

Comparison of the Economics of Cheddar Cheese Manufacture by Conventional and Milk Fractionation/ Concentration Technologies

by

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Part 5 of a Research Effort on Cheddar Cheese Manufacturing
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PREFACE

Richard D. Aplin, David M. Barbano, and Susan J. Hurst are Professor of Agricultural Economics, Associate Professor of Food Science, and research associate, Department of Agricultural Economics; New York State College of Agriculture and Life Sciences, Cornell University, respectively.

This publication is the fifth in a series of publications on Cheddar Cheese manufacturing costs. The series of publications reports the results of a major research effort aimed at helping to answer questions such as the following:

1. 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?
2. 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?
3. 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?
4. How large a cost advantage do large Cheddar cheese plants have over smaller-scale plants?
5. 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?
6. What are the costs and relative profitability of producing whey powder and whey protein concentrate? What are key factors affecting the costs of producing these whey products?
7. What would be the impact on manufacturing costs and profits of using milk fractionation and concentration processes (i.e., ultrafiltration, reverse osmosis and evaporation) in Cheddar cheese plants?

This publication focuses on question #7 above. It reports the results of using the economic-engineering approach to evaluate the potential impacts of using four in-plant milk fractionation/concentration technologies on the costs and profitabilities of producing Cheddar cheese, whey powder, and whey protein concentrate.

Questions 1 through 6 above are addressed in earlier publications which involved the study of 11 plants operating in the

Northeast and North Central regions. The study of the 11 plants is reported in a 1987 publication entitled "Economic Performance of 11 Cheddar Cheese Manufacturing Plants in Northeast and North Central Regions." Data from these plants were used as part of the base for an economic-engineering study with the results reported in "Cheddar Cheese Manufacturing Costs -- Economies of Size and Effects of Difference Current Technologies," also issued in 1987.

The feasibility and potential profitability of producing specialty cheeses, such as Jarlsberg and Havarti, in modified Cheddar cheese plants as well as in plants designed to produce only specialty cheese was reported in a July 1989 publication entitled "Diversification of the Cheddar Cheese Industry Through Specialty Cheese Production."

The costs and profitabilities of handling sweet whey and manufacturing whey powder and whey protein concentrate under various production and market conditions were reported in an April 1990 publication entitled "Whey Powder and Whey Protein Concentrate Production Technology, Costs and Profitability".

The results of the research on Cheddar and on whey products production will be merged to examine the costs and profitability of integrated cheese and whey operations under various operating and revenue conditions. The publication reporting the combined Cheddar and whey operations should be available early in 1992.

Financial assistance for the overall cheese manufacturing cost project has been provided from four sources: 1) Agricultural Cooperative Service of the United States Department of Agriculture, 2) New York State Department of Agriculture and Markets, 3) New York State's dairy farmers through the New York State Milk Promotion Order, and 4) the Wisconsin Milk Marketing Board. The funding provided by the Wisconsin Milk Marketing Board focused on the research of milk fractionation/concentration technologies which is reported in this publication. In addition, funds to publish much of the research were partially provided by the Cornell Program on Dairy Markets and Policy, through a grant from 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, with broad experience in various industries including cheese, to provide much of the information needed to budget costs. On the research reported in this publication, we actually worked with Daniel Surfus of Mead & Hunt, Inc. Several dairy equipment companies provided cost and engineering data on general dairy equipment.

We also wish to thank several of our colleagues at Cornell. Scott McPherson helped write the computer programs needed for data analysis. Mary Jo DuBrava made significant contributions to the typing of the publication.

Constructive criticisms of the manuscript were made by some of our colleagues in the Department of Agricultural Economics and a number of people in industry.

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DIGEST AND HIGHLIGHTS

Objectives and Methodology

The principal objective of this study was to evaluate the potential impacts of using four in-plant milk fractionation/concentration technologies on the costs and profitabilities of producing Cheddar cheese, whey powder, and whey protein concentrate (WPC). The four technologies were low concentration factor (1.5X) ultrafiltration (UF), 1.2X reverse osmosis (RO), 1.2X evaporation, and medium concentration factor (6.5X) UF. In addition, the savings a cheese plant might realize by using milk which was fractionated using 2X UF at the farm was estimated. Based on processing research using these technologies, the concentration factors were selected to reflect approaches that have been demonstrated to be technically feasible.

The economic engineering or synthetic costing approach was used to estimate cheese and whey manufacturing costs for four plant sizes with each milk fractionation or concentration technology. The same plant sizes were modeled for conventional cheese and whey processing plants for comparison. Manufacturing costs estimated using the economic engineering approach indicate what could be expected with new plants, engineered and performing to achievable standards. Performance in an actual plant would vary with quality of management and labor, actual prices paid for fixed and variable inputs, milk composition and quality, and yield of products. The effect of these real-life factors could be very significant. Nevertheless, we think the cost and profitability differences among plants actually using these various milk fractionation/concentration technologies estimated by using our research approach are reliable.

Summary of Key Findings

1.5X Ultrafiltration, 1.2X Reverse Osmosis, and 1.2X Evaporation

Assuming No Increase in Cheese Yields or Milk Throughput

To form a basis for comparison with conventional cheese making technology, it was necessary to determine the impact of the 1.5X UF, the 1.2X RO, and 1.2X evaporation on cheese and whey product manufacturing costs and profitability for each plant size assuming no increased throughput or increased cheese yield is achieved. As with conventional technologies, there were large economies of scale associated with the milk fractionation/concentration technologies. However, as expected given these assumptions, the milk fractionation/concentration technologies slightly increase cheese and whey product manufacturing costs and decrease the profitability in most cases. The work to arrive at these relatively unexciting conclusions was necessary to form the basis for the next phase of the evaluation.

Assuming Increased Cheese Yields and Increased Milk Throughput Increase Cheese Yield

Increased Cheddar cheese yields are theoretically possible using 1.5X UF, 1.2X RO, and 1.2X evaporation, due to increased retention of whey solids in the cheese. Based on theoretical yield calculations, the 1.5X UF process could increase cheese yield by as much as 0.5% (from 10.16 lbs to 10.21 lbs per cwt of raw milk), and 1.2X RO and 1.2X evaporation have the potential to raise cheese yields by up to 0.8% (from 10.16 lbs to 10.24 lbs per cwt of raw milk).

If the full yield increases were realized, the increase in profits over those in a conventional plant would be sizable, resulting in fairly short payback periods and favorable internal rates of return. Even if only half the yield increase were realized, 1.2X RO would be profitable in all plant sizes studied, and 1.5X UF would be more profitable in all but the smallest plant, while 1.2X evaporation (the highest cost technology) would still be more profitable in the two largest size plants.

Increased Throughput

The use of milk fractionation/concentration technologies permits up to 10% more milk to be processed daily without requiring extensive remodeling of the downstream cheese making equipment. If the use of 1.5X UF, 1.2X RO, or 1.2X evaporation enabled a plant to process more raw milk per day and thus increase its daily cheese and whey production, the plant's total daily operating profit would be significantly higher than that of a conventional plant with the same original raw milk handling capacity. In fact, plants increasing their throughput using UF, RO or evaporation would actually be cost competitive with large conventional plants handling the same milk volume without milk fractionation/concentration technologies.

Increased Throughput and Yield

The combination of improved profitability due to increased throughput, along with increased profitability due to higher cheese yield makes all three of these technologies attractive. However, the projected benefits are based on the assumption that all cheese manufactured is of equal quality to that produced in conventional plants. The technical risks along these technologies may not be equal.

As with most other scale sensitive technologies, the larger the plant the greater the benefits from increased cheese yield and increased throughput due to these technologies. Thus, large cheese plants are in the best position to profitably adopt these technologies.

Despite the potential gains in profitability from increased cheese yields and/or increased throughput, there are two things that have much larger effects on profitability. Profitability is influenced much more by differences in plant capacities (assuming

equal operational performance) and by differences in fat retention in the cheese (which is unrelated to the milk fractionation technologies) than by using 1.5X UF, 1.2X RO, or 1.2X evaporation. However, our research suggests that if a company is going to build a new Cheddar plant, management should seriously consider incorporating a milk fractionation/concentration technology.

Cautions

The choice of a particular milk fractionation/concentration technology would be influenced by the specific conditions (i.e., plant size, permeate utilization opportunities, available milk supply, etc.) at an existing cheese plant. Differences in durability and sanitation of equipment are important factors for long-term success of any of the technologies. Evaporation might be viewed as a lower risk technology from sanitation, cheese quality, and performance achievement points of view.

6.5X Ultrafiltration

Using medium concentration factor UF (i.e., 6.5X) has the potential to increase cheese yields by 4 to 8% (i.e., from 10.16 to 10.57 or 10.97 lbs per cwt of raw milk). However, large capital investments would be required and there would be additional risks, particularly in maintaining cheese and WPC quality. The 6.5X UF system also has other technical risks. If the targeted ultrafiltration rates and capacity of milk processed per day cannot be achieved consistently (due to cleaning and fouling problems), then poor performance of the UF system will decrease overall plant profitability.

In fact, our analysis suggests that using 6.5X UF probably would have to result in a yield increase of 6% in the larger plants (i.e., 1,400,000 lbs of milk per day and higher) and approximately 8% in the smaller plants to justify the large investment involved and to compensate for the increased production risks. If these levels of yield increases were not expected to be realized, the investment payback period may be too long, and the IRR too low, to make the investment in 6.5X UF attractive to cheese plant managers.

