours per day, were considered together with three weekly production schedules, 7-, 6-, and 5-days per week. The combination of a weekly and a daily schedule determined one alternative of production and at the same time provides a level of plant utilization. These alternative production schedules are indicated in Table 17 together with their resulting levels of plant utilization.

Adjustments both in the daily and weekly production schedules produced changes in the production costs per pound of cheese in the same direction. In other words, both increases in the number of days per week and increases in the number of operating hours per day reduced average unit costs of production. Likewise, decreases in the number of days per week increased unit costs as did decreases in the number of hours per operating day. However, the magnitude of the changes was different for each adjustment and for different plant sizes. Tables 18 and 19 present the changes in cost per pound of cheese resulting from

Table 17. Percent Plant Capacity Utilization for Model Cheddar Cheese Plants with Different Production Schedules.

Daily Schedule[a]	Weekly Schedule		
	7-day	6-day	5-day
	(Percentage)		
24-hours	100	86	71
21-hours	83	71	60
18-hours	67	57	48

[a] The plant milk filling time in a 24-hour day is 18.5 hours; in a 21-hour day is 15.4 hours; and in a 18-hour day is 12.3 hours.

increasing the number of hours per day and the number of days per week for a group of selected technological systems. For all plant sizes and all technologies studied, the average production costs decreased with either an increase in the number of production hours per day or an increase in the

Table 18. Production Costs for Four Technological Systems Operating 6-Days per Week and Different Daily Production Schedules.

Technological System/ Plant Size[a]	Daily Production Schedule		
	18-hours	21-hours	24-hours
	(Cents per Pound of Cheese)		
Automatic Cheddaring & 640/40-Pound Cutting:			
a) 480,000 Pounds	26.6	24.5	23.0
b) 1,800,000 Pounds	13.9	12.9	12.3
Advanced Cheddaring & Block Former:			
a) 480,000 Pounds	25.8	23.7	22.3
b) 1,800,000 Pounds	13.7	12.7	12.1
Standard Stirred Curd & Block Former:			
a) 480,000 Pounds	24.9	23.0	21.7
b) 1,800,000 Pounds	13.5	12.6	12.0
Advanced Stirred Curd & Block Former:			
a) 480,000 Pounds	24.5	22.6	21.4
b) 1,800,000 Pounds	13.6	12.6	12.0

[a] Plant size given in pounds of milk per day.

number of operating days per week. The cost impacts of operating more hours per day and more days per week were comparable for the four selected technologies. Moreover, the smaller the plant, the larger the cost advantage of operating more hours per day and more days per week. By and large, these reductions in production costs resulted from increasing the use of the fixed assets and from taking additional advantage of other fixed costs (e.g. certain labor, certain utilities) in those plants.

Figures 6 and 7 illustrate the changes in unit cost for two selected technologies and plant sizes for all the different production schedules studied. The relationships observed between production organizations and unit cost hold for all the other plants studied. For any plant size, a 7-day, 24-hour production schedule resulted in the lowest average cost of production. The results also indicate that the daily production schedule (i.e. the number of production hours per day) has more of an impact on the costs of production than the weekly production schedule (i.e. the number of operating days per week). For example, the

Table 19. Production Costs for Four Technological Systems Operating <u>21-Hours per Day</u> and Different Weekly Production Schedules.

Technological System/ Plant Size[a]	Weekly Production Schedule		
	5-days	6-days	7-days
	(Cents per Pound of Cheese)		
Automatic Cheddaring & 640/40-Pound Cutting:			
a) 480,000 Pounds	25.5	24.5	23.7
b) 1,800,000 Pounds	13.4	12.9	12.5
Advanced Cheddaring & Block Former:			
a) 480,000 Pounds	24.6	23.7	23.0
b) 1,800,000 Pounds	13.2	12.7	12.4
Standard Stirred Curd & Block Former:			
a) 480,000 Pounds	23.8	23.0	22.4
b) 1,800,000 Pounds	13.0	12.6	12.3
Advanced Stirred Curd & Block Former:			
a) 480,000 Pounds	23.5	22.6	22.0
b) 1,800,000 Pounds	13.1	12.6	12.3

[a] Plant size given in pounds of milk per day.

model plants had the same level of plant utilization (71%) with a 5-day, 24-hour production schedule or with a 6-day, 21-hour production schedule. However, the cost per pound of cheese was different between these two organizations of production for all plant sizes and technologies. The 6-day, 21-hour schedule always had a higher cost than the 5-day, 24-hour schedule (Figure 8). This difference in cost is explained mainly by the additional start up costs and cleaning costs incurred in the 6-day production organization vs. the 5-day production organization. The importance of the impact of the changes in production schedules also can be observed for all size plants in Figures 9 and 10.

Changes in production schedules have a larger impact on fixed costs of production (i.e. capital investment, property taxes, insurance costs, and other fixed expenses). Fixed costs per pound of cheese almost double with a change in production schedule from 7-days, 24-hours to 5-days, 18-hours. This makes fixed costs relatively more important and variable costs relatively less important in plants with lower plant capacity utilization.

Figure 6. Average Production Costs in a Cheddar Cheese Plant with 480,000 Pounds of Daily Milk Capacity, Using Standard Cheddaring and Regular 40-Pound Technologies, and Operating with Different Production Schedules and Various Levels of Plant Capacity Utilization.

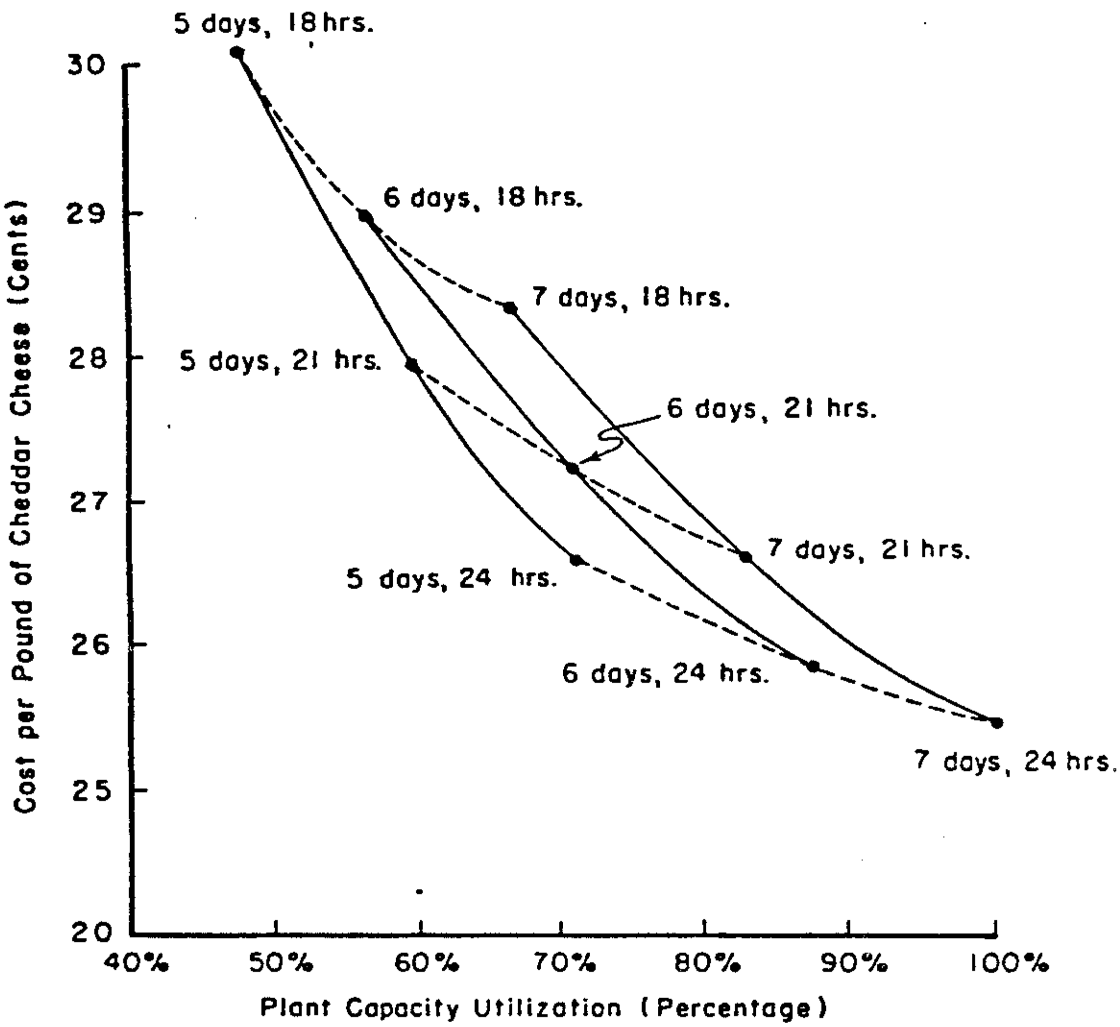


Figure 7. Average Production Costs in a Cheddar Cheese Plant with 1,800,000 Pounds of Daily Milk Capacity, Using Advanced Stirred Curd and Block Former Technologies, and Operating with Different Production Schedules and Various Levels of Plant Capacity Utilization.

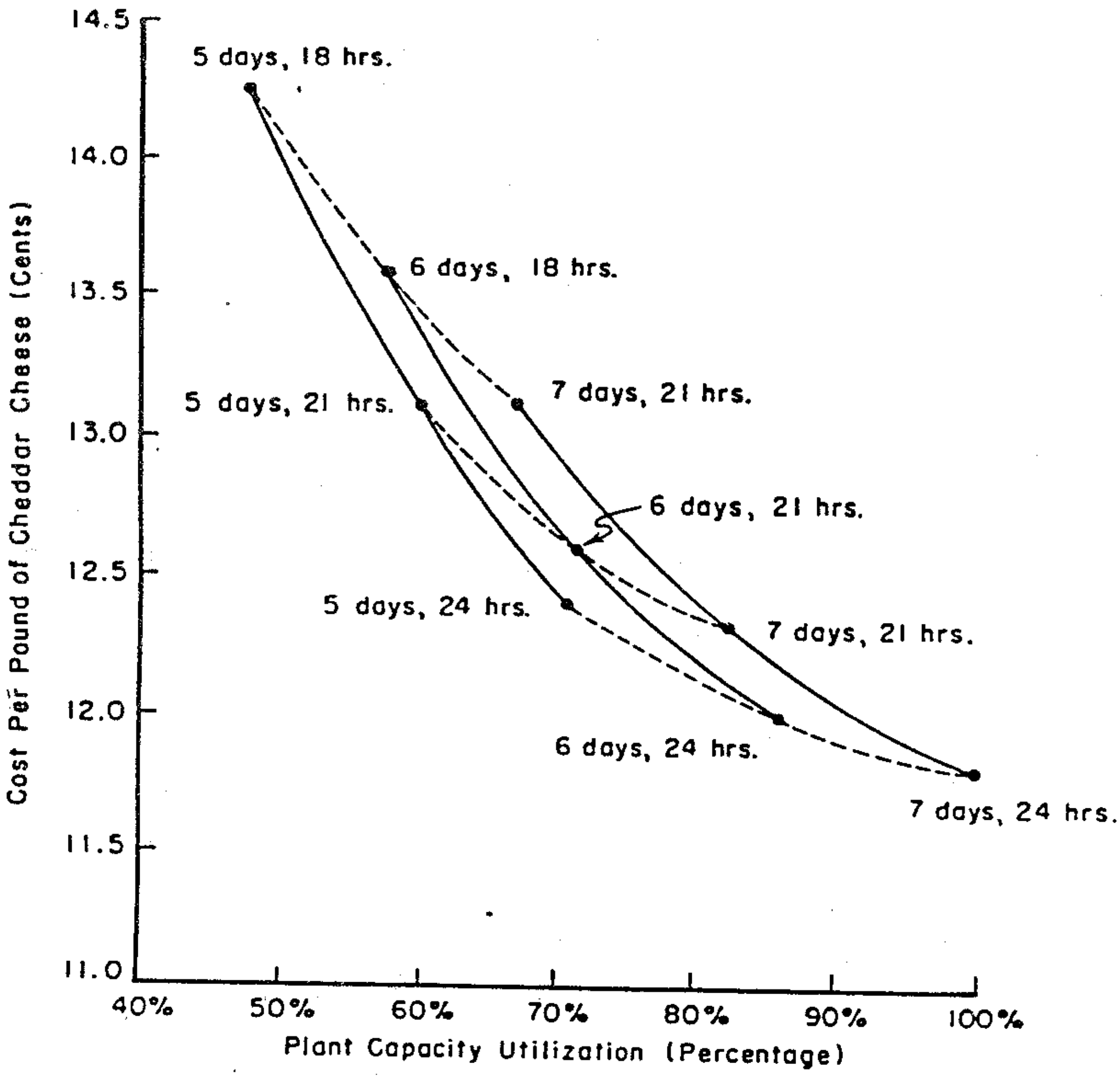


Figure 8. Average Production Costs for Different Size Cheddar Cheese Plants Using Automatic Cheddaring and 640/40-Pound Technologies, Operating Two Different Production Schedules with the Same Level of Plant Capacity Utilization.