2X Ultrafiltration on the Farm

The potential savings in manufacturing costs for a plant receiving half of its original milk solids in the form of 2X UF retentate, processed on-farm, are estimated to range from \$.062 to \$.092 per cwt of retentate depending on plant size. These savings represent the value of the retentate to the plant operator over that of the raw whole milk and would be the source of plant premiums to partially compensate producers for their higher possible on-farm costs from using UF. These cost savings for the cheese plant appear small, particularly when compared to the plant premiums that other studies have determined would be necessary to allow profitable adoption of on-farm UF by all but the largest farms.

FINAL CAUTIONS

Overall, cheese plant managers must evaluate carefully the various options to improve their businesses' profitability and make appropriate decisions based on the specific set of conditions and exceptions unique to each operation. The impacts of maximizing the efficiency of current technology should be considered carefully relative to adoption of new technology. While new technologies may offer the potential for improved economic performance, it should be realized that a business that does a poor job of managing and utilizing current technology will likely have an even more difficult time improving profits by implementation of new, more complex technologies.

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INTRODUCTION

Motivation for Study

The structure of the United States Cheddar cheese manufacturing industry has changed significantly in the last 20 years. The two major changes have been automation of the cheese manufacturing process and an increase in the average cheese manufacturing capacity of individual plants. The change in capacity has been due to both a growth in the market for cheese and a consolidation of many small cheese plants. As plant capacities and level of automation of the cheese manufacturing technology have increased, large reductions in cheese manufacturing costs have been realized. New technologies that have the potential to further reduce cheese manufacturing costs or increase cheese yields, such as milk concentration and fractionation technologies, are of great interest to the cheese industry. These are not commonly used for Cheddar cheese manufacture. However, they have the potential for improving profitability of Cheddar cheese manufacture.

Implementation of milk concentration and fractionation technologies for cheese manufacturing requires significant capital investment and changes in the manufacturing process. Therefore, cheese manufacturers are hesitant to adopt these technologies without a thorough evaluation of both the potential profitability and the technical feasibility of successful implementation. However, the results of small scale research trials using these technologies for cheese making have indicated that they can increase cheese yield. The amount of cheese yield increase can vary depending on the type of technology and the degree of concentration. Therefore, a systematic evaluation of the economic potential of the various approaches for implementation of these technologies is needed.

Evaluation of the potential impact of new technologies on manufacturing costs and profitabilities can be done using the economic engineering approach. This approach has been used to determine the effects of plant capacity, operating schedule, and different conventional Cheddar cheese manufacturing technologies on manufacturing costs and profitability (1). A similar study has been done for whey powder and whey protein concentrate manufacturing (2). The results from these studies provide an understanding of how differences in conventional cheese manufacturing technologies influence costs and profitability. The economic engineering approach can also be used to determine the potential impact of the implementation of milk concentration and fractionation technologies on cheese costs and profitability.

Overview of Concentration Methods

Vacuum evaporation and reverse osmosis (RO) are both milk concentration methods, as opposed to ultrafiltration (UF) which is a milk fractionation method. Milk concentration methods remove only water from milk, thereby concentrating all of the milk solids while ultrafiltration selectively removes a portion of the lactose and minerals as well as water from the milk. These technical differences

affect the integration of each of these technologies into the cheese manufacturing process as well as have varying affects on cheese and whey manufacturing costs and profitabilities. For example, milk concentration technologies are used to reduce milk volumes by about 20% prior to conventional cheese manufacture, while UF may be used to reduce milk volumes by a much higher percentage, depending on whether a low concentration factor or medium concentration factor approach to cheese manufacturing is used.

The milk concentration technologies evaluated in this study are 1.2X concentration of whole milk by RO or evaporation, both of which are used prior to conventional Cheddar cheese manufacture. Low concentration UF (1.5X) is primarily studied when it is used in the cheese plant itself, again prior to conventional Cheddar cheese manufacture, but a brief analysis of using low concentration factor UF on individual farms is also included. In addition, medium concentration factor UF (i.e. 6.5X) is also studied, using a continuous coagulation cheese making process. The costs and profitabilities of making Cheddar cheese with each of these technologies were in turn compared with the cost and profitability of conventional Cheddar cheese making.

STUDY OBJECTIVES

The principal objective of this phase of the research was to evaluate the potential impacts of four in-plant milk fractionation/concentration technologies on the costs and profitabilities of manufacturing Cheddar cheese, whey powder and whey protein concentrate (WPC). The technologies studied were low concentration factor (1.5X) ultrafiltration (UF), 1.2X reverse osmosis (RO), 1.2X evaporation, and medium concentration factor (6.5X) UF.

The specific objectives of the study were to:

- 1) Estimate the **manufacturing costs** for current (non-aged) Cheddar cheese and whey products for each milk fractionation/concentration technology over a range of plant sizes and compare them with the costs of manufacturing in conventional Cheddar and whey plants using no milk concentration technologies.
- 2) Compare the relative **profitabilities** of manufacturing Cheddar and whey products in plants using milk fractionation/concentration technologies with the profitabilities in conventional Cheddar and whey plants using no milk concentration technologies.
- 3) Measure the potential effects on profitability of an **increase in cheese yields** and/or an **increase in the milk volume processed**, either of which might result from using the milk fractionation/concentration technologies.

- 4) Estimate the savings in Cheddar cheese and whey product manufacturing costs that might be realized if some farmers used ultrafiltration to fractionate their milk while still on the farm.

METHODOLOGY

Overview of Cost Estimation Methodology

Because the objectives of this study required comparing costs of various technological systems not currently used in the U.S. to manufacture Cheddar cheese (at least on any broad scale), the economic-engineering approach or synthetic method was chosen as the means to estimate the Cheddar and whey product manufacturing costs. One of the key advantages of this approach is its ability to analyze systems not currently in operation but which are technically feasible.

The economic-engineering approach allows for comparisons among systems by standardizing different physical and operational characteristics. Thus, differences in costs due to technologies can be isolated from other cost influencing factors, such as plant size or operating schedule. Operational characteristics such as these can be varied systematically to determine the sensitivity of costs and profitability to each individual factor.

The economic-engineering method has been used for many years, particularly for estimating costs for new production technologies, where data from actual plant operations is insufficient or unavailable, as well as for isolating the effect of individual cost-influencing factors. However, to achieve valid cost estimations considerable knowledge, care, and experience must be used to avoid oversimplifying technical relationships or underestimating costs.

The data and insights used in this study to estimate manufacturing costs and cost differences came from several sources:

- 1) a survey of 11 actual Cheddar plants (3);
- 2) an engineering consulting firm (Mead & Hunt, Inc., Madison, Wisconsin) with considerable experience in the cheese industry;
- 3) equipment manufacturers; and
- 4) the authors' knowledge of cheese manufacturing and dairy technologies.

To ascertain the probable impact on costs and profitabilities of using the new milk fractionation/concentration technologies, model cheese and whey product plants were specified, a costing procedure defined, and production costs estimated.

The model cheese and whey plants were designed to simulate production of Cheddar cheese and either whey powder or WPC.

Production costs were estimated using the same four plant sizes for each technology as well as for the conventional operations. Cost estimates and possible revenues were analyzed to estimate the impacts of the milk fractionation/concentration technologies on profitability of Cheddar and whey operations as compared with conventional operations. Finally, the potential effects on profitability of an increase in cheese yields and/or an increase in milk volumes processed, either or both of which might result from using the milk fractionation/concentration technologies, were analyzed.

The economic-engineering approach or synthetic costing method as used in this study basically involved a four-step procedure:

- 1) Define the production process in each plant, develop process flow diagrams, and divide the production process into operating stages or centers.
- 2) Determine the specific methods and equipment to be used in operating each center. Determine the initial purchase price of all equipment as well as construction costs for each center.
- 3) Based on equipment specifications and experience, determine the amounts of each input factor (e.g. labor, utilities, supplies, maintenance, etc.) needed for each center and convert these physical quantities into monetary terms.
- 4) Sum the production costs for each operating center along with overall expenses not associated with any one center (e.g. communications, travel, telephone, etc.). These summed costs represent the total cost of production for each plant. In this analysis, total production costs were then reduced to an average cost per hundredweight (cwt) of raw milk processed.

This study of the impacts of milk fractionation/concentration technologies was greatly facilitated by the previous research done by the authors and their colleagues on Cheddar cheese (1) and whey product manufacturing (2). The economic-engineering approach was used in both these earlier studies to estimate costs and profitabilities f&w manufacturing Cheddar cheese and whey products using conventional technologies with no milk fractionation or concentration.

Thus, to adapt the programs developed in the earlier research to this study, a key factor was identifying the additional center(s) necessary when adding a specific milk fractionation or concentration technology (in most cases only the concentration center itself) to a conventional Cheddar plant. Also required was identifying modifications needed in other cheese or whey plant centers as a result of incorporating the new technology. In short, the conventional cheese and whey operations modeled in the earlier studies were modified to include UF, RO or evaporation of the milk before processing. Once these modifications were identified, cost estimations were made using the four step economic-engineering approach along with updating factor prices for each center.

The cost estimations for the previously modeled conventional plants were also updated to current factor price levels for each center to provide an accurate base for comparisons. Thus, the impacts of milk fractionation or concentration technologies on production costs per cwt of raw milk were estimated by comparing estimated costs in the modified plants to estimated production costs for the conventional cheese and whey plants.

Model Plant Specifications

General Cheddar Cheese Plant Specifications

Regardless of milk concentration and fractionation technologies, all model Cheddar cheese manufacturing plants are based on four milk manufacturing capacities: 720,000; 960,000; 1,440,000; and 2,400,000 lbs of milk per day. All plants are designed to process the same quantity of milk per hour and per day as conventional plants of the same size, again regardless of the fractionation/concentration technology used. Plant capacity is based upon a plant operating 7 days per week, 24 hours per day schedule. A total of nine possible operating schedules were studied, 5, 6, or 7 days per week and 18, 21, or 24 hours per day (Table 1). The combination of a weekly and daily schedule results in a level of capacity utilization. Whey plants are assumed to operate on the same schedule as the Cheddar plants.

In the basic scenario, cheese yields are assumed to be the same for all technologies except for the medium concentration factor (6.5X) UF. This results in the same quantity of cheese produced per hour and per day in all plants of the same capacity. This provides an equal basis for comparison of differences in manufacturing costs due to using milk fractionation/concentration technologies.

In later scenarios for 1.5X UF, 1.2X RO, and 1.2X evaporation, cheese yields are increased up to 0.8% (depending on the technology) and milk throughput volumes are increased 10%. This maximum 10% increase in milk throughput was based on the 10% tolerance typically built into cheese making equipment for handling seasonal changes in milk composition which temporarily increase cheese yields per unit volume of milk. However, in the base analyses, milk volumes processed and quantities of Cheddar cheese produced are assumed to remain the same in plants using 1.5X UF, 1.2X RO, and 1.2X evaporation technologies as in conventional Cheddar plants of the same size. Cheese yields resulting from the 6.5X UF are assumed to increase 4% to 8%.

All general Cheddar cheese plant specifications and construction are the same as reported in a previous study of conventional Cheddar cheese manufacturing costs (1). In that study, each cheese plant was modeled as a series of operating centers which collectively represented an entire cheese plant. Based on that information, the Cheddar cheese manufacturing method chosen for this study (for all milk fractionation/concentration technologies, except

Table 1 Percent Plant Capacity Utilization for Cheddar Cheese and Whey Operations with Different Production Schedules.

Daily Schedule ¹	Weekly Schedule		
	7 days	6 days	5 days
	Percent of Capacity Utilization		
24 hours	100	86	71
21 hours	83	71	60
18 hours	67	57	48

¹ Plant milk filling time in a 24 hour day is 18.5 hours; in a 21 hour day, 15.4 hours; and in a 18 hour day, 12.3 hours. Clean-up time is assumed to be 4 hours per day regardless of operating schedule.

6.5X UF) was standard stirred curd, packaged as 640 lb blocks. All plants are designed to produce a non-aged Cheddar cheese, using a microbial rennet. Cheese quality is assumed to remain constant regardless of plant capacity or the use of milk fractionation/concentration technologies. All plants are designed with cold storage facilities to hold 10 days of cheese inventory, with no aging facilities.

Except for 6.5X UF (which will be discussed in a following section), all cheese plants using milk fractionation/concentration technologies are modeled with two whey plant scenarios: one producing human food grade whey powder, the other producing 34.5% whey protein concentrate. The general specifications and construction of these whey plants were also taken from previous economic engineering research (2). Very little modification of the conventional whey plants was necessary to accompany cheese plants using milk fractionation/concentration technologies.

Low Concentration Factor UF (1.5X)

To model these plants a UF center was added to each of the four sizes of conventional Cheddar cheese plants taken from the previous research. This milk fractionation center was designed to contain the UF equipment, as well as the CIP equipment necessary for cleaning the UF system. The UF equipment itself consists of spiral wound polyethersulfone UF membranes in a multistage system. The number of UF modules per stage and the number of stages in the system vary with plant capacity. The 720,000 lbs per day plant was designed with a 2 stage UF system with 18 modules per stage. The largest plant modeled (2,400,000 lbs of milk per day) required a 3 stage UF system with 30 modules per stage. UF membrane life was assumed to be 12 months.

The milk fractionation center was designed to receive milk directly from the pasteurizer at a temperature of 120°F. After

fractionation into retentate and permeate, the retentate is cooled to 88°F before entering conventional cheese vats. Because cheese production per hour and per day are assumed to remain the same as in a conventional operation, the cheese vats are only partially filled with retentate. If they were filled to capacity with retentate, more cheese per vat would be produced and the conventionally sized, down-stream equipment would not be able to handle the additional cheese. By only partially filling the vats, cheese production per vat remains the same as in a conventional operation and no remodeling or enlarging of the cheese making equipment is required. Thus, after the retentate enters the vats, the cheese is produced in exactly the same fashion using the same down-stream equipment as a conventional plant, with both assumed to use the standard stirred curd manufacturing process.

To produce human food grade whey powder in plants designed to accompany 1.5X UF cheese plants, all of the UF permeate produced in the cheese plant must first be recombined with the whey from cheese making. Once this is done, the resulting whey (at this point identical to whey from a conventional cheese plant) can be concentrated and dried in a conventional whey powder plant. No additional whey plant equipment is needed, only piping for bringing the permeate into the whey plant.

Whey plants producing 34.5% WPC were also designed to accompany the 1.5X UF cheese plants. These plants are also almost identical to standard WPC plants with one exception. The UF systems are slightly smaller due to some of the permeate having already been removed in the UF process in the cheese plant.

Due to the variety of ways that permeate can be handled (depending on plant size, location, and market conditions), UF permeate produced by the milk fractionation system is assumed to breakeven, with any handling or processing costs covered by revenues generated from the sale of the processed permeate. This assumption was also used for permeate produced in WPC plants. Thus, no specific permeate holding or processing equipment is included in the cheese or whey plants. However, this study does include a sensitivity analysis on the effects of potential losses or gains from UF permeate on overall cheese and whey profitability.

Reverse Osmosis (1.2X)

Similarly to the 1.5X UF scenarios, the 1.2X RO plants were modeled by adding a concentration center with a RO unit to the same four sizes of conventional Cheddar plants. This center would also receive whole milk directly from the pasteurizer at 120°F and deliver 88°F retentate to the cheese vats. It is not necessary to separate the milk before using 1.2X RO if the system back pressure regulator is modified to reduce the shearing of milk fat globules (4). In contrast to the 1.5X UF process, however, the milk volume with 1.2X RO is only reduced 20%. Thus, since the 1.2X RO retentate is not as concentrated as 1.5X UF retentate, the vats will be filled more fully, but still not to the same volume as vats in a conventional plant. Here again the objective was to maintain cheese production at

the same rate per hour and per day as in a conventional cheese plant of the same size, with no changes in the down-stream cheese making equipment.

The RO system itself uses polyamide membranes, again with an assumed membrane lifespan of 12 months. As with the UF unit, the size of the RO unit varies with the plant capacity. The concentration center also contains all CIP equipment necessary for cleaning the RO unit.

As the RO permeate is virtually pure water extracted from the milk, a portion of this "cow water" is reused to make cleaning solutions for use by the CIP system for the RO unit.

The whey powder plants modeled to accompany 1.2X RO cheese plants have the same equipment as a conventional whey plants, however, their utilities are slightly less per cwt of raw milk than for whey plants accompanying conventional cheese plants. This is due to some of the water having already been removed from the whey during the RO process. Thus, less energy is required in the whey plant to produce the whey powder.

Whey plants producing 34.5% WPC were also designed to accompany the 1.2X RO cheese plants. Like the WPC plants accompanying the 1.5X UF cheese plants, these WPC plants are also almost identical to standard WPC plants. Here again though, the UF systems are slightly smaller due to some of the water having already been removed in the RO process in the cheese plant.

Evaporation (1.2X)

These model plants are the same as the 1.2X RO plants except that in this case the concentration center contains a thermocompression vacuum evaporator. In the two smaller plants modeled (720,000 and 960,000 lbs of milk per day), the evaporators each have two evaporator sections, two separator sections and one extraction pump. The evaporators in the two larger plants (1,440,000 and 2,400,000 lbs of milk per day) each have three evaporator sections, three separator sections and two extraction pumps. CIP equipment for the system is also included in this center.

Again, the concentration system lies between the pasteurizer and the cheese vats, receiving 120°F milk and concentrating it through evaporation to 1.2X before delivering the concentrate to the cheese vats at 88°F. It would be also possible to eliminate the pasteurizer and incorporate the heating of the milk to full pasteurization temperature and a holding tube directly in the evaporator system. This would be slightly more efficient than having a sperate pasteurizer evaporator. The cheese vats are filled to the same level as used in the RO plants, since the same concentration factors are assumed for RO and evaporation. This allows the down-stream equipment to remain the same size as in a conventional cheese plant, with cheese making proceeding as usual with the standard stirred curd manufacturing process, packaged into 640 lb blocks.

Since both the evaporation and RO scenarios have the same concentration factor, (1.2X), the whey powder and WPC plants modeled to accompany the 1.2X evaporation plants are identical to those designed for the 1.2X RO plants, both in terms of equipment and utility usage.

Medium Concentration Factor UF (6.5X)

These model plants are very different from the previous plants discussed, requiring more than the simple addition of a concentration or fractionation center for implementation. While the cheese plants are still designed to handle the same volumes of milk per day as the four model conventional plants, using 6.5X UF is assumed to increase cheese yields from 4% to 8%. Thus, instead of 10.16 lbs of cheese per cwt of raw milk, (the assumed yield in the conventional plants) cheese yields in plants using 6.5X UF are assumed to range from 10.57 to 10.97 lbs per cwt. This increase in cheese yields is due to increased retention of nonfat solids, which normally escape in the whey. This increase of nonfat solids, however, must be balanced by an increase in the fat content of the milk to maintain the proper ratio of fat to solids in the cheese.