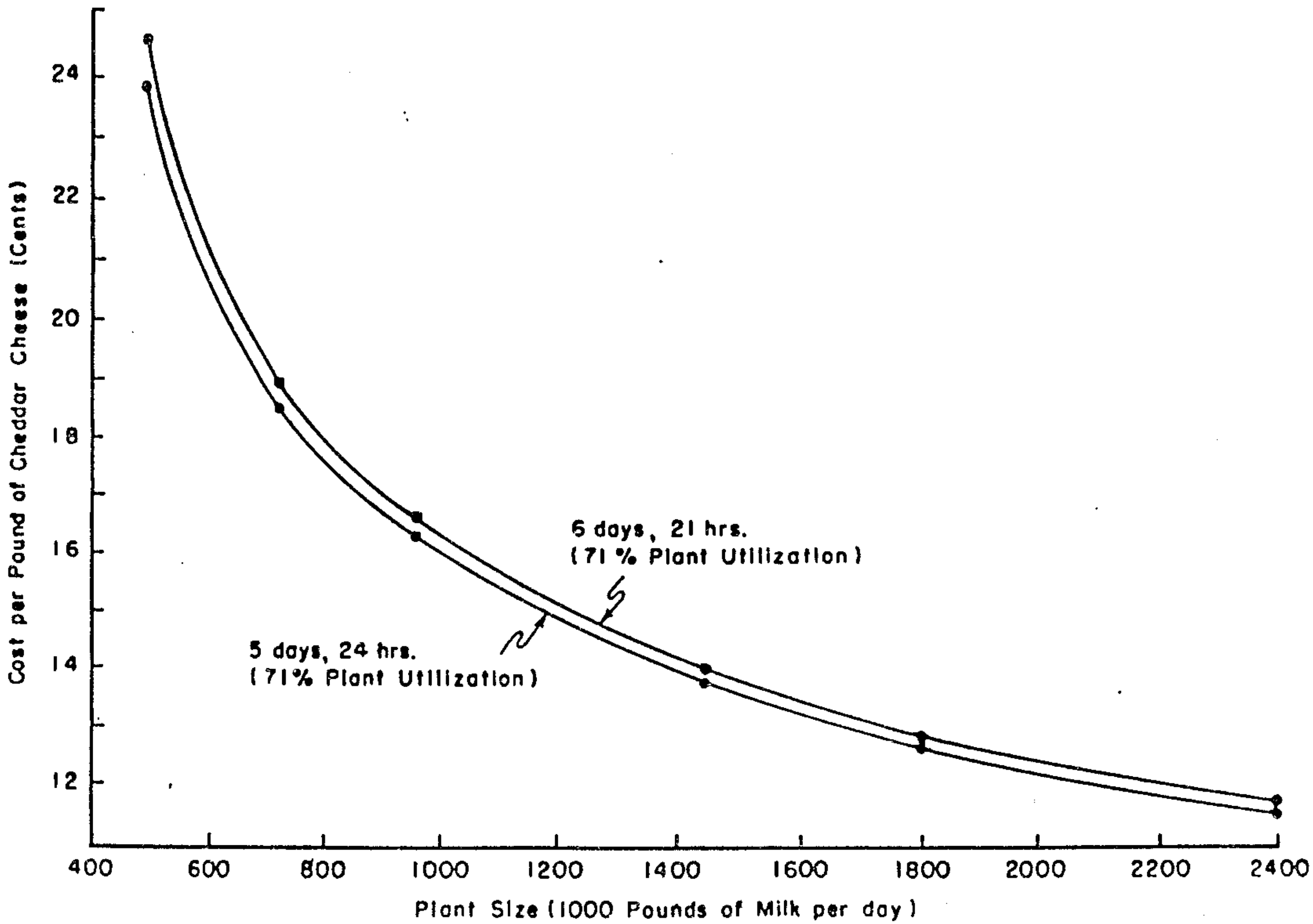


Figure 9 Average Production Costs for Different Size Cheddar Cheese Plants Using Automatic Cheddaring and 640/40-Pcund Technologies, Operating 7 Days per Week and Various Daily Production Schedules.

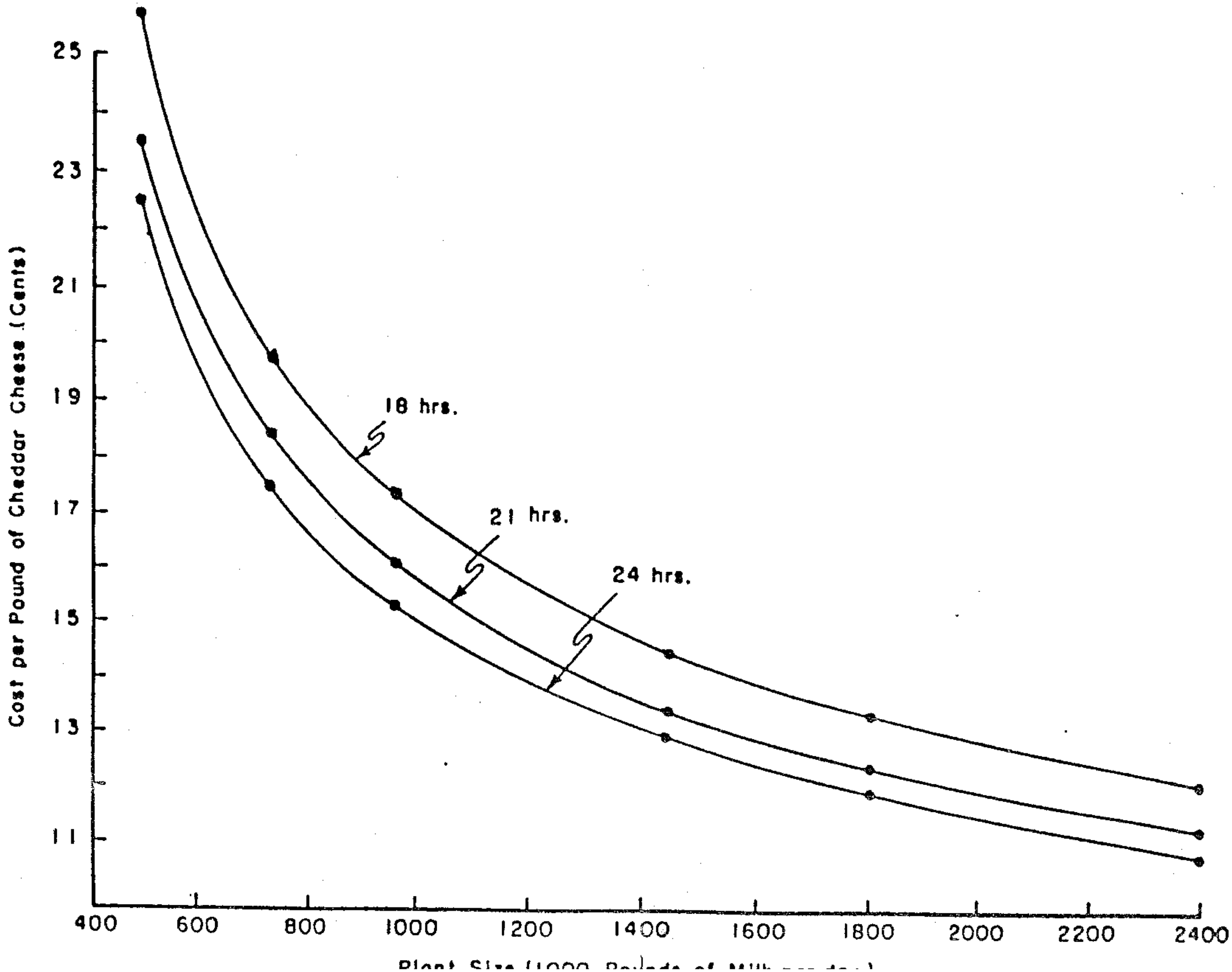
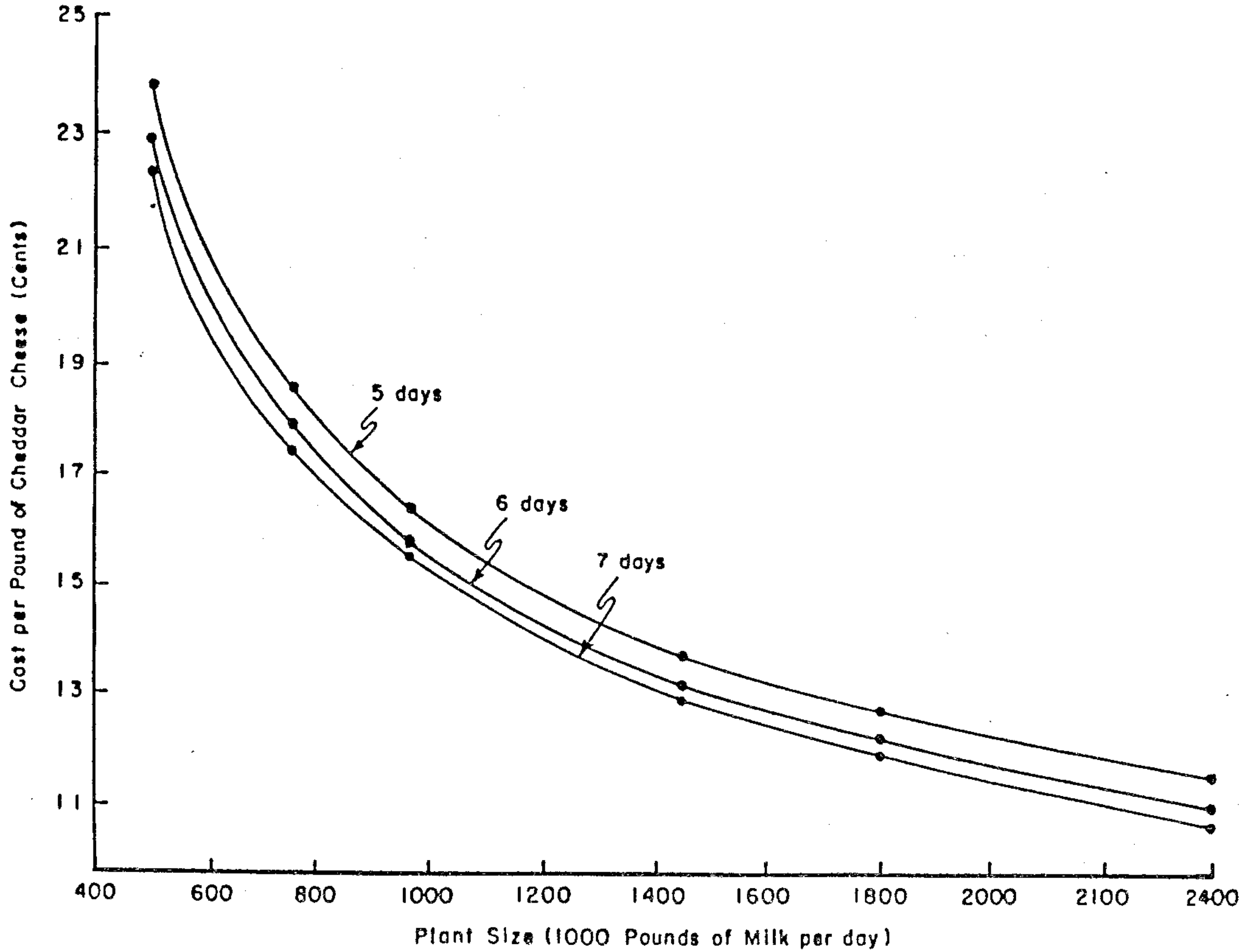