This is done by adding fresh cream to the milk, standardizing it to 3.87%, 3.94%, or 4.00% fat depending on the assumed increase in cheese yield (4%, 6%, or 8%, respectively). To do this, however, necessitates adding cream storage tanks and standardizing equipment in the receiving center. (All other model plants for both conventional cheese operations as well as those using concentration/fractionation technologies are assumed to use non-standardized milk averaging 3.7% fat.) The standardized milk is pasteurized and then cooled to 120°F before being pumped to the UF system.

Due to the much higher concentration factor, the UF systems are considerably larger than those modeled for the 1.5X UF plants. Again, each system varies by plant size. To achieve approximately a 6.5X concentration factor, the UF systems range from a 3 stage unit with 108 modules for the 720,000 lb plant to 9 stages with 324 modules for the 2,400,000 lb plant. Membrane lifespan is again assumed to be 12 months.

Another difference in the 6.5X UF plants is that instead of starter media, 10% of the previous day's retentate is used to grow the starter culture for the current day's cheese production. Thus, once the UF process is begun each day, the first 10% of the retentate produced is diverted to the starter center, where it is inoculated and fermented for use the next day.

The remaining 90% of the retentate is cooled to 98°F and fed directly into a continuous coagulator, where it is mixed with rennet and the fermented retentate. The size of the continuous coagulator ("Alcurd") equipment also varies with plant size. For the 720,000 lb plant one continuous coagulator is required, compared to three necessary for the largest plant (2,400,000 lbs). Each continuous coagulator consists of a dosing pump (three heads), two flow meters,

two in-line mixers, a cutting unit, power supply and controls. Concentrate storage and CIP equipment are also included in the continuous coagulator centers.

Once the cheese curds leave the coagulator (at 98°F), they are transferred to a modified draining, matting and cheddaring (DMC) system where they undergo syneresis and begin the automatic cheddaring process (as opposed to the standard stirred curd process assumed in the other scenarios modeled). The finished cheese is milled, salted and packaged in 640 lb blocks just as in the other model plants, however. Cheese quality is also assumed to remain the same as in conventional plants.

The composition of the "whey" that drains from the cheese curds in the modified DMC is very different than normal cheese whey. It has a protein content of 40% to 44% (expressed as a percent of total solids). Once the whey cream is removed by separation, the remaining concentrated liquid "whey" is diluted using UF permeate obtained from the cheese plant. This "whey" is diluted with the permeate to 34.5% protein level (as a percent of total solids) and then dried, producing a standard 34.5% WPC. As in the 1.5X UF plants modeled, the remaining UF permeate is assumed to breakeven.

If the "whey" was not diluted with permeate before being dried, the resulting WPC would have a higher protein content than the standard 34.5% and be a unique product, for which there is no preexisting market or market price. No UF system is needed in these WPC plants, as the "whey" is already fractionated due to the UF process in the cheese plants. No options for producing whey powder are considered, due to the large differences in whey composition as compared to whey normally derived from Cheddar cheese manufacture.

As an indirect benefit, using 6.5X UF may improve cheese quality consistency through the required use of milk standardization and the emphasis on quality control. However, this depends almost entirely on plant management.

Cost Estimation

Introduction

The monetary costs involved in processing Cheddar cheese and whey products are a function of the physical quantities of the resources used and the prices which must be paid to obtain these production factors. For valid results, the economic-engineering or synthetic costing technique requires detailed information on the input-output relationships of production and on the prices of the resources used in the manufacturing process.

This section presents the methods used to determine production costs for the cheese and whey product plants. Assumptions concerning raw materials and composition of outputs are discussed, along with the data sources. Finally, production cost items and methods of calculating costs are described.

Assumptions

Certain assumptions were made so that valid comparisons of manufacturing costs could be drawn among plants using the various milk fractionation/concentration technologies. The assumptions concern inputs, outputs, and production techniques for all model plants.

The costs per unit of inputs for the cheese and whey product processing were held constant across all plants.

It is assumed that operations of each of the model cheese and whey plants reflect good management practices. Plants are assumed to operate at high but achievable levels of efficiency with respect to input usage and product yields. The assumptions on milk composition (fat, protein, and total solids), and product yields are shown in Table 2 for the plants using 1.5X UF, 1.2X RO, and 1.2X evaporation as well as the so-called conventional plants. The assumed yields for the medium concentration factor (6.5X) plant can be found in the later section that focuses on that technology. All cheese and whey product yields reflect conditions in Wisconsin, based on an extensive 1984 milk composition study (5).

Data Sources

Data used to estimate cheese and whey manufacturing costs were obtained from several sources. Mead & Hunt, Inc. of Madison, Wisconsin, an engineering consulting firm with extensive experience in the cheese industry, provided the technical coefficients used in this study. Prices and specifications for major pieces of equipment were obtained by Mead & Hunt, Inc. from equipment manufacturers. Information provided by these consulting engineers included cost information on land, building structures, production equipment, labor requirements, utility demands, and other expenses. Mead & Hunt, Inc. also compiled the technical data on the Cheddar cheese and whey product plants, modeled in the earlier studies (1, 2), which were updated and modified for use in this study.

Industry suppliers provided cost data on production materials and cleaning supplies, as well as other inputs.

Land, Building & Equipment Costs

Engineering consultants determined the amount of land necessary for construction of each plant, including space for employee parking, truck parking and turn-arounds. Additional land and building space required for adding milk fractionation-concentration technologies were taken into account and included in the manufacturing cost estimation. Land purchase costs were assumed to be \$31,000 per acre. Rough and finish grading, paving, landscaping, underground utility installation, and engineering fees were estimated at an additional \$33,000 per acre.

Table 2 Average Milk Composition (Wisconsin), and Assumed Dairy Product Yields for Cheddar & Whey Products

	No Concentration, 1.5X UF, 1.2X RO, & 1.2X Evaporation
Milk Composition ¹	
Percent Fat	3.68
Percent Protein	3.27
Cheddar Yield (Lbs Per Cwt Raw Milk)	10.16
40% Whey Cream Yield (Lbs Cream Per Cwt Raw Milk) ²	.58
34.5% Protein WPC (Lbs Per Cwt Raw Milk)	1.64
Whey Powder (Lbs Per Cwt Raw Milk)	5.80

¹ Milk composition based on 1984 Wisconsin survey.

² Assumes 93% fat retention in the cheese and 90% recovery of the fat not recovered in the cheese for all plants.

Building costs were determined by the engineering consultants based on the equipment size and specifications for each center in the plant, including centers specifically required for milk fractionation/concentration. Building costs include engineering fees, electrical, plumbing, pneumatic, refrigeration, structural, and ventilation aspects for each operating center in the plant. Equipment requirements and costs were determined by the engineering consultants and by equipment manufacturers for each plant center. All plants were modeled using modern, present-day automation. Equipment costs include engineering fees, and delivery and installation costs.

The major differences in equipment between conventional cheese and whey powder or WPC plants and Cheddar operations using the milk fractionation/concentration technologies studied here are outlined in the earlier section entitled "Model Plant Specifications".

Details of the building areas and land requirements for each cheese and whey product plant are provided in the Appendix. Details of selected items of equipment are given in the Appendix which is available as a separate publication.

The plants are constructed to be economically functional for the long run, yet not plush. As described earlier, the model plants only provide cheese and whey product storage capacity equivalent to 10 days production. The storage of products beyond 10 days is viewed as part of the marketing process, not the manufacturing process. The cheese is designed to be a fresh commodity-type cheese, sold with no

aging. Thus, no cheese-aging facilities are included in the cheese plant. The office center and related areas are reserved for the plant management and operation supervisors. No space for corporate offices or marketing activities is included.

Capital Investment Costs

The estimated additional total capital investment required to add the various milk fractionation/concentration technologies to the previously modeled conventional Cheddar plants are summarized in Table 3 for all plant sizes. Looking at just the 720,000 and 960,000 lbs capacity plants, the additional capital required is very similar for adding either 1.5X UF or 1.2X evaporation (i.e. approximately \$450,000), while adding 1.2X RO is less expensive. For 1.5X UF or 1.2X evaporation this additional investment amounts to approximately 6.5% of the estimated total capital investment for a cheese plant of 960,000 lbs pe day, compared to 4% to add 1.2X RO. For larger plants, (i.e. 1,440,000 and 2,400,000 lbs of milk per day), the capital investment required for 1.2X evaporation is considerably more than for either 1.5X UF or 1.2X RO.

Details of the initial capital investments for each of the plant sizes for each technology are provided in the Appendix.

Capital Depreciation and Interest Charges

An annual charge was calculated to account for capital costs and economic depreciation over the life of the assets. The methodology used is the same as in the Mesa-Dishington et al. study (1) and is presented in the Appendix. A six percent real interest rate was used as the opportunity cost of money. Because production and revenue factors were estimated in fall 1988 and do not reflect future inflation, this was viewed as a reasonable interest rate, net of inflation.

Annual land cost using the six percent real interest rate is assumed to equal the opportunity cost of capital tied up in the land. Possible appreciation or depreciation of the land values over the duration of the investment are not incorporated into the cost.

Costs of the building and equipment were annualized by using present value techniques¹, again assuming a six percent real interest rate and reflecting the expected lives of individual pieces of equipment. These techniques are designed to capture the cost of money tied up in the investment and the expected economic depreciation of assets.

¹ Assumptions made concerning capital costs tied up in the construction of the cheese and whey plants were that the land would be purchased two years before the plant became operational, with 30% of the sitework and structural costs occurring 18 months before plant completion. The remaining 70% of these costs would be incurred one year before the plant opened, with equipment purchased six months before the opening.