Figure 10. Average Production Costs for Different Size Cheddar Cheese Plants Using Automatic Cheddaring and 640/40-Pound Technologies, Operating 24 Hours per Day and Various Weekly Production Schedules.



Any change in the production schedules also affects more drastically the unit costs in smaller plants than it does in larger ones. This is particularly important since smaller plants already have a very large cost disadvantage given by the size of the operation.

Economies of Size

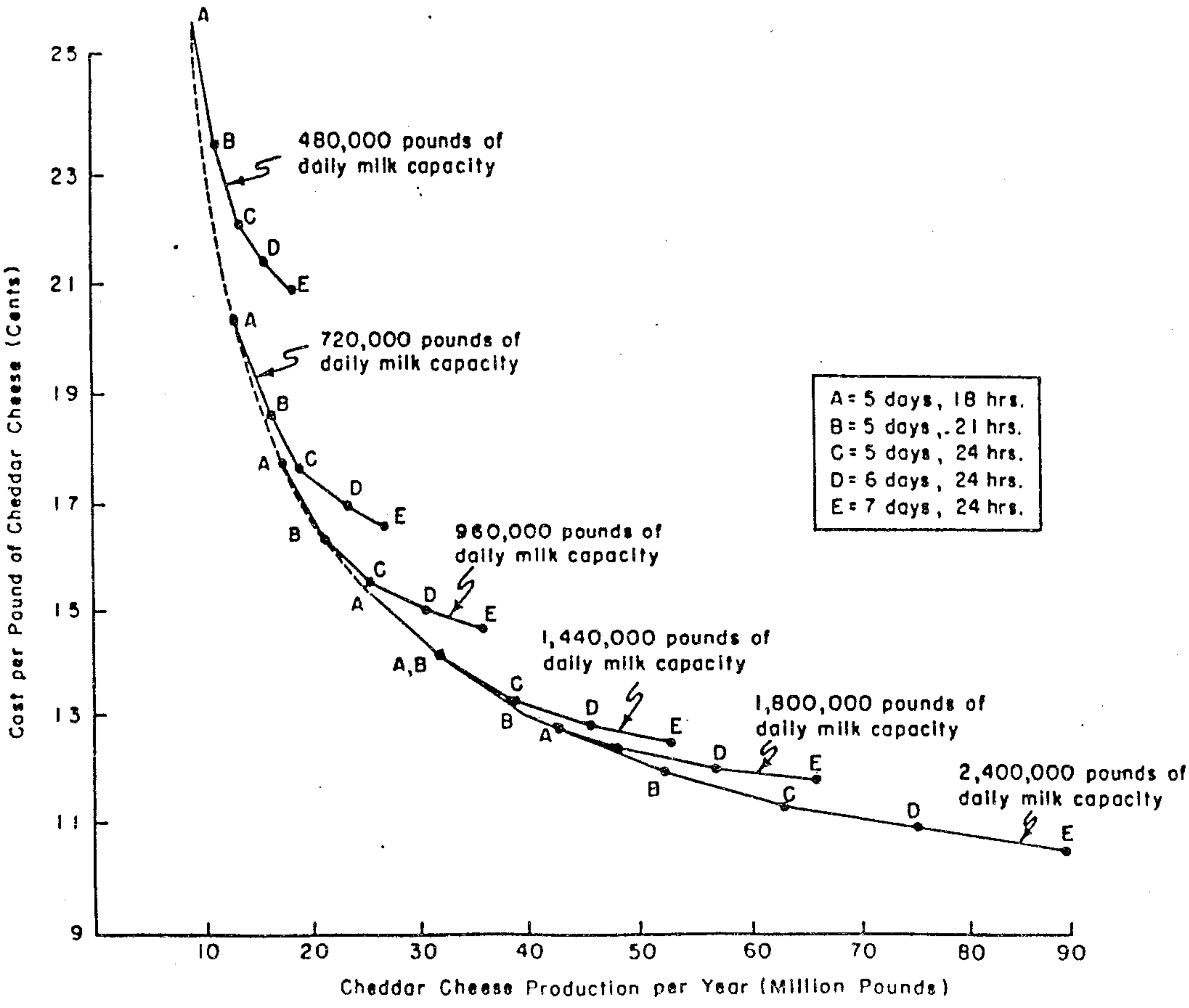
The long-run cost curve is a planning curve. Once a plant is built and production is undertaken, the firm operates on one of the short-run curves. In the long-run all factors of production are variable. The capital resources used in production (i.e. building and equipment) wear out and management can replace them with new, more efficient ones. Management abilities change because of experience and additional training. In the long-run a firm can also change the size of an operation. Thus, in this period managements that are planning to re-equip or build new plants can evaluate all the production alternatives available and select the technologies that are best for each level of output.

The long-run cost curve for Cheddar manufacturing is the envelope of the short-run cost curves of the different plant sizes, giving the least cost for each level of output (Figure 11). The advanced stirred curd technology provided the least cost cheesemaking system for operations with a capacity of 1,440,000 pounds of daily milk capacity or less. For the 1,800,000-pound plant size, the standard stirred curd as well as the advanced stirred curd technologies provided the least-cost cheesemaking options. On the other hand, the standard stirred curd and the advanced cheddaring provided the minimum cost cheesemaking technologies for the 2,400,000-pound plant size. Finally, either the block former and/or the 640/40-pound and cutting line technologies provided the least cost hooping/packaging systems for the different plant sizes studied.

The industry apparently faces significant economies of size in the production of Cheddar cheese. An output of about 8.3 million pounds of cheese per year processed in a plant with a daily milk processing capacity of 480,000 pounds, can be produced at a cost of approximately 27.8 cents per pound. However, an output of about 87.4 million pounds of cheese produced in a plant with a daily milk processing capacity of 2,400,000, only costs approximately 11.0 cents per pound. These economies of size in Cheddar cheese manufacturing can also be observed in the different cost items. For example, when the total output per year increases from about 8.3 million to 87.4 million pounds of cheese, labor cost per pound of cheese drops by about 70% and capital costs per pound of cheese by about 77%.

The economies of size are particularly important for average processing volumes of milk of less than 1,500,000 pounds per day or total production less than 40 and 50 million pounds of cheese per year. In this range of production the evidence indicates that a new large plant that operates at much less than full capacity will produce a specific volume of cheese per year at lower unit cost than a new, but smaller plant operating at full capacity. The economies, of size more than offset some of the diseconomies resulting from operating a plant at less than full capacity. For example, a total output of about 17 million pounds of cheese per year could be produced at a 3 to 4 cents lower

Figure 11. Long-Run Cost Curve for Cheddar Cheese Production.



cost per pound in a Cheddar cheese plant with 960,000 pounds of daily milk capacity than in a plant with 480,000 pounds of capacity.

In general, the higher capital costs resulting from the additional capital investment required to build and equip a larger plant are more than offset by the savings in labor costs obtained when processing a given throughput in a larger operation. The major reason for lower unit costs being achieved in processing a given volume of milk in a larger plant operating below full capacity than in a smaller plant operating at capacity, is that labor costs in the smaller size plants usually account for as much as four times the capital costs on a cost per pound of production basis. In other words, the average labor savings obtained from running the same volume of production in a larger operation instead of a smaller one could only be offset by an increase in total investment costs generating increases in average capital costs of about four times the magnitude of those labor savings.

It should be remembered that the long-run results observed here need to be considered together with raw milk assembly costs and the cheese marketing conditions for a particular location before a plant selection is done for a certain level of output. Some of the economies of production could be substantially offset by diseconomies in some of the other activities of a business.

Sensitivity of Production Cost Estimates

The production cost estimates reported thus far have been calculated under stated conditions. The various assumptions used in modeling the Cheddar cheese plants were fixed and no changes considered up to this point. To observe the impact of production costs of changing specific variables, some of those initial assumptions were relaxed. The results were tested for their sensitivity with respect to three variables considered particularly important in Cheddar plants: cheese yield, labor rates and interest rates. Also, the sensitivity of the results to various levels of capital investments was tested.

Effect of Cheese Yields. Cheddar cheese yields normally vary widely during the year as a result of seasonal changes in milk composition and theoretical cheese yield (Barbano, DellaValle, and Olson). In addition, there can be plant-to-plant and day-to-day differences in the efficiency of recovery of the theoretical cheese solids present in the milk supply. Any change in yield (whether it is due to change in the cheese yield potential of the milk or to inefficient recovery of potential cheese solids) has a direct impact on cheese production costs because less cheese is produced with the same amount of labor, ingredients, and equipment. The lower the cheese yield, the higher the production costs per pound of cheese and visa versa. A second, or indirect, impact of lower cheese yields is the cost to the cheese operation of not producing as much cheese as otherwise would have been produced and thus losing sales revenues. In the following discussion we will address the direct and indirect impacts of differences in cheese yield.

In all comparisons made in this study, it is assumed that the differences in price that cheese plants pay for milk will accurately reflect the differences in yield potential of the milk (thus a plant that buys milk with a lower cheese yield potential pays a proportionately lower price - in reality this may not be true). It is also assumed that the recovery of theoretical yield in each case is 100%. Direct production costs impacts per pound of cheese for three different cheese yield potentials are presented in Table 20 for a selected group of technological systems. The absolute changes in production costs due to changes in

Table 20. Production Costs for a Selected Group of Model Cheddar Cheese Plants with Different Cheese Yield Potentials.