Table 3 Additional Capital Investment (Land, Building, and Equipment) Required for Milk Fractionation/Concentration Technologies Over the Investment Required for a Conventional Cheddar Plant

Plant Capacity ¹	1.5X UF	1.2X RO	1.2X Evaporation
(Dollars)			
720,000	445,000	274,000	435,000
960,000	464,000	309,000	463,000
1,440,000	484,000	387,000	578,000
2,400,000	576,000	531,000	759,000

¹ Plant capacities are in terms of pounds of raw milk received per day.

It is assumed that the lifespans of the cheese and whey plants are 25 years when operated at 100% capacity or up to 35 years at less than 100% capacity (35 years is assumed to be the maximum lifespan due to obsolescence, regardless of the capacity the plant has actually operated at). Three equipment lifespans were assumed; 5, 10, and 15 years, based on 100% utilization. At lower levels of utilization, equipment lifespans are also lengthened. Salvage values of the building and equipment are assumed to be zero.

Repair and Maintenance Costs

Repair and maintenance was estimated by the engineering consultants using recommendations from the equipment manufacturers for purchased parts and purchased labor. Structural maintenance was divided into fixed and variable categories while equipment maintenance was considered entirely variable. Variable maintenance is tied to the milk and whey volumes processed in the plant, while fixed maintenance is a set amount regardless of the plant's utilization. Both structural and equipment maintenance were estimated by operating center and then totaled for each plant situation.

It should be noted that the repair and maintenance category only reflects purchased parts and maintenance. Most of the labor for repair and maintenance is provided by plant staff. The cost of this labor is in the plant labor expense category and amounts to at least twice as much as the purchased repair and maintenance expense.

Insurance Costs

Insurance for the model plants includes fire and extended coverage on building and equipment. The annual average insurance rate estimated by the consulting engineers was \$5.34 per \$1000 of

building and equipment value. The values of the building and equipment are assumed to be 85% of their initial cost.

Property Taxes

Property taxes were based on the market value of the land, building, and equipment. Market value of land and building was assumed to be 100% of the original investment cost, while market value of equipment was assumed to be 50% of the original cost. An average rate of \$39.00 per \$1000 of market value was used to determine the annual property taxes of each plant.

Salaries, Wages, and Labor Costs

Labor requirements for the model plants were determined based on production schedules, plant sizes, technology used, and activities performed in each center. These estimated labor requirements were established by the consulting engineers and equipment suppliers, and evaluated by authors.

Labor costs were divided between supervisory and direct labor. Supervisory labor includes only the plant manager and his or her assistants. Supervisory labor is designated as a wholly fixed cost per year. All other employees are considered direct labor, which is divided into variable and fixed components. Variable labor is used where the amount of work varies with the amount of milk being processed, while fixed labor is for positions which require a constant effort, such as cleaning or setting up the plant at the start of each operating day. Both fixed and variable labor requirements for each plant center were determined by the engineering consultants and equipment manufacturers. The basic labor requirements for each of the model plants are given in the Appendix.

A flat wage rate of \$9.75 per hour was assumed for all direct labor, with 32% for fringe benefits. Supervisory labor was estimated to cost 30% more per hour than direct labor, with an additional wage adjustment based on plant size. Fringe benefits include welfare fund, retirement fund, social security, life insurance, medical and dental insurance, unemployment insurance, sick leave, and paid vacations.

Utility Costs

The major utilities in the plants are electricity, natural gas, water, and sewage. The engineering consultants and the equipment manufacturers determined the utility needs for each piece of equipment. Where steam was used, the natural gas required to produce the steam was estimated. Water consumption was calculated using known flow rates for equipment and estimated usage. Both electricity and natural gas were estimated based on fixed and variable usage in each operating center, with the fixed component charged at a flat rate per kilowatt hour or therm. The variable amount was based on usage per million lbs of milk in the cheese plant. Electricity was assumed to cost \$.06 per kilowatt hour, natural gas \$.38 per therm.

The plants are assumed to have their own water wells, so there are no direct charges for water. The costs of building and maintaining the water well are included in the capital costs. A metering/monitoring manhole is provided for BOD tests, suspended solids tests and flow measurement to verify discharge volumes. A flat rate of \$1.65 per 1,000 gallons of sewage treated was assumed. The basic utility requirements for each of the model plants are shown in the Appendix.

Cost of Materials

Materials costs include laboratory, production, packaging, and cleaning supplies. Together, these represent a significant proportion of the manufacturing costs for Cheddar cheese and whey product production.

Laboratory Supplies. The cheese and whey plants in this study are assumed to perform all of the standard control and quality tests recommended for such operations. The tests are used to determine if antibiotics are present in the milk, milk bacteria counts, milk fat and protein levels, pH, fat and protein in the unseparated whey, pH of whey at draw, fat in separated whey, fat in whey cream, cheese moisture, cheese fat, cheese pH and cheese salt levels. Laboratory tests are performed on each incoming load of raw milk and every vat of cheese produced. Depending on the whey product produced, fat and moisture level tests are done on the finished whey powder, with fat, moisture, and protein level tests required for WPC. BOD tests are also performed on all fluids before they enter the municipal sewage system. All plants are assumed to perform the same types of tests, regardless of any milk fractionation/concentration methods used.

Production Materials. Production supplies for the cheese operation include calcium chloride, color, rennet, salt, and starter culture, while Novalox is required by the whey plants to bleach whey produced from colored Cheddar. The quantities of these materials were determined based on standard acceptable manufacturing requirements, with costs being obtained from material suppliers and actual cheese plant invoices. These costs reflect fall 1988 prices and shipping charges, with no allowance for volume discounts.

One of the advantages of using milk fractionation/concentration technologies is the decrease in production materials required. Plants using 1.5X UF, 1.2X RO or 1.2X evaporation are assumed to cut their usage of rennet by 25% and starter media by 20% per cwt of original raw milk. This decrease in required materials is due to the reduced volume of liquid and increased concentration of protein in the cheese vats after the milk fractionation or concentration. Although the same amount of cheese is produced per vat, the amount of rennet and starter media required for proper coagulation and acid production is more a function of the volume in the vats than of the final amount of cheese produced. This is true for current (non-aged) varieties of Cheddar (including Cheddar intended for further processing). This reduction in production materials may not be possible when manufacturing aged Cheddar, however, as it would decrease the rate and intensity of flavor development. Production

materials' costs for a plant using 1.5X UF, 1.2X RO or 1.2X evaporation are thus reduced to \$1,559 per million lbs of raw milk, compared to \$1,907 for a conventional plant, a savings of 18%.

Medium concentration factor UF (6.5X) requires an entirely different starter culture center than a conventional plant, and a drastically reduced quantity of production materials. In a plant using 6.5X UF, the starter culture is grown in 10% of the previous day's retentate, eliminating the need for starter media entirely. Thus, total production materials' costs are reduced by two-thirds, to \$625 per million lbs of raw milk.

Packaging Supplies. The cheese is packaged in vacuum-packed plastic bags and placed in reusable corrugated cardboard cartons. All cheese is assumed to be shipped in 640 lb blocks. Whey plant packaging supplies include bags, pallets, and overwrap for the pallets. The cost of packaging supplies per lb of cheese is not affected by milk fractionation/concentration technologies.

Cleaning Supplies. Cleaning supplies were determined by the engineering consultants and by the equipment manufacturers. For centers with CIP equipment, cleaning supplies were estimated by calculating the flow rate and the length of time the CIP system operated each day. Plants using milk fractionation/concentration technologies required additional cleaning supplies for the extra equipment centers. These additional cleaning supplies varied according to technology, with 1.5X UF plants requiring the least additional and 1.2X evaporation plants requiring the most. WPC plants also require additional cleaning supplies for the membranes.

Other Expenses

Other expenses include communications, travel, laundry, telephone, and other services. The costs for these expenses were based on earlier studies of cheese plants and modified by the engineering consultants to be applicable to the model plants (1, 2). These expenses were calculated on a monthly or yearly basis with some variation due to plant size but no difference due to the use of milk fractionation/concentration technologies.

Production Inventory

A ten-day production inventory cost is assumed in this study for both cheese and whey products. This cost reflects the capital expense or opportunity cost for the period between the time the resources are used in production and the time when the finished product leaves the plant. The inventory cost was determined using a six percent real interest rate on the value of the resources which comprise the variable costs of production.

Profitability Estimation

Overview

Since 6.5X UF is assumed to definitely increase cheese yields, and the other the milk fractionation/concentration technologies might also result in an increase in cheese yields or milk volumes processed, the potential impacts of these technologies on profitability as well as costs were analyzed.

The profitability analyses focus on the combined costs and revenues of producing cheese and whey products. These combined costs consist of all manufacturing costs, including cheese and whey production costs and the raw milk cost. No marketing or administrative costs are assumed. The combined revenues include all revenues realized at the plant from cheese, whey powder or WPC, and whey cream. The goal is to estimate differences in operating profits at the manufacturing or plant level for plants using milk fractionation/concentration technologies as compared to conventional cheese and whey operations by subtracting these combined costs from the combined revenues.

The milk, cheese, whey cream, WPC, and whey powder prices used in the profitability analysis reflect conditions in Wisconsin during the 2-year period ending December 1, 1989 (Table 4).

Raw milk and product prices in 1990-91 in many cases changed dramatically from the 1988-89 averages mentioned above. Although this volatility affects the absolute levels of cheese and whey product profitability, the underlying conclusions are based on the differences in profitability between operations using the various milk fractionation/concentration technologies, which have not changed significantly.