Plant Type	Cheese Yield	Plant Size (Pounds of Milk per Day) 480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(#/CWT)	(Cents per Pound of Cheese)					
Standard Cheddaring & 40# Hooping	10.3	26.4	20.5	17.9	15.2	13.7	12.2
	10.0	27.2	21.0	18.4	15.6	14.0	12.5
	9.5	28.5	22.1	19.3	16.3	14.7	13.1
Standard Stirred Curd & Block Former	10.3	22.3	17.8	15.6	13.4	12.3	11.2
	10.0	23.0	18.3	16.1	13.8	12.6	11.5
	9.5	24.1	19.2	16.8	14.5	13.2	12.1
Automatic Cheddaring & 640/40# Cutting	10.3	23.8	18.4	16.1	13.5	12.6	11.3
	10.0	24.5	18.9	16.6	13.9	12.9	11.6
	9.5	25.7	19.9	17.4	14.6	13.5	12.2
Advanced Stirred Curd & Block Former	10.3	22.0	17.5	15.4	13.3	12.3	n.a.
	10.0	22.6	18.0	15.9	13.6	12.6	n.a.
	9.5	23.8	18.9	16.6	14.3	13.2	n.a.
Advanced Cheddaring & Block Former	10.3	23.0	18.2	15.9	13.6	12.4	11.2
	10.0	23.7	18.7	16.4	13.9	12.7	11.5
	9.5	24.9	19.6	17.2	14.6	13.3	12.0
Daily Change in Cheese Production per 1% Change in Cheese Yield (Pounds)		400	600	800	1,200	1,500	2,000

a Plants operating 21 hours per day and 6 days per week.

n.a. = not applicable.

cheese yield potential are larger for the smaller, higher cost plants than for the larger, lower cost plants across all technologies. However, the percentage impact on the production cost of a change in cheese yield was similar for all systems and plant sizes. A cheese yield change of one percent generated a change, in the opposite direction, of about one percent in the production costs per pound of cheese. This relationship reflects the fact that, except for packaging supplies which vary directly with the weight of cheese produced, the total production costs in a Cheddar cheese operation are not affected by changes in the cheese yield. On the other hand, the volume of cheese over which those total production costs are spread varies the same relative amount as the cheese yield. The 480,000 plant size with standard cheddaring & 40 lb hooping (Table 20) would have an additional cost of 2.1 cents per pound of cheese to handle milk with a 9.5 lb per hundred weight yield potential versus a milk that would yield 10.3 lbs per hundred weight. Since the milk only had a yield potential of 9.5 lbs per hundred weight, which was assumed to be reflected in the price paid for the milk, there would be no indirect loss due to cheese yield potential that was not actually recovered.

In previous studies of cheese manufacturing performance[7], it has been determined that not all Cheddar cheese plants have the same efficiency of recovery of theoretical cheese solids. Our previous report indicated an average percent recovery of 97.1%, with a range from 99.04% to 94.43%. The data presented in Table 21 give an assessment of the impact of variation in efficiency recovery of potential cheese yield on manufacturing costs per pound of cheese.

The <u>indirect</u> impact resulting from the lost cheese sales revenue is much more significant than the higher direct manufacturing cost per pound of cheese resulting from the lower cheese yield. The indirect impact of lower cheese production per day resulting from less than optimal recovery of cheese yield potential can be measured using an opportunity cost concept. The opportunity cost represents the forgone revenues resulting from lower cheese sales. Any additional pound of cheese manufactured at the plant from the milk processed would have generated additional revenues equal to the wholesale price of cheese minus the packaging costs directly associated with that additional cheese. Thus, the total indirect cost impact of lower cheese yield efficiency can be measured by multiplying the pounds of cheese that were not produced by the wholesale price of cheese minus the packaging costs for that cheese.

For example, we may have two identical cheese plants that have purchased milk with the same Cheddar cheese yield potential and we assume that they have paid the same price for that milk. An evaluation of the true impact of lower efficiency of recovery of cheese yield potential is given in Table 21, a 480,000 lb per day standard cheddaring plant with a 40 lb hooping line has a production cost per pound of cheese of 27.2 cents at a yield of 10 lbs per hundred weight or in other words 100% efficiency. At a 9.5 lb yield per hundred weight, the plant would have a true cheese manufacturing cost of 34.8

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[7]Mesa-Dishington, et al, ibid, and D. M. Barbano, and J. W. Sherbon. "Cheese Yields in New York", <u>J. of Dairy Science</u>, 67:1873-1883, 1984.

Table 21.- Production Costs for a Selected Group of Model Cheddar Cheese Plants with Different Cheese Yield efficiencies with Lost Revenues from Lower Yields Considered[a]

Plant Type	Cheese[b] Yield	Plant Size (Pounds of Milk per Day) 480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(#/CWT)	(Cents per Pound of Cheese)					
Standard Cheddaring & 40# Hooping	10.0	27.2	21.0	18.4	15.6	14.0	12.5
	9.5	34.8	28.4	25.6	22.6	21.0	19.4
Standard Stirred Curd & Block Former	10.0	23.0	18.3	16.1	13.8	12.6	11.5
	9.5	30.4	25.5	23.1	20.8	19.5	18.4
Automatic Cheddaring & 640/40# Cutting	10.0	24.5	18.9	16.6	13.9	12.9	11.6
	9.5	32.0	26.2	23.7	20.9	19.8	18.5
Advanced Stirred Curd & Block Former	10.0	22.6	18.0	15.9	13.6	12.6	n.a.
	9.5	30.1	25.2	22.9	20.6	19.5	n.a.
Advanced Cheddaring & Block Former	10.0	23.7	18.7	16.4	13.9	12.7	11.5
	9.5	31.2	25.9	23.5	20.9	19.6	18.3
Daily Change in Cheese Production per 1% Change in Cheese Yield (Pounds)		400	600	800	1,200	1,500	2,000

a Plants operating 21 hours per day and 6 days per week. Lost revenue from lower yields (i.e. wholesale price less packaging costs) assumed to be $1.20 per pound.

b A 9.5#/cwt yield would correspond to a 95% efficiency of recovery of cheese yield potential assuming all plants use a milk with a cheese yield potential of 10#/cwt.

n.a. = not applicable.

cents per pound or an increase of 7.6 cents per pound. Of the 7.6 cents per pound difference in manufacturing cost, 1.3 cents is a result of direct costs while 6.3 cents (82.9%) is due to the lost revenue (indirect cost) because cheese that should have been recovered based on the yield potential was lost in the by-product streams. These losses can be in the form of fat in the whey, whey fines, floor waste, separator sludge, etc. Some of these cheese solids that were not recovered as cheese may be recovered in by-products and some value may be obtained for them. This value would be credited against the 6.3 cents in lost revenue. Fat recovered from whey would be the major by-product recovery item of significant value. The value of cheese solids in by-products is lower than in cheese.

This example illustrates clearly the significant impact that a 5% difference in cheese yield efficiency can have on Cheddar cheese manufacturing costs. It is not uncommon to see this amount of difference between plants and in the 11 cheese plant survey the observed high/low range in cheese yield efficiency was approximately 5%.

Effect of Various Labor Rates. Wage rates in Cheddar cheese operations vary widely from plant to plant and, to some extent, regionally. Since Cheddar production is relatively labor intensive for all the technologies studied, any variation in labor cost translates into relatively important changes in the unit costs of production.

The costs per pound of cheese for a selected group of technological systems were calculated using various wage rates representative of the range of labor rates observed in the Cheddar plants visited earlier in the study. Changes in the cost of labor affected the smaller plants and the labor intensive technologies (e.g. standard cheddaring with regular 40-pound technologies) more than the larger plants and the capital intensive technologies (Table 22). The differences in average production costs between smaller and larger operations increased with higher wages and decreased with lower wages. Changes in wage rates had a larger effect on smaller plants than larger ones because of lower labor productivity in the smaller operations. Depending on the technology in use and the size of the operation, production costs change between 30 and 60 percent of the relative change in the cost per hour of labor.

Effect of Interest Rates. A 6 percent real interest rate was used in estimating the production costs for the model plants. The real interest rate of a firm may change if the risk factor for that business also changes. To assess the impacts on the production costs of changes in the interest rate, various interest rates were studied (Table 23).

In general, a change of one percent in the interest rate had a very small impact on the average cost of producing a pound of cheese. The relative insensitivity of unit production costs to interest rates results from the relatively small importance of capital costs in Cheddar cheese operations compared to other production cost categories (e.g. labor and materials). The effects of changes in the interest rate are slightly larger in the more capital intensive technologies (e.g. automatic cheddaring, advanced stirred curd, advanced cheddaring). However, except for the smallest plant (i.e. 480,000 pounds of milk per day), the effects of different interest rates are essentially the same in

Table 22. Production Costs for a Selected Group of Model Cheddar Cheese Plants with Different Labor Wages[a].

Plant Type	Labor Wages	Plant Size (Pounds of Milk per Day) 480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	($/Hr.)	(Cents per Pound of Cheese)					
Standard Cheddaring & 40# Hooping	7	23.8	18.6	16.4	14.1	12.8	11.5
	9	27.2	21.0	18.4	15.6	14.0	12.5
	11	30.6	23.4	20.4	17.1	15.2	13.5
Standard Stirred Curd & Block Former	7	20.5	16.5	14.6	12.7	11.7	10.8
	9	23.0	18.3	16.1	13.8	12.6	11.5
	11	25.5	20.1	17.5	14.9	13.5	12.3
Automatic Cheddaring & 640/40# Cutting	7	22.0	17.2	15.2	12.9	12.0	11.0
	9	24.5	18.9	16.6	13.9	12.9	11.6
	11	26.9	20.6	18.0	14.9	13.8	12.3
Advanced Stirred Curd & Block Former	7	20.3	16.3	14.5	12.6	11.8	n.a.
	9	22.6	18.0	15.9	13.6	12.6	n.a.
	11	25.0	19.7	17.2	14.7	13.5	n.a.
Advanced Cheddaring & Block Former	7	21.3	17.0	15.0	12.9	11.9	10.8
	9	23.7	18.7	16.4	13.9	12.7	11.5
	11	26.1	20.4	17.8	15.0	13.6	12.2

[a] Plants operating 21 hours per day and 6 days per week.

n.a. = not applicable.

Table 23. Production Costs for a Selected Group of Model Cheddar Cheese Plants with Different Interest Rates[a].

Plant Type	Real Interest Rate	Plant Size (Pounds of Milk per Day) 480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(%)	(Cents per Pound of Cheese)					
Standard Cheddaring & 40# Hooping	4	26.6	20.6	18.0	15.2	13.7	12.2
	6	27.2	21.0	18.4	15.6	14.0	12.5
	8	27.7	21.5	18.8	15.9	14.3	12.8
Standard Stirred Curd & Block Former	4	22.4	17.8	15.7	13.5	12.3	11.2
	6	23.0	18.3	16.1	13.8	12.6	11.5
	8	23.6	18.8	16.5	14.2	12.9	11.8
Automatic Cheddaring & 640/40# Cutting	4	23.8	18.4	16.1	13.5	12.5	11.3
	6	24.5	18.9	16.6	13.9	12.9	11.6
	8	25.2	19.5	17.1	14.3	13.3	12.0
Advanced Stirred Curd & Block Former	4	22.1	17.6	15.5	13.3	12.3	n.a.
	6	22.6	18.0	15.9	13.6	12.6	n.a.
	8	23.2	18.5	16.3	14.0	13.0	n.a.
Advanced Cheddaring & Block Former	4	23.0	18.2	15.9	13.6	12.4	11.2
	6	23.7	18.7	16.4	13.9	12.7	11.5
	8	24.3	19.2	16.8	14.3	13.1	11.8

[a] Plants operating 21 hours per day and 6 days per week.

n.a. = not applicable.

all size plants. This can be explained by the lack of any specific relationship in the relative importance of capital costs in the various size plants.