This is why, in analyzing the profitability estimates, the focus should be on the difference, if any, in the profitabilities, rather than the absolute levels of profitability. The profitability estimates presented here depend on many conditions, including plant and managerial efficiency, raw milk and cream prices, labor and utility costs, etc., all of which must be assessed for each individual business situation. On the other hand, the differences between these estimates for plants using various technologies or different sized plants are probably reliable estimates. This is due to the fact that the assumptions are the same for each profitability estimate, thus canceling each other out when compared as differences.

In scenarios where increased profits might result from using milk fractionation/concentration (i.e. increased cheese yields or increased volumes of milk processed), the economic desirability of investing in the technology is evaluated using two measures besides profits per cwt: payback period and internal rate of return on investment (IRR).

Table 4 Average Cheese and Whey Product Prices Based on Wisconsin Averages, January 1988 - December 1989¹

Raw Milk (\$ Per Cwt) ²	\$12.70
37% Moisture Commodity Cheddar, 640 Lb Blocks (\$ Per Lb)	\$ 1.32
Whey Cream 40% bf (\$ Per Lb of Cream)	\$ 0.52
34.5% Protein WPC (\$ Per Lb)	\$ 0.72
Whey Powder, Extra Grade (\$ Per Lb)	\$ 0.18

¹ USDA, Dairy Market News, Agricultural Marketing Service, Dairy Division, selected issues, 1988-1989.

² Based on the Minnesota-Wisconsin milk price plus allowances to account for quality, volume, and competitive premiums, hauling subsidies, and other raw milk procurement costs incurred by cheese plants.

The payback period is calculated as the number of years required for the increase in cheese yield or volume of milk processed to pay back the added capital investment required for the milk

fractionation/concentration technology. For example, if the investment in 1.5X UF for a plant with a capacity of 960,000 lbs of milk per day (assuming a 0.25% increase in cheese yield) had a 3.9 years payback, it means that the firm would recover the initial investment in about 4 years, entirely from benefits expected to result from adopting the 1.5X UF technology.

An IRR on an investment is determined by calculating the interest rate that equates an investment's initial capital outlay with the present value of the cash income stream generated by the investment. In this study, the IRR is the percentage or interest rate that equates the total added capital investment required to equip a Cheddar/whey operation with a particular milk fractionation/concentration technology with the present value of the increase in profits (expressed in cash flow terms) from using the technology.

The IRR represents the highest rate of interest an investor could afford to pay, without losing money, if all the funds to finance the investment were borrowed and the loan (both principal and accrued interest) were to be repaid out of the cash benefits from the investment as they were earned. Thus, the estimated IRRs can be compared with the plant's cost of capital to determine not only whether the investment in milk fractionation/concentration technology would be wise, but also to show how much margin there would be to allow for risk and uncertainty. If the IRR exceeds the real or inflation-free cost of capital, then the value of the plant would be increased by making the investment.

In situations where the fractionation/concentration technology would actually increase costs and reduce operating profits, no payback period or rate of return is calculated.

The payback periods and rates of return on investment are calculated to reflect two different situations. The first assumes the manufacturer is building a new Cheddar/whey operation and must decide whether to adopt a fractionation/concentration technology or build a new conventional cheese plant. The second situation is based on modifying an existing cheddar plant by adding UF, RO or evaporation technology. The base case considered in this study assumes new cheese and whey plants but paybacks and IRRs are calculated for both scenarios. Payback periods and IRRs may differ in these two situations because of the different capital investments required when building a new cheese and whey operation from scratch versus modifying an existing operation.

Actually, the capital investment for the cheese plant is the same in both situations, as only the difference in cost between building a new plant with UF, RO, or evaporation as compared to building a new conventional plant is considered. This was done in computing paybacks and rates of return on investment because the consideration for this scenario is not whether or not to build a new cheese plant, but whether or not to adopt a milk fractionation/concentration technology.

However, in a cheese and WPC operation, the capital investment to build a new WPC plant would be less if the cheese plant were to use UF, RO, or evaporation (because of reduced whey volume) than if the plant were built to accompany a new conventional plant. If an existing cheese and WPC operation were to be modified though, no benefits from lower capital investment in the whey plant could be realized as the existing structure would already be constructed and used as is. Thus, payback periods will be longer and rates of return lower on the investment of modifying an existing Cheddar/WPC operation than the case where a new operation would be constructed. For whey powder, this difference does not exist as the capital costs are the same for building a new whey powder plant to accompany a conventional cheese plant as one using UF, RO or evaporation.

Profitability Calculation Example

Cheddar cheese and whey product revenues were determined using the assumed yields and product prices found in Tables 2 and 4. Cheese and whey manufacturing costs were estimated for the four model plant sizes under various technologies and operating conditions. To calculate total profitability, these costs were subtracted from the assumed revenues. This approach is outlined for Cheddar and WPC in Table 5, and for Cheddar and whey powder in Table 6.

Note that in the profitability worksheets **no charge for raw whey is made to the whey operation** due to the arbitrary nature of such a charge or transfer price. Thus, to the extent that the raw whey has value, the "operating profit from cheese" **understates** the profitability of cheese while the "operating profit from whey"

Table 5 Sample Worksheet to Calculate Profitability of Cheddar and WPC Production in a Cheddar Plant Using No Milk Fractionation/Concentration Technology¹

Note: Assumes breakeven on permeate in the WPC plant.

Item	\$/Cwt Milk	
REVENUES		
Cheddar Cheese ²		
Yield (Lbs/Cwt Raw Milk)	10.16	
Price (\$/Lb Cream)	1.32	
Revenue		13.41
Whey Cream ³		
Yield (Lbs/Cwt Raw Milk)	.58	
Price (\$/Lb Cream)	.52	
Revenue		0.30
Total Revenues		<u>13.71</u>
COSTS		
Cheese Manufacturing Cost		1.61
Raw Milk Cost		12.70
Total Costs		<u>14.31</u>
<u>OPERATING PROFIT FROM CHEESE</u>		<u>-.60</u>
REVENUES		
WPC Yield (Lbs/Cwt Raw Milk)	1.64	
WPC Price (\$/Lb WPC)	.72	
Total Revenues		<u>1.18</u>
COSTS		
Whey Manufacturing Costs (\$/Cwt Raw Milk)		<u>.61</u>
<u>OPERATING PROFIT FROM WHEY</u>		<u>.57</u>
<u>PROFIT FROM CHEESE & WHEY</u>		<u>-.03</u>

¹ Plant operating 5 days per week, 24 hours per day with a capacity of 960,000 pounds of milk per day.

² The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar with 93% fat retention.

³ Assumes 90% recovery of theoretical whey cream yield with a value of \$1.33 per lb of fat.

Table 6 Sample Worksheet to Calculate Profitability of Cheddar and Whey Powder Production in a Cheddar Plant Using No Milk Fractionation/Concentration Technology¹

Item		\$/Cwt Milk
REVENUES		
Cheddar Cheese ²		
Yield (Lbs/Cwt Raw Milk)	10.16	
Price (\$/Lb Cheese)	1.32	
Revenue		13.41
Whey Cream ³		
Yield (Lbs/Cwt Raw Milk)	.58	
Price (\$/Lb Cream)	.52	
Revenue		0.30
Total Revenues		<u>13.71</u>
COSTS		
Cheese Manufacturing Cost		1.61
Raw Milk Cost		12.70
Total Costs		<u>14.31</u>
<u>OPERATING PROFIT FROM CHEESE</u>		<u>-.60</u>
REVENUES		
Whey Powder Yield (Lbs/Cwt Raw Milk)	5.80	
Whey Powder Price (\$/Lb Powder)	.18	
Total Revenues		<u>1.04</u>
COSTS		
Whey Manufacturing Costs (\$/Cwt Raw Milk)		<u>.79</u>
<u>OPERATING PROFIT FROM WHEY</u>		<u>.25</u>
<u>PROFIT FROM CHEESE & WHEY</u>		<u>-.35</u>

¹ Plant operating 5 days per week, 24 hours per day with a capacity of 960,000 pounds of milk per day.

² The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar with 93% fat retention.

³ Assumes 90% recovery of theoretical whey cream yield with a value of \$1.33 per lb of fat. overstates the profitability of the whey operation. The combined profit from the cheese and whey operation is the important number.

RESULTS OF COST AND PROFITABILITY ANALYSIS

Introduction

This phase of the research on Cheddar cheese manufacturing focused on comparing the costs and profitability of manufacturing Cheddar cheese, whey powder and whey protein concentrate (WPC) in conventional plants using no milk fractionation/concentration technology with the costs of using 1.5X ultrafiltration (UF), 1.2X reverse osmosis (RO), 1.2X evaporation or 6.5X ultrafiltration (medium concentration factor UF) in the cheese plant prior to cheese making. The economics of using 2X UF to fractionate milk on individual farms is also analyzed.

The estimated manufacturing costs include only the costs associated with plant production, that is from the raw milk receiving room through and including the cheese chilling room and the whey product storage area. They do not include the cost of raw milk, milk assembly, cheese aging, cheese or whey marketing, permeate handling or any management or administration except direct plant management.

However, when comparing the potential profitabilities of the various fractionation/concentration technologies, all costs (except marketing and administration) and credits are included for all technologies. The costs of raw milk and all revenues from cheese, whey cream, and whey products are considered together with the manufacturing costs to determine net returns to the various technologies compared to returns from conventional plants not using any milk fractionation/concentration technologies.