Effect of Differences in Investment Costs. Although the initial capital investments in the model plants were carefully estimated, managers, for various reasons, might be interested in the effects on production costs of initial capital investments being higher than those assumed in the basic model plants. Thus the effects of having four different levels of investments--35%, 70%, 100% and 140% higher than assumed--on the cost per pound were determined (Table 24). The reasons for selecting these particular levels of higher investment are explained below.

1. 35 Percent Higher Investment. The construction of the model plants can be described as conservative and functional--not fancy. The model plants provide only for plant office space--not "plush" corporate office space. Although the control systems in the plants use programmable controllers, the plants could have been built with a higher level of automatic controls. Moreover, no allowance for contingencies is in the model plant investment costs. The use of more expensive (but not more functional) construction materials, the provision of more costly corporate office space, and the provision for superautomation and for contingencies could well increase the initial capital investment along the order of 30 to 35 percent.

Since the aging of the cheese was considered part of the marketing function--not the production function--no aging cooler was provided. The provision of storage for 6-months aging would require an investment equal to about 25% of the cheese plant investment in the case of the smallest plants modeled and approximately 50% of the investment in the largest plants. Looking at all six sizes of plants modeled, the added investment for 6-months aging storage would average approximately 35% of the cheese plant investment.

Thus increasing the capital investment by 35 percent can be viewed as representing either the provision of a fancier plant with more highly-automated controls or charging production with the investment in 6-months aging storage.

2. 70 Percent Higher Investment. The costs of producing Cheddar cheese if the initial capital investments were 70 percent higher than in the basic model plants also represents either one of two possible situations. First, the provision for more expensively constructed, more highly automated plants together with charging the investment in 6-months aging storage to production (see above scenario).

The other possible situation represented by increasing investment costs 70 percent would be one where revenues from the whey operations covered the annual operating costs of the whey plant, but not the capital costs (i.e. depreciation and interest). Thus management viewed the capital costs associated with the whey plant as part of the cheese production costs.

3. 100 Percent Higher Investment. The initial investments would be about 100 percent higher than in the basic model plants if the plants were constructed with more expensive materials, more highly automated control system and larger office space (scenario number 1 above) and if the capital investment in the whey plant were charged to cheese production (see scenario number 2 above).

4. <u>140 Percent Higher Investment</u>. An increase of 140 percent in the capital investment in the model plants represents the situation where the investments in 6-months of aging storage and in the whey plants are charged to cheese production along with the provision of a plant constructed with more costly materials, more highly-automated control systems and with a corporate office.

The effects of higher investment rates are somewhat smaller than might be expected by some (Table 24). An increase in capital investment in the larger plants has a much smaller effect on the cost per pound of cheese than for the smaller plants. For example, the increase in the cost per pound for the smallest plant, 480,000 pounds of milk a day, is 2.33 times greater than for the largest plant, 2,400,000 pounds of milk a day. This reflects the fact that capital costs become a smaller percentage of total cost per pound of cheese as plant size increases. Although as plant size increases the actual increase in per pound cheese costs due to increased capital cost is significantly smaller, the percentage increase in cost is only marginally smaller.

Table 24. Effects of Increases in Initial Capital Investments on Costs for a Selected Group of Model Cheddar Cheese Plants[a]

Plant Size[b]		Percentage Increase in Capital Investment Over Basic Model Plants			
		35%	70%	100%	140%
		Cents per Pound of Cheese and Percentage			
480,000	Total Cost - ¢	23.8	25.2	26.4	28.0
	Increase - ¢	1.4	2.8	4.0	5.6
	- %	6.3	12.5	17.9	25.0
720,000	Total Cost - ¢	19.0	20.1	21.0	22.3
	Increase - ¢	1.1	2.2	3.1	4.4
	- %	6.2	12.3	17.3	24.6
960,000	Total Cost - ¢	16.6	17.6	18.4	19.4
	Increase - ¢	0.9	1.9	2.7	3.7
	- %	5.7	12.1	17.2	23.6
1,440,000	Total Cost - ¢	14.1	14.9	15.5	16.4
	Increase - ¢	0.8	1.6	2.2	3.1
	- %	6.0	12.0	16.5	23.3
1,800,000	Total Cost - ¢	12.9	13.5	14.1	14.9
	Increase - ¢	0.7	1.3	1.9	2.7
	- %	5.7	10.7	15.6	22.1
2,400,000	Total Cost - ¢	11.7	12.3	12.8	13.5
	Increase - ¢	0.6	1.2	1.7	2.4
	- %	5.4	10.8	15.3	21.6

[a] Plants using automatic cheddaring technology with block former and operating 24 hours per day, 6 days per week.

[b] Pounds of milk per day

GLOSSARY

Aged Cheddar - Cheddar cheese that has been stored six months or more at temperatures between 35 and 45° F.

Assembly - The physical movement of milk from the farm where it is produced to the plant where it is processed. This may involve transshipment through a receiving station but does not include plant-to-plant transfers. Milk assembly involves the logistics of routing milk trucks from farms to plants and the costs are principally those involved with the pic up and hauling of the milk.

Bacteria Count - A process to control quality of milk by counting the number of bacteria per milliliter, grading the best results when less bacteria is observed.

Barrel Cheese - Round style of cheese with a diameter of 22 inches and a height of 34 inches. Its minimum weight is 470 pounds. The cheese in this style is held for storage in plastic lined steel or corrugated paper containers. Generally has low moisture content, less than 34.5%, and is used as a raw material for manufacture of processed cheese and cheese foods.

Biological Oxygen Demand (BOD) - The amount of oxygen required for digestion of organic material in solution in waste water. It is a measure of the pollution power of liquids.

Capital Investment - The money needed to supply the necessary manufacturing and plant facilities is called the "fixed capital investment", while the money needed for the operation of the plant is referred to as "working capital." The sum of the fixed capital investment and the working capital is known as the total capital investment.

Casein - Casein is a fraction of milk protein, representing about 80 percent of true protein found in milk. Milk casein is of special importance in cheesemaking, because the yield of cheese is dependent largely upon the milk casein content.

Cheddaring - Main distinctive feature of one of the Cheddar methods of cheesemaking. It has two basic steps: a) matting of the curd and, b) cutting curd mat into blocks and continuing the operation of piling and repiling curd blocks for about two hours. The purpose is to control bacteria growth, to obtain a more uniform structure of the cheese, to control the cheese moisture, and to attain proper texture of the curd.

Cheese Ripening (Aging) - Process during which the curd, in the form of freshly made cheese, is subjected to the action of microorganisms and enzymes to produce characteristic flavors, texture, and other desired properties.

Clean in Place (CIP) - Automatic system to clean equipment without disassembling it with no or very little effort on the part of the operator.

Commodity Credit Corporation (CCC) - An agency within the U.S. Department of Agriculture. Price support purchases and many other stabilization and related activities involving expenditures of funds are conducted in the name of CCC.

Cooking - Heating the curd to increase the speed of whey removal. Increasing the temperature of the mixture of curd and whey hastens formation of lactic acid, accelerates the action of rennet and thus assists in reducing the moisture content of the curd.

Curd - Thick casein-rich part of coagulated milk.

Dairy Price Support Program - A program of the Federal government to support milk prices through purchases of manufactured dairy products by the USDA. The purpose is to stabilize milk prices and enhance incomes for milk producers. The target farm price goal is achieved by setting the purchase price for manufactured dairy products at appropriate levels. Different systems can be used to determine the support price or purchase price.

Daisy - Style of Natural cheese cylindrical in shape, 13 1/2 inches in diameter, 4 1/2 inches high and weighs from 20-22 pounds. If three cheeses are packed in a box they are called triple daisies.

Economic-Engineering Approach - Also referred as the building block approach, the engineering approach, or the synthetic approach. It synthesizes cost functions from engineering, biological, or other detailed specifications of input-output relationships.

Economies and Diseconomies of Scale - Are a special case of economies or diseconomies of size. Refer to the impact of an increased output upon average costs when all inputs increased in the same proportion.

Economies and Diseconomies of Size - Refer to the impact of output expansion upon average costs. The inputs are combined in any ratio that minimizes the cost at each level of output.

40-Pound Block - Style of Natural cheese that is rectangular in shape. The dimensions are 14 3/16 x 11 3/16 x 6 1/2 inches high and weighs a little over 40 pounds.

Grade A Milk - Milk produced and processed under the strictest sanitary regulations prescribed, inspected, and approved by the Interstate Milk Shippers Division of America Public Health Departments. In most markets milk used in any dairy products intended for consumption in fluid form must meet this inspection standard.

Grade B Milk - Milk produced and processed in keeping with sanitary regulations prescribed, inspected, and approved by public health authorities for milk to be used for manufactured products only.

Lactic Acid - Produced in milk during cheesemaking. This may be accomplished by the addition of a prepared culture of actively growing lactic acid bacteria, called starter. These bacteria ferment the lactose in the milk to lactic acid. The major purposes of the laqctic acid are (1) to make possible the proper coagulation of the milk by rennet, (2) to repress the growth of undesirable microorganisms in the milk, and (3) it is the chief agent that makes possible the control of moisture in the curd and also the control of cheese texture.

Manufactured Dairy Products - Include most dairy products which are not sold in fluid form with the exception of condensed or evaporated milk. These products include cheese varieties, butter, evaporated whole milk, condensed whole milk, condensed skim milk, whole milk powder, non-fat dry milk, ice cream, ice cream mix, frozen desserts, aerated cream, frozen and plastic cream. Manufactured products require, in most cases, more processing to reach final form than do fluid milk products.

Midget - Style of Natural cheese cylindrical in shape, 9 3/4 inches in diameter, 5 inches high and weighs 11-12 pounds. If packed two to a box, they are called junior twins.

Milk Ripening - Refers to the formation of lactic acid (prior to addition of rennet) by the addition of a prepared culture of actively growing lactic acid bacteria, called starter.

Milk Solids - Milk solids make for about 13 percent of the total milk components. The other 87 percent is water. The most significant ones are fat, protein, casein, lactose, and minerals.

Natural Cheese - Cheese made directly from whole milk using the butterfat, protein, and minerals of milk to make up the curd for the Natural cheese. The curds are pressed into various forms to provide the finished product.

Pasteurization - Process of heat-treating liquid foods to prevent bacteria or organic spoilage.

Protein - Total protein refers to all the nitrogen in milk or cheese regardless of its form. True protein is the total protein minus the non-protein nitrogen (NPN) fraction, arising from free aminoacids and related fractions. Milk has about 3.2 percent protein and Cheddar cheese about 24 percent.

Rennet - Or rennin, is a substance that coagulates milk, generally used in cheesemaking. It can be obtained from animals (e.g. calf rennet is the most common), microbes, or be artificially produced.

Reverse Osmosis (RO) - Is, for all practical purposes, a concentration method. It is a membrane filtration process drive by application of high pressure (500-700 psi). Ideally, only water passes through reverse osmosis membranes. However, a trace amount of minerals and some other very low molecular weight substances may pass through reverse osmosis membranes.

Setting or Renneting - Adding rennet-extract (e.g. enzyme from calf stomach) to milk in cheesemaking. Causes the milk to change from a liquid to a solid in about 30 minutes at 88° F.

640-Pound Block - Square style of cheese with dimensions of 30 x 24 x 30 inches and a weight of approximately 640 pounds. Commonly used for Cheddar cheese it is held in curing in lined wood fabricated containers or corrugated paper boxes.

Standardized Milk - Milk used by some processors in which one or more of the milk components are adjusted to meet a predetermined content. Typically, fat is either removed as cream or non-fat dry milk is added to increase non-fat solids. It is a practice used for fluid milk pricessing, cheesemaking, and many other dairy products.

Starter - Dairy starters are cultures of harmless, active bacteria, grown in milk or whey, which impart certain characteristics and qualities to various milk products. There are at least 40 distinct types of starter cultures for milk fermentation having marked morphology and utility differences. The starter culture used in Cheddar cheese manufacturing belongs to the lactic acid streptococcus group. The addition and growth of starter in cheesemaking before rennet is added is known as milk ripening.

Stirred Curd or Granular Cheese - Rennet-coagulated form of Cheddar style cheese made without cheddaring. The curd is not matted and milled, instead the curd is stirred continually until placed in hoops. Omission of the cheddaring step makes stirred curd cheesemaking simpler and shorter, but higher risks to undesirable bacteria growth if milk quality is poor.

Synthetic Analysis - See economic-engineering approach.

Technological System - As used here, refers to a plant design with a specific technology combination, a defined size, and given production and operational conditions.

Three-tier System - It refers here to a cheesemaking process in which the cooking, the cheddaring or stirring of the curd, and the salting, take place in three different areas with three different pieces of equipment.

Two-tier System - Refers to a cheesemaking process in which the cooking and the cheddaring or stirring of the curd take place in two different pieces of equipment. In this process the salting is done in the same equipment as the cheddaring or the stirring of the curd.

Ultrafiltration (UF) - Designates a membrane separation process, that fractionates some milk solids components and selectively concentrates other solids components of milk or, of whey, based primarily on molecular size (a sieving effect). Generally, milk fat, milk protein, and a significant amount of minerals, do not pass through the membrane, while lactose, water, and some soluble minerals pass through the membrane.

Whey - Watery portion or serum (what remains after coagulation) that separates from the curd during cheesemaking.

Appendices

Table A1. Cheddar Cheese Plant Construction Costs, 1985.

Plant Center	Ceiling Height[b]	Typical Cost
	(Feet)	(Dollars Per Square Foot)
Milk Receiving	16	79
Milk Treatment (HTST)	16	68
Cream Separator & Fine Saver	16	68
Starter Culture	16	82
Cheesemaking:		
Standard Cheddaring	16	66
Standard Stirred Curd	16	66
Automatic Cheddaring (DMC)	20	64
Advanced Stirred Curd (EFV)	16	66
Advanced Cheddaring (Alf-o-matic)	20	71
Cheese Hooping/Packaging:		
Regular 40#	16	90
640/40# with Cutting line	16	90
Block Former	26	91
Cheese Chilling	16/20/24	56
Dry Storage	16/20/24	43
Refriger., Maint., & Boiler	16/20	49
CIP	16	72
Laboratory	8	90
Offices[a]	8	110
Lunch Room[a]	8	99
Lockers & Restrooms[a]	8	98
Waste Treatment[a]	8	213
Water Well	8	44

[a]Equipment included in structural cost.

[b]When more than one ceiling height is reported they indicate different ceiling heights for different size plants.

Table A2. Initial Equipment Investment for Various Operating Centers in Model Cheddar Cheese Plants of Different Sizes.

Plant Center	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Dollars)					
Milk Receiving	213,000	234,000	277,000	360,000	406,000	612,000
Milk Treatment (HTST)	281,000	308,000	331,000	403,000	429,000	561,000
Separator & Fine Saver	370,000	420,000	474,000	593,000	811,000	899,000
Starter Culture	226,000	234,000	241,000	301,000	332,000	366,000
Cheesemaking:						
Standard Cheddaring	603,000	669,000	698,000	985,000	997,000	1,275,000
Standard Stirred Curd	558,000	662,000	691,000	971,000	983,000	1,211,000
Automatic Cheddaring	887,000	998,000	1,074,000	1,278,000	1,312,000	1,540,000
Advanced Stirred Curd	726,000	776,000	777,000	1,163,000	1,437,000	n.a.
Advanced Cheddaring	1,309,000	1,352,000	1,453,000	1,606,000	1,751,000	1,927,000
Cheese Hooping/Packaging:						
Regular 40#	187,000	225,000	335,000	394,000	423,000	522,000
640/40# & Cutting Line	657,000	787,000	1,013,000	1,281,000	1,547,000	1,993,000
Block Former	423,000	572,000	786,000	1,042,000	1,191,000	1,473,000
Cheese Chilling	13,000	17,000	21,000	25,000	31,000	42,000
Refriger., Maint., & Boiler	353,000	432,000	470,000	561,000	644,000	733,000
CIP	62,000	62,000	62,000	62,000	62,000	62,000
Laboratory	111,000	111,000	111,000	112,000	112,000	112,000

Table A3. Daily Building and Equipment Repair and Maintenance Costs for a Selected Group of Model Cheddar Cheese Plants of Different Sizes Operating with 7-day and 24-hour Production Schedules.

Plant Type	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Dollars Per Day)					
Standard Cheddaring with Reg. 40# Hooping	127	142	153	191	205	244
Standard Stirred Curd with Block Former	137	156	171	217	248	280
Automatic Cheddaring with 640/40# Cutting	165	182	195	232	264	294
Advanced Stirred Curd with Block Former	149	166	181	236	274	n.a.
Advanced Cheddaring with Block Former	143	162	178	220	253	283

n.a. = not applicable

Table A4. Electricity Daily Requirements for a Selected Group of Model Cheddar Cheese Plants of Different Sizes Operating with a 24-hour Production Schedule.

Plant Center	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(KWH)					
Standard Cheddaring with Reg. 40# Hooping	2,397	2,672	2,822	4,063	4,398	5,164
Standard Stirred Curd with Block Former	2,397	2,851	3,223	4,421	4,934	5,880
Automatic Cheddaring with 640/40# Cutting	2,646	2,920	3,114	4,399	4,774	5,607
Advanced Stirred Curd with Block Former	2,584	3,038	3,705	4,803	5,026	n.a.
Advanced Cheddaring with Block Former	2,579	3,018	3,530	4,330	5,002	5,852

n.a. = not applicable

Table A5. Natural Gas Daily Requirements for a Selected Group of Model Cheddar Cheese Plants of Different Sizes Operating with a 24-hour Production Schedule.

Plant Center	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Therms)					
Standard Cheddaring with Reg. 40# Hooping	1,300	1,717	2,127	2,954	3,546	4,538
Standard Stirred Curd with Block Former	1,300	1,717	2,127	2,954	3,546	4,538
Automatic Cheddaring with 640/40# Cutting	1,495	1,912	2,322	3,246	3,838	4,828
Advanced Stirred Curd with Block Former	1,328	1,758	2,194	3,029	3,708	n.a.
Advanced Cheddaring with Block Former	1,456	1,832	2,241	3,121	3,833	4,811

n.a. = not applicable

Table A6. Costs of Production Materials Used in Cheddar Cheese Manufacturing, 1985.

	Requirements per 1,000 Pounds of Milk		Cost
	(Quantity)	(Units)	Dollars
Calcium Chloride	3.00	ounces	0.073
Color[a] (double strength)	0.50	ounces	0.073
Rennet[b] (single strength)	3.00	ounces	1.386
Salt	2.85	pounds	0.203
Starter Culture:[c]			
Traditional Bulk Starter Media	1.20	pounds	1.133
Starter Bacteria	1.44	milliliters	0.048
TOTAL COST PER 1,000 POUNDS OF MILK			$2.90

[a] Assumes production of 50 percent white and 50 percent colored Cheddar cheese.

[b] Assumes calf rennet will be used for manufacture of high quality aged Cheddar cheese.

[c] Assumes bulk starter culture used at one percent of milk volume; bulk starter culture media with 12 percent solids; and 1.2 milliliters of frozen bacteria concentrate sets about one gallon of bulk starter.

Table A7. Costs of Laboratory Supplies for Different Size Model Cheddar Cheese Plants.

Plant Size	Cost of Laboratory Supplies
(Pounds of Milk per Day)	(Dollars Per Million Pounds of Milk)
480,000	90.40
720,000	72.71
960,000	63.10
1,440,000	59.08
1,800,000	55.13
2,400,000	52.81

[a] Includes only the cost of chemicals and materials for various tests on milk, whey, whey cream, and cheese. It also includes BOD testing.

Table A8. Typical Daily Costs of Cleaning Supplies for Model Cheddar Cheese Plants of Different Sizes.

Plant Size	Cost of Cleaning Supplies
(Pounds of Milk per Day)	(Dollars Per Day)
480,000	328
720,000	333
960,000	366
1,440,000	401
1,800,000	440
2,400,000	500

Table A9. Other General Expenses for Model Cheddar Cheese Plants of Different Sizes.

Expense Item	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Dollars Per Year)					
Laundry	9,600	14,400	19,200	24,000	28,800	34,800
Account. & Office Supplies	4,000	6,000	8,000	10,000	12,000	14,000
Communications & Travel	2,500	3,600	4,800	7,000	9,000	12,000
Telephone	10,800	16,200	21,600	27,000	32,400	37,200
Other Services	3,000	4,000	5,000	6,000	7,000	8,000
TOTAL	29,900	44,200	58,600	74,000	89,200	106,000

Table A10. Average Production Costs for Different Size Cheddar Cheese Plants with Standard Cheddaring and Regular 40-Pound Technologies Operating Various Production Schedules.

Cost Item	Plant Size (Pounds of Milk per Day)					
	480,000 (5-days, 18-hours)		960,000 (6-days, 21-hours)		2,400,000 (7-days, 24-hours)	
	Cost per Pound (Cents)	Percentage (%)	Cost per Pound (Cents)	Percentage (%)	Cost per Pound (Cents)	Percentage (%)
Labor						
Supervisory	1.3	4.2	0.5	2.9	0.2	1.8
Direct Fixed	1.5	4.0	0.7	3.7	0.3	2.6
Direct Variable	13.2	43.8	7.8	42.2	3.8	32.2
Total Labor	15.9	52.9	9.0	48.8	4.3	36.6
Capital Costs						
Depreciation & Interest	4.5	14.9	2.0	10.7	1.0	8.9
Utilities						
Electricity	0.3	1.0	0.2	1.0	0.1	1.1
Fuel	1.5	5.0	1.1	6.2	0.9	8.0
Water & Sewage	0.2	0.7	0.1	0.5	0.1	0.5
Total Utilities	2.0	6.7	1.4	7.7	1.1	9.6
Materials						
Laboratory	0.1	0.3	0.1	0.3	0.1	0.4
Production	2.9	9.6	2.9	15.8	2.9	24.6
Packaging	1.4	4.7	1.4	7.5	1.4	11.7
Cleaning	1.0	3.4	0.5	2.5	0.2	1.8
Total Materials	5.4	18.0	4.8	26.1	4.5	38.5
Repair & Maintenance	0.3	1.0	0.2	0.9	0.1	0.9
Property Tax & Insurance	1.4	4.7	0.6	3.3	0.3	2.7
Production Inventory	0.2	0.6	0.2	1.2	0.2	1.8
Other Expenses	0.4	1.2	0.2	1.3	0.1	1.0
TOTAL	30.1	100.0	18.4	100.0	11.8	100.0
Pounds of Cheese per Year	8.3 Million		25.0 Million		87.4 Million	

Table A11. Average Production Costs for Different Size Cheddar Cheese Plants with Standard Stirred Curd and Block Former Technologies Operating Various Production Schedules.