The estimated production costs reflect feasible production systems operated with good management under the assumptions made in this study. Actual plants currently using these technologies may be using other production methods, operating with different factor costs, and using partially or fully depreciated assets. Thus, the cost estimates may not necessarily reflect the production costs of cheese and whey plants in actual operation. However, this study provides reliable estimates of the cost differences that might well be realized in plants using the various technologies. It also provides useful information about the dynamics of the manufacturing scenarios, the effects of various fat retention levels and plant size, as well as an assessment of the profit potential of these milk fractionation/concentration technologies.

The profitabilities of Cheddar and whey product manufacturing assume that the same quality product is produced with all the technologies studied. Thus the same market prices for the cheese and whey products are assumed regardless of whether the cheese is produced in a "conventional" cheese plant or one using a milk concentration or fractionation technology. The profitabilities of Cheddar and WPC manufacture also are based on the assumption that revenues from permeate breakeven with permeate processing costs. The effects on profitability of possible gains or losses from permeate could be large and are considered separately using sensitivity analysis. However, except for the 6.5X UF technology the whey from

the cheese plants using milk fractionation/concentration technologies can be made into either whey powder or WPC regardless of the technology used. Thus, the issue of possible gains or losses from handling permeate is an important issue in deciding whether to manufacture WPC or powder, not in deciding whether or not to adopt a milk fractionation/concentration technology. This makes the economics of permeate handling irrelevant in comparing the profitabilities of conventional plants with plants using 1.5X UF, 1.2X RO or 1.2X evaporation. See the Appendix for more analysis of permeate handling.

The analyses are reported in dollars per cwt of raw milk received (rather than dollars per lb of cheese) to have a common basis for comparing costs and profitabilities for Cheddar and WPC with those for Cheddar and whey powder. Many of the results are presented in the text as differences; differences in the costs or the profitabilities between a plant using one of the new technologies and a conventional plant. In many instances, the cost and profitability data which are used to calculate the differences are reported in the Appendix.

Wages, fringe benefits, utility rates, equipment, packaging, production material, and structural costs all reflect 1989 prices. Raw milk, cheese, and whey product prices used in the profitability comparisons reflect average prices for Wisconsin for the 2-year period ending December 1989.

Outline of Results

The economics of manufacturing Cheddar cheese by conventional methods compared to using milk fractionation/concentration technologies are reported in three major sections:

- 1) Using 1.5X UF, 1.2X RO, and 1.2X evaporation on milk in the plant prior to cheese making.
- 2) Using medium concentration factor (6.5X) UF on the milk in the plant prior to cheese making.
- 3) Using 2X UF on farms supplying milk to cheese plants.

The results of the analysis of 1.5X UF, 1.2X RO, and 1.2X evaporation are reported as follows:

First, costs are compared assuming the cheese yield per original hundredweight of milk does not increase and that the total volume of milk processed at the plant remains constant regardless of the technology used.

Second, the impacts on profitability of possible increases in cheese yield per hundredweight of original raw milk that might be achieved with the fractionation/concentration technologies are evaluated, still assuming that the total volume of milk processed is constant.

Third, the probable impacts on total daily operating profit are estimated for the somewhat special case that 1.5X UF, 1.2X RO, or 1.2X evaporation would enable a plant already operating at full capacity with no concentration technology to process up to 10% more milk, thus increasing the total milk volume handled per day.

Fourth, the impacts of these fractionation/concentration technologies on total daily operating profit are evaluated assuming their use enables a plant operator to both increase cheese yields and increase total milk volume processed.

Following the analysis of the low concentration factor technologies, analyses of using medium concentration factor UF (6.5X) technology in the plant are reported and benefits from potential increases in cheese yields are compared to potential higher investment costs and added risks of using the technology.

Finally, some of the economics of using 2X UF at the farm rather than at the plant are addressed.

1.5X UF, 1.2X RO, AND 1.2X EVAPORATION IN CHEDDAR CHEESE OPERATIONS

Comparisons of Manufacturing Costs Across Technologies Assuming No Increase in Cheese Yields and No Increase in Milk Volumes Processed

Overview of Cheese and Whey Manufacturing Costs

Using 1.5X UF or 1.2X RO in a Cheddar plant prior to cheese making had a relatively small impact on the combined costs of manufacturing cheese and whey (Tables 7 & 8). In most scenarios, the total Cheddar and WPC or Cheddar and whey powder manufacturing costs are usually less than \$0.01 per cwt of milk different in plants using 1.5X UF or 1.2X RO from the costs in conventional cheese and whey operations (Tables 7 & 8). However, a change in costs of only a cent per cwt of milk can lead to significant changes in profits, given the volume of milk handled annually.

Although 1.5X UF and 1.2X RO have similar impacts on cheese and whey product manufacturing costs, 1.2X RO appears to increase costs slightly less in smaller plants and to reduce costs slightly more in larger plants than 1.5X UF because of differing capital investments required for the two technologies.

In general, using 1.5X UF has the effect of not only increasing manufacturing costs for smaller plants but also providing no savings for those producing whey powder (Table 7). Although 1.2X RO increases costs slightly in the 720,000 and 960,000 lb capacity cheese plants, operators producing whey powder have a slightly larger cost advantage (or smaller disadvantage) than those producing WPC, as compared to conventional plants (Table 8).

Table 7 Differences in the Manufacturing Costs of Cheddar, WPC and Whey Powder Between Conventional Cheese Plants and Those Using 1.5X UF for Four Plant Sizes Using Four Operating Schedules.^{1, 2}

- Notes:** 1) A negative sign indicates that the manufacturing cost for cheese or whey products is lower in plants using 1.5X UF.
 2) Breakeven is assumed on the UF permeate produced in the WPC plants and in the 1.5X UF cheese plants.

Manufacturing Cost & Plant Capacity ³	Plant Operating Schedules			
	5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
	(\$/Cwt of Milk)			
Cheddar				
720,000	.039	.031	.022	.013
960,000	.022	.016	.011	.003
1,440,000	.009	.005	.001	-.004
2,400,000	-.002	-.005	-.008	-.012
WPC				
720,000	-.005	-.004	-.003	-.003
960,000	-.009	-.008	-.005	-.005
1,440,000	-.011	-.010	-.009	-.006
2,400,000	-.002	-.002	0	-.001
Whey Powder				
720,000	0	0	0	0
960,000	0	0	0	0
1,440,000	0	0	0	0
2,400,000	0	0	0	0
Cheddar & WPC				
720,000	.034	.027	.019	.010
960,000	.013	.008	.006	.003
1,440,000	-.002	-.005	-.008	-.004
2,400,000	-.004	-.007	-.008	-.013
Cheddar & Whey Powder				
720,000	.039	.031	.022	.013
960,000	.022	.016	.011	.003
1,440,000	.009	.005	.001	-.004
2,400,000	-.002	-.005	-.008	-.012

¹ The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all methods with 93% fat retention.

² See the Appendix for the actual cheese and whey manufacturing costs.

³ Plant capacities are in terms of pounds of raw milk received per day.

Table 8 Differences in the Manufacturing Costs of Cheddar, WPC and Whey Powder Between Conventional Cheese Plants and Those Using 1.2X RO for Four Plant Sizes Using Four Operating Schedules.^{1, 2}

- Notes:** 1) A negative sign indicates that the manufacturing cost for cheese or whey products is lower in plants using 1.2X RO.
 2) Breakeven is assumed on the UF permeate produced in the WPC plants and in the 1.5X UF cheese plants.

Manufacturing Cost & Plant Capacity ³	Plant Operating Schedules			
	5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
	(\$/Cwt of Milk)			
Cheddar				
720,000	.022	.018	.011	.007
960,000	.015	.012	.008	.002
1,440,000	.009	.006	.002	-.002
2,400,000	.004	.002	-.002	-.006
WPC				
720,000	-.004	-.003	-.003	-.002
960,000	-.008	-.007	-.005	-.007
1,440,000	-.009	-.008	-.008	-.005
2,400,000	-.001	-.001	0	0
Whey Powder				
720,000	-.007	-.007	-.007	-.007
960,000	-.007	-.007	-.007	-.007
1,440,000	-.007	-.007	-.007	-.007
2,400,000	-.007	-.007	-.007	-.006
Cheddar & WPC				
720,000	.018	.015	.008	.005
960,000	.007	.005	.003	-.003
1,440,000	0	-.002	-.006	-.007
2,400,000	.003	.001	-.002	-.006
Cheddar & Whey Powder				
720,000	.015	.011	.004	0
960,000	.008	.005	.001	-.005
1,440,000	.002	-.001	-.005	-.009
2,400,000	-.003	-.005	-.009	-.012

¹ The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all methods with 93% fat retention.

² See the Appendix for the actual cheese and whey manufacturing costs.

³ Plant capacities are in terms of pounds of raw milk received per day.

Using 1.5X UF and 1.2X RO has relatively small net effects on the combined cheese and whey manufacturing costs because decreases in the whey product manufacturing costs tend to offset the increases in cheese manufacturing costs due to the new technologies (Tables 7 & 8). The lower whey manufacturing costs are due to the transference of some of the processing normally done in the whey plant to the cheese plant, as a result of the new technologies. In the case of whey powder, however, there is absolutely no change in manufacturing costs when using 1.5X UF in the cheese plant. This is due to the fact the UF permeate must be combined with the whey from cheese making before producing whey powder, so no transference of processing costs occurs.