Cost Item	Plant Size (Pounds of Milk per Day)					
	480,000 (5-Days, 18-Hours)		960,000 (6-Days, 21-Hours)		2,400,000 (7-Days, 24-Hours)	
	Cost per Pound	Percentage	Cost per Pound	Percentage	Cost per Pound	Percentage
	(Cents)	(%)	(Cents)	(%)	(Cents)	(%)
Labor						
Supervisory	1.3	4.8	0.5	3.4	0.2	2.0
Direct Fixed	1.4	5.2	0.6	3.6	0.3	2.5
Direct Variable	9.1	35.1	5.5	34.0	2.9	26.7
Total Labor	11.7	45.1	6.6	40.9	3.4	31.2
Capital Costs						
Depreciation & Interest	4.7	18.1	2.1	13.3	1.1	10.5
Utilities						
Electricity	0.3	1.2	0.2	1.3	0.1	1.4
Fuel	1.5	5.8	1.1	7.1	0.9	8.8
Water & Sewage	0.2	0.8	0.1	0.7	0.1	0.7
Total Utilities	2.0	7.8	1.5	9.1	1.2	10.8
Materials						
Laboratory	0.1	0.3	0.1	0.4	0.1	0.5
Production	2.9	11.2	2.9	18.1	2.9	26.9
Packaging	1.2	4.6	1.2	7.4	1.2	11.0
Cleaning	1.0	4.0	0.5	2.8	0.2	1.9
Total Materials	5.2	20.1	4.6	28.7	4.4	40.3
Repair & Maintenance	0.3	1.2	0.2	1.1	0.1	1.1
Property Tax & Insurance	1.4	5.5	0.6	4.0	0.3	3.0
Production Inventory	0.2	0.9	0.2	1.3	0.2	1.9
Other Expenses	0.4	1.4	0.2	1.5	0.1	1.1
TOTAL	25.9	100.0	16.1	100.0	10.8	100.0
Pounds of Cheese per Year	8.3 Million		25.0 Million		87.4 Million	

Table A12. Average Production Costs for Different Size Cheddar Cheese Plants with Automatic Cheddaring and 640/40-Pound with Conversion Technologies Operating Various Production Schedules.

Cost Item	Plant Size (Pounds of Milk per Day)					
	480,000 (5-Days, 18-Hours)		960,000 (6-Days, 21-Hours)		2,400,000 (7-Days, 24-Hours)	
	Cost per Pound	Percentage	Cost per Pound	Percentage	Cost per Pound	Percentage
	(Cents)	(%)	(Cents)	(%)	(Cents)	(%)
Labor						
Supervisory	1.3	4.5	0.5	3.3	0.2	2.0
Direct Fixed	1.3	4.8	0.6	3.4	0.3	2.4
Direct Variable	9.1	32.6	5.2	31.2	2.5	23.5
Total Labor	11.7	41.8	6.3	37.9	3.0	27.9
Capital Costs						
Depreciation & Interest	6.0	21.3	2.6	15.9	1.4	12.5
Utilities						
Electricity	0.3	1.2	0.2	1.2	0.1	1.3
Fuel	1.7	6.1	1.2	7.5	1.0	9.3
Water & Sewage	0.2	0.7	0.1	0.6	0.1	0.6
Total Utilities	2.2	8.0	1.5	9.3	1.2	11.2
Materials						
Laboratory	0.1	0.3	0.1	0.4	0.1	0.5
Production	2.9	10.4	2.9	17.5	2.9	26.8
Packaging	1.2	4.4	1.2	7.4	1.2	11.4
Cleaning	1.0	3.7	0.5	2.8	0.2	1.9
Total Materials	5.2	18.8	4.7	28.1	4.4	40.6
Repair & Maintenance	0.4	1.3	0.2	1.3	0.1	1.1
Property Tax & Insurance	1.9	6.7	0.8	4.9	0.4	3.7
Production Inventory	0.2	0.8	0.2	1.3	0.2	1.9
Other Expenses	0.4	1.3	0.2	1.4	0.1	1.1
TOTAL	28.0	100.0	16.6	100.0	10.8	100.0
Pounds of Cheese per Year	8.3 Million		25.0 Million		87.4 Million	

Table A13. Average Production Costs for Different Size Cheddar Cheese Plants with Advanced Stirred Curd and Block Former Technologies Operating Various Production Schedules.

Cost Item	Plant Size (Pounds of Milk per Day)					
	480,000 (5-Days, 18-Hours)		960,000 (6-Days, 21-Hours)		1,800,000 (7-Days, 24-Hours)	
	Cost per Pound	Percentage	Cost per Pound	Percentage	Cost per Pound	Percentage
	(Cents)	(%)	(Cents)	(%)	(Cents)	(%)
Labor						
Supervisory	1.3	4.9	0.5	3.4	0.3	2.3
Direct Fixed	1.3	5.1	0.6	3.5	0.3	2.9
Direct Variable	8.5	33.3	5.2	32.7	3.3	27.9
Total Labor	11.1	43.2	6.3	39.6	3.9	33.1
Capital Costs						
Depreciation & Interest	4.9	19.1	2.2	13.6	1.3	11.3
Utilities						
Electricity	0.3	1.3	0.2	1.4	0.2	1.4
Fuel	1.5	6.0	1.2	7.5	1.0	8.8
Water & Sewage	0.2	0.8	0.1	0.8	0.1	0.7
Total Utilities	2.1	8.1	1.5	9.6	1.3	10.9
Materials						
Laboratory	0.1	0.4	0.1	0.4	0.1	0.5
Production	2.9	11.3	2.9	18.3	2.9	24.7
Packaging	1.2	4.6	1.2	7.5	1.2	10.1
Cleaning	1.0	4.0	0.5	2.9	0.2	2.1
Total Materials	5.2	20.3	4.6	29.1	4.4	37.3
Repair & Maintenance	0.3	1.3	0.2	1.2	0.2	1.3
Property Tax & Insurance	1.5	5.7	0.6	4.0	0.4	3.2
Production Inventory	0.2	0.9	0.2	1.3	0.2	1.8
Other Expenses	0.4	1.4	0.2	1.5	0.1	1.2
TOTAL	25.6	100.0	15.9	100.0	11.8	100.0
Pounds of Cheese per Year	8.3 Million		25.0 Million		65.5 Million	

Table A14. Average Production Costs for Different Size Cheddar Cheese Plants with Advanced Cheddaring and Block Former Technologies Operating Various Production Schedules.

Cost Item	Plant Size (Pounds of Milk per Day)					
	480,000 (5-Days, 18-Hours)		960,000 (6-Days, 21-Hours)		2,400,000 (7-Days, 24-Hours)	
	Cost per Pound	Percentage	Cost per Pound	Percentage	Cost per Pound	Percentage
	(Cents)	(%)	(Cents)	(%)	(Cents)	(%)
Labor						
Supervisory	1.3	4.6	0.5	3.3	0.2	2.0
Direct Fixed	1.4	5.1	0.6	3.6	0.3	2.4
Direct Variable	8.8	32.5	5.3	32.4	2.6	24.7
Total Labor	11.4	42.2	6.4	39.3	3.1	29.2
Capital Costs						
Depreciation & Interest	5.7	21.0	2.5	15.1	1.2	11.4
Utilities						
Electricity	0.3	1.2	0.2	1.4	0.1	1.4
Fuel	1.7	6.2	1.2	7.4	1.0	9.4
Water & Sewage	0.2	0.8	0.1	0.7	0.1	0.7
Total Utilities	2.2	8.2	1.5	9.4	1.2	11.4
Materials						
Laboratory	0.1	0.3	0.1	0.4	0.1	0.5
Production	2.9	10.7	2.9	17.7	2.9	27.1
Packaging	1.2	4.4	1.2	7.3	1.2	11.1
Cleaning	1.0	3.8	0.4	2.6	0.2	1.9
Total Materials	5.2	19.3	4.6	28.0	4.4	40.7
Repair & Maintenance	0.3	1.2	0.2	1.2	0.1	1.1
Property Tax & Insurance	1.6	6.0	0.7	4.3	0.3	3.2
Production Inventory	0.2	0.8	0.2	1.3	0.2	1.9
Other Expenses	0.4	1.3	0.2	1.4	0.1	1.1
TOTAL	27.0	100.0	16.4	100.0	10.7	100.0
Pounds of Cheese per Year	8.3 Million		25.0 Million		87.4 Million	

Table A15. Average Production Costs in Different Size Cheddar Cheese Plants with Different Production Technologies, Operating 24 Hours per Day and 7 Days per Week.

Production Technology	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Cents per Pound of Cheese)					
Standard Cheddaring						
Regular 40-Pound	25.5	19.8	17.3	14.7	13.2	11.8
640/40-Pound & Cut.	23.7	18.5	16.4	13.9	12.8	11.5
Block Former	23.1	18.6	16.5	14.1	12.7	11.5
Automatic Cheddaring						
Regular 40-Pound	24.3	18.7	16.2	13.6	12.4	11.1
640/40-Pound & Cut.	22.5	17.4	15.3	12.9	12.0	10.8
Block Former	21.9	17.5	15.4	13.0	11.9	10.8
Advanced Cheddaring						
Regular 40-Pound	24.2	18.4	16.0	13.5	12.3	11.0
640/40-Pound & Cut.	22.3	17.2	15.1	12.8	11.9	10.7
Block Former	21.8	17.2	15.2	12.9	11.8	10.7
Standard Stirred Curd						
Regular 40-Pound	23.7	18.2	15.8	13.5	12.2	11.1
640/40-Pound & Cut.	21.8	16.9	14.9	12.7	11.8	10.8
Block Former	21.3	17.0	15.0	12.9	11.8	10.8
Advanced Stirred Curd						
Regular 40-Pound	23.3	17.9	15.6	13.3	12.2	n.a.
640/40-Pound & Cut.	21.4	16.6	14.7	12.5	11.8	n.a.
Block Former	20.9	16.7	14.7	12.7	11.8	n.a.

n.a. = not applicable

Table A16. Average Production Costs in Different Size Cheddar Cheese Plants with Different Production Technologies, Operating 24 Hours per Day and 6 Days per Week.

Production Technology	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Cents per Pound of Cheese)					
Standard Cheddaring						
Regular 40-Pound	25.9	20.1	17.6	14.9	13.4	12.0
640/40-Pound & Cut.	24.2	18.9	16.8	14.2	13.1	11.8
Block Former	23.6	18.9	16.8	14.3	13.0	11.7
Automatic Cheddaring						
Regular 40-Pound	24.8	19.1	16.6	13.9	12.6	11.3
640/40-Pound & Cut.	23.0	17.9	15.7	13.2	12.3	11.1
Block Former	22.4	17.9	15.7	13.3	12.2	11.1
Advanced Cheddaring						
Regular 40-Pound	24.7	18.8	16.4	13.8	12.6	11.2
640/40-Pound & Cut.	22.4	17.6	15.5	13.1	12.2	11.0
Block Former	22.3	17.7	15.5	13.2	12.1	10.9
Standard Stirred Curd						
Regular 40-Pound	24.1	18.5	16.1	13.7	12.5	11.3
640/40-Pound & Cut.	22.4	17.3	15.3	13.0	12.1	11.0
Block Former	21.7	17.3	15.3	13.2	12.0	11.0
Advanced Stirred Curd						
Regular 40-Pound	23.7	18.2	15.9	13.5	12.5	n.a.
640/40-Pound & Cut.	22.0	17.0	15.0	12.8	12.1	n.a.
Block Former	21.4	17.1	15.1	13.0	12.0	n.a.

n.a. = not applicable

Table A17. Average Production Costs in Different Size Cheddar Cheese Plants with Different Production Technologies, Operating 24 Hours per Day and 5 Days per Week.

Production Technology	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Cents per Pound of Cheese)					
Standard Cheddaring						
Regular 40-Pound	26.6	20.6	18.1	15.3	13.8	12.3
640/40-Pound & Cut.	24.9	19.5	17.3	14.6	13.5	12.1
Block Former	24.2	19.5	17.2	14.7	13.3	12.1
Automatic Cheddaring						
Regular 40-Pound	25.5	19.6	17.1	14.3	13.0	11.6
640/40-Pound & Cut.	23.9	18.5	16.3	13.7	12.7	11.5
Block Former	23.2	18.5	16.2	13.8	12.5	11.4
Advanced Cheddaring						
Regular 40-Pound	25.4	19.4	16.9	14.2	12.9	11.5
640/40-Pound & Cut.	23.8	18.3	16.1	13.6	12.6	11.3
Block Former	23.1	18.3	16.1	13.7	12.5	11.3
Standard Stirred Curd						
Regular 40-Pound	24.7	19.0	16.6	14.1	12.8	11.6
640/40-Pound & Cut.	23.1	17.9	15.8	13.4	12.5	11.4
Block Former	22.4	17.9	15.7	13.5	12.4	11.3
Advanced Stirred Curd						
Regular 40-Pound	24.4	18.7	16.4	13.9	12.8	n.a.
640/40-Pound & Cut.	22.8	17.6	15.6	13.3	12.5	n.a.
Block Former	22.1	17.6	15.5	13.4	12.4	n.a.

n.a. = not applicable

Table A18. Average Production Costs in Different Size Cheddar Cheese Plants with Different Production Technologies, Operating 21 Hours per Day and 7 Days per Week.

Production Technology	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Cents per Pound of Cheese)					
Standard Cheddaring						
Regular 40-Pound	26.6	20.6	18.0	15.3	13.7	12.2
640/40-Pound & Cut.	24.9	19.4	17.2	14.5	13.4	12.0
Block Former	24.3	19.4	17.2	14.7	13.2	12.0
Automatic Cheddaring						
Regular 40-Pound	25.5	19.5	17.0	14.2	12.9	11.5
640/40-Pound & Cut.	23.7	18.4	16.1	13.5	12.5	11.3
Block Former	23.1	18.4	16.1	13.6	12.4	11.3
Advanced Cheddaring						
Regular 40-Pound	25.4	19.3	16.8	14.1	12.8	11.4
640/40-Pound & Cut.	23.6	18.1	15.9	13.4	12.5	11.2
Block Former	23.0	18.2	15.9	13.6	12.4	11.2
Standard Stirred Curd						
Regular 40-Pound	24.8	19.0	16.5	14.0	12.7	11.5
640/40-Pound & Cut.	23.0	17.8	15.7	13.3	12.4	11.3
Block Former	22.4	17.8	15.7	13.5	12.3	11.2
Advanced Stirred Curd						
Regular 40-Pound	24.4	18.7	16.3	13.8	12.8	n.a.
640/40-Pound & Cut.	22.7	17.5	15.4	13.1	12.4	n.a.
Block Former	22.0	17.5	15.5	13.3	12.3	n.a.

n.a. = not applicable

Table A19. Average Production Costs in Different Size Cheddar Cheese Plants with Different Production Technologies, Operating 21 Hours per Day and 6 Days per Week.

Production Technology	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Cents per Pound of Cheese)					
Standard Cheddaring						
Regular 40-Pound	27.2	21.0	18.4	15.6	14.0	12.5
640/40-Pound & Cut.	25.5	19.9	17.6	14.9	13.7	12.3
Block Former	24.8	19.9	17.6	15.0	13.6	12.3
Automatic Cheddaring						
Regular 40-Pound	26.1	20.0	17.4	14.6	13.2	11.8
640/40-Pound & Cut.	24.5	18.9	16.6	13.9	12.9	11.6
Block Former	23.8	18.9	16.6	14.0	12.8	11.6
Advanced Cheddaring						
Regular 40-Pound	26.0	19.8	17.2	14.5	13.2	11.7
640/40-Pound & Cut.	24.4	18.7	16.4	13.8	12.9	11.5
Block Former	23.7	18.7	16.4	13.9	12.7	11.5
Standard Stirred Curd						
Regular 40-Pound	25.3	19.4	16.9	14.4	13.0	11.7
640/40-Pound & Cut.	23.7	18.3	16.1	13.7	12.7	11.6
Block Former	23.0	18.3	16.1	13.8	12.6	11.5
Advanced Stirred Curd						
Regular 40-Pound	25.0	19.1	16.7	14.2	13.1	n.a.
640/40-Pound & Cut.	23.3	18.0	15.9	13.5	12.8	n.a.
Block Former	22.6	18.0	15.9	13.6	12.6	n.a.

n.a. = not applicable

Table A20. Average Production Costs in Different Size Cheddar Cheese Plants with Different Production Technologies, Operating 21 Hours per Day and 5 Days per Week.

Production Technology	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Cents per Pound of Cheese)					
Standard Cheddaring						
Regular 40-Pound	27.9	21.6	18.9	16.0	14.4	12.9
640/40-Pound & Cut.	26.5	20.7	18.2	15.4	14.2	12.8
Block Former	25.6	20.5	18.1	15.5	14.0	12.7
Automatic Cheddaring						
Regular 40-Pound	27.0	20.7	18.0	15.0	13.6	12.2
640/40-Pound & Cut.	25.5	19.7	17.3	14.5	13.4	12.1
Block Former	24.7	19.6	17.2	14.5	13.2	12.0
Advanced Cheddaring						
Regular 40-Pound	26.9	20.5	17.8	15.0	13.6	12.1
640/40-Pound & Cut.	25.5	19.5	17.1	14.4	13.4	12.0
Block Former	24.6	19.4	17.0	14.5	13.2	11.9
Standard Stirred Curd						
Regular 40-Pound	26.1	20.0	17.4	14.8	13.4	12.1
640/40-Pound & Cut.	24.6	19.0	16.7	14.2	13.2	12.0
Block Former	23.8	18.9	16.6	14.5	13.0	11.9
Advanced Stirred Curd						
Regular 40-Pound	25.8	19.8	17.2	14.6	13.5	n.a.
640/40-Pound & Cut.	24.3	18.8	16.5	14.1	13.3	n.a.
Block Former	23.5	18.7	16.4	14.1	13.1	n.a.

n.a. = not applicable

Table A21. Average Production Costs in Different Size Cheddar Cheese Plants with Different Production Technologies, Operating 18 Hours per Day and 7 Days per Week.

Production Technology	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Cents per Pound of Cheese)					
Standard Cheddaring						
Regular 40-Pound	28.3	21.9	19.1	16.1	14.5	12.9
640/40-Pound & Cut.	26.7	20.8	18.3	15.5	14.2	12.8
Block Former	26.0	20.8	18.3	15.6	14.1	12.7
Automatic Cheddaring						
Regular 40-Pound	27.3	20.9	18.1	15.1	13.7	12.2
640/40-Pound & Cut.	25.7	19.8	17.3	14.5	13.4	12.1
Block Former	24.9	19.8	17.3	14.6	13.3	12.0
Advanced Cheddaring						
Regular 40-Pound	27.2	20.7	17.9	15.1	13.6	12.1
640/40-Pound & Cut.	25.6	19.6	17.1	14.4	13.4	12.0
Block Former	24.9	19.6	17.1	14.5	13.2	11.9
Standard Stirred Curd						
Regular 40-Pound	26.5	20.2	17.5	14.9	13.5	12.1
640/40-Pound & Cut.	24.9	19.2	16.8	14.3	13.2	12.0
Block Former	24.1	19.1	16.7	14.4	13.1	11.9
Advanced Stirred Curd						
Regular 40-Pound	26.1	20.0	17.3	14.7	13.5	n.a.
640/40-Pound & Cut.	24.5	18.9	16.6	14.1	13.3	n.a.
Block Former	23.8	18.8	16.5	14.2	13.1	n.a.

n.a. = not applicable

Table A22. Average Production Costs in Different Size Cheddar Cheese Plants with Different Production Technologies, Operating 18 Hours per Day and 6 Days per Week.

Production Technology	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Cents per Pound of Cheese)					
Standard Cheddaring						
Regular 40-Pound	29.0	22.4	19.6	16.5	14.8	13.2
640/40-Pound & Cut.	27.6	21.5	18.9	16.0	14.7	13.2
Block Former	26.8	21.4	18.8	16.0	14.5	13.1
Automatic Cheddaring						
Regular 40-Pound	28.1	21.5	18.6	15.6	14.1	12.6
640/40-Pound & Cut.	26.6	20.5	17.9	15.0	13.9	12.5
Block Former	25.8	20.4	17.8	15.1	13.7	12.4
Advanced Cheddaring						
Regular 40-Pound	28.0	21.3	18.4	15.5	14.0	12.5
640/40-Pound & Cut.	26.6	20.4	17.8	15.0	13.9	12.4
Block Former	25.8	20.2	17.7	15.0	13.7	12.3
Standard Stirred Curd						
Regular 40-Pound	27.1	20.8	18.0	15.3	13.9	12.5
640/40-Pound & Cut.	25.7	19.8	17.3	14.8	13.7	12.4
Block Former	24.9	19.7	17.3	14.8	13.5	12.3
Advanced Stirred Curd						
Regular 40-Pound	26.8	20.5	17.8	15.1	13.9	n.a.
640/40-Pound & Cut.	25.4	19.6	17.1	14.6	13.8	n.a.
Block Former	24.5	19.4	17.1	14.6	13.6	n.a.

n.a. = not applicable

Table A23. Average Production Costs in Different Size Cheddar Cheese Plants with Different Production Technologies, Operating 18 Hours per Day and 5 Days per Week.

Production Technology	Plant Size (Pounds of Milk per Day)					
	480,000	720,000	960,000	1,440,000	1,800,000	2,400,000
	(Cents per Pound of Cheese)					
Standard Cheddaring						
Regular 40-Pound	30.1	23.2	20.2	17.1	15.4	13.7
640/40-Pound & Cut.	28.8	22.4	19.7	16.7	15.3	13.8
Block Former	27.8	22.2	19.5	16.7	15.0	13.6
Automatic Cheddaring						
Regular 40-Pound	29.2	22.4	19.4	16.2	14.6	13.1
640/40-Pound & Cut.	28.0	21.6	18.8	15.8	14.6	13.1
Block Former	27.0	21.4	18.7	15.7	14.3	12.9
Advanced Cheddaring						
Regular 40-Pound	29.3	22.2	19.2	16.1	14.6	13.0
640/40-Pound & Cut.	28.0	21.4	18.7	15.7	14.6	13.0
Block Former	27.0	21.2	18.5	15.7	14.3	12.9
Standard Stirred Curd						
Regular 40-Pound	28.2	21.6	18.7	15.9	14.4	13.0
640/40-Pound & Cut.	26.9	20.8	18.2	15.5	14.3	13.0
Block Former	25.9	20.6	18.0	15.4	14.1	12.8
Advanced Stirred Curd						
Regular 40-Pound	27.9	21.3	18.5	15.7	14.5	n.a.
640/40-Pound & Cut.	26.6	20.5	18.0	15.3	14.4	n.a.
Block Former	25.6	20.3	17.8	15.3	14.2	n.a.

n.a. = not applicable