Cheese manufacturing costs per se did not always increase as a result of the new technologies, however. In the case of the largest plant studied, (2,400,000 lbs of milk per day), and with the 1,440,000 lb plant working at 100% capacity, the cheese manufacturing costs themselves are slightly lower when using 1.5X UF or 1.2X RO (Tables 7 & 8). This, added to the slight decrease in whey manufacturing costs except for whey powder with 1.5X UF), results in combined cheese and whey manufacturing costs that are actually less than in conventional operations for the two largest sized plants under many operating schedules and even for the 960,000 lb plant when using 1.2X RO at 100% capacity (Tables 7 & 8).

Using 1.2X evaporation was found to increase Cheddar manufacturing costs more than either 1.5X UF or 1.2X RO, while the savings in whey manufacturing costs are the same as with 1.2X RO. Using 1.2X evaporation increased the total manufacturing cost for cheese and whey products for all plant sizes regardless of operating schedules. The cost disadvantage of using 1.2X evaporation is due primarily to higher capital investment and higher fuel and labor requirements and is most obvious on a cwt basis in smaller plants and those with shorter operating schedules. For example, the net increase in cheese and whey operating costs from using 1.2X evaporation in the cheese plant ranged from \$0.014 per cwt for the 2,400,000 lb Cheddar and whey powder plant operating at 100% of capacity (7 days per week, 24 hours per day) to \$0.082 per cwt in the smallest Cheddar and WPC plant operating at 48% of capacity (5 days per week, 18 hours per day), (Table 9).

Although evaporation does increase cheese manufacturing costs more than using 1.5X UF or 1.2X RO, it can also be viewed as a lower risk technology both from a sanitation and cheese quality perspective.

These cost comparisons assume no change in cheese yields or throughput (i.e. the volume of milk processed per day). The effects on costs and profitability of the milk fractionation/concentration technologies if they do result in increased cheese yields or increased milk throughput are analyzed in later sections.

Table 9 Differences in the Manufacturing Costs of Cheddar, WPC and Whey Powder Between Conventional Cheese Plants and Those Using 1.2X Evaporation for Four Plant Sizes Using Four Operating Schedules.^{1, 2}

Notes:1) A negative sign indicates that the manufacturing cost for cheese or whey products is lower in plants using 1.2X evaporation.

2) Breakeven is assumed on the UF permeate produced in the WPC plants and in the 1.5X UF cheese plants.

Manufacturing Cost & Plant Capacity ³	Plant Operating Schedules			
	5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
	(\$/Cwt of Milk)			
Cheddar				
720,000	.086	.079	.067	.059
960,000	.069	.064	.057	.048
1,440,000	.046	.041	.033	.028
2,400,000	.036	.032	.025	.020
WPC				
720,000	-.004	-.003	-.003	-.002
960,000	-.008	-.007	-.005	-.007
1,440,000	-.009	-.008	-.008	-.005
2,400,000	-.001	-.001	0	0
Whey Powder				
720,000	-.007	-.007	-.007	-.007
960,000	-.007	-.007	-.007	-.007
1,440,000	-.007	-.007	-.007	-.007
2,400,000	-.007	-.007	-.007	-.006
Cheddar & WPC				
720,000	.082	.076	.064	.057
960,000	.061	.057	.052	.043
1,440,000	.037	.033	.025	.023
2,400,000	.035	.031	.025	.020
Cheddar & Whey Powder				
720,000	.079	.072	.060	.052
960,000	.062	.057	.050	.041
1,440,000	.039	.034	.026	.021
2,400,000	.029	.025	.018	.014

¹ The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all methods with 93% fat retention.

² See the Appendix for the actual cheese and whey manufacturing costs.

³ Plant capacities are in terms of pounds of raw milk per day. Components of Cheddar Cheese Manufacturing Costs

As indicated earlier, the difference in manufacturing costs on a per cwt basis between a conventional Cheddar cheese operation and one using milk concentration/fractionation technologies is largest in the smallest plants, with 1.5X UF and 1.2X RO actually becoming less expensive than a conventional operation as plant size increases (depending on operating schedule). For example, using 1.5X UF in the 720,000 lb plant increases cheese manufacturing costs by \$0.013 to \$0.039 per cwt of raw milk, depending on operating schedule, compared to a reduction in costs of \$0.002 to \$0.012 for the largest plant (Table 7). Thus, using 1.5X UF costs approximately four cents per cwt more than a conventional cheese operation in the smallest plant operating 5 days, 18 hours per week, but can save the plant over one cent per cwt in the largest plant operating 7 days per week, 24 hours per day. On an annual basis, with these operating schedules, this would increase cheese manufacturing costs approximately \$49,000 for the smallest plant but decrease cheese manufacturing costs for the largest plant by \$105,000.

For 1.2X RO the range of differences is slightly smaller with an increase in costs of \$0.022 for the 720,000 lb plant operating 5 days, 18 hours per week (\$27,000 annually) to a decrease in costs of \$0.006 per cwt in the largest plant operating 100% of capacity (an annual savings of \$52,000) (Table 8). However, these figures reflect only the changes in cheese manufacturing costs and do not include any possible savings in whey product manufacturing costs.

Using 1.2X evaporation in the cheese plant increases cheese manufacturing costs for all plant sizes and operating schedules, ranging from \$0.086 per cwt for the smallest plant operating 5 days, 18 hours per week (approximately \$107,000 annually) to \$0.02 per cwt for the 2,400,000 lb plant operating 7 days per week, 24 hours (over \$175,000 annually) (Table 9). Again, any savings in whey processing realized because of the technologies are not included here.

What factors lead to increases in Cheddar cheese manufacturing costs for most plants using milk concentration/ fractionation technologies?

The 960,000 lb plant operating 5 days per week, 24 hours per day (71% of capacity) will be used to illustrate in more detail the effects of using milk fractionation/concentration on cheese manufacturing cost components (Table 10). While the magnitude of the technology's effect depends on plant size and operating schedule, the direction of the effect on each manufacturing cost component is the same. In this example, we assume no increase in cheese yields or in the volume of milk processed per day. It is further assumed that breakeven is achieved on the permeate handling in the 1.5X UF plant.

Using milk fractionation/concentration raises the level of capital investment over that of conventional plants due to the need for a fractionation/concentration center ². The larger capital

² The increases in capital costs are provided in Table 3, page 14.

Table 10 Comparison of Costs of Manufacturing Non-Aged Cheddar in a Conventional Plant with Plants Using Three Milk Fractionation/Concentration Technologies. All Plants Have a Capacity of 960,000 Lbs of Raw Milk Per Day^{1,2}

Note: Assumes breakeven on UF permeate. **Bold** cost components are those affected by the fractionation/concentration technologies.

Cost Item	No Concentration	1.5X UF	RO	Evaporation
(\$/Cwt of Milk)				
Labor				
Supervisory	.048	.048	.048	.048
Direct Fixed	.052	.052	.052	.052
Direct Variable	.479	.484	.484	.495
Total Labor	.579	.584	.584	.595
Capital Costs				
Depreciation & Interest	.272	.292	.285	.291
Utilities				
Electricity	.018	.018	.018	.019
Fuel	.084	.084	.084	.121
Water & Sewage	.009	.009	.010	.009
Total Utilities	.111	.111	.112	.149
Materials				
Laboratory	.007	.007	.007	.007
Production	.170	.139	.139	.139
Packaging	.278	.278	.278	.278
Cleaning	.039	.040	.042	.046
Total Materials	.494	.464	.466	.470
Repair & Maintenance	.021	.032	.035	.023
Property Tax & Insurance	.090	.095	.093	.095
Production Inventory	.021	.021	.021	.022
Other Expenses	.026	.026	.026	.026
TOTAL	1.614	1.625	1.622	1.671

¹ The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all methods with 93% fat retention and an annual production of 25.4 million pounds.

² All plants operating 5 days per week, 24 hours per day.

investment then leads to higher depreciation and interest charges, as well as higher property taxes and insurance costs. Maintenance and repair costs are also somewhat higher in plants using milk fractionation/concentration, due to the addition of the extra center as well as the maintenance and replacement of UF or RO membranes which are not found in conventional cheese plants. The additional center also leads to increased labor and cleaning costs, with this being particularly true for plants using evaporation (Table 10).

However, plants using milk fractionation/concentration have an advantage in lower production material costs (i.e. rennet and starter media) (Table 10). This savings is enough to offset much, if not all, of the increased costs, particularly in plants using 1.5X UF or 1.2X RO. The reduction in production materials is possible due to the increased concentration of the milk. Using milk fractionation/concentration technologies allows rennet and starter media to be reduced 25% and 20% respectively per cwt of original milk from the levels required in conventional plants. It is assumed that a "current" or non-aged commodity-type Cheddar is being produced in all plants (including the conventional plant), and the rennet is assumed to be microbial, rather than the much more expensive calf rennet.

Because of economies of scale in some expense categories (i.e. depreciation, interest, property taxes, maintenance, repair, labor, and cleaning), the estimated increase in these manufacturing expenses due to using milk fractionation/concentration is less per cwt of milk in larger plants than in smaller plants. On the other hand, the decrease in production material costs per cwt is constant across all plant sizes. Thus, as plant size increases and the plant operates closer to capacity, the savings in production materials costs from using milk fractionation/concentration technologies remains the same per cwt while cost increases from using the technologies decrease per cwt. This results in the largest 1.5X UF and 1.2X RO Cheddar plants having lower manufacturing costs per cwt than a conventional plant of the same size under most operating schedules (Tables 7 & 8).

The decrease in production material costs is not enough to offset increases in other manufacturing cost components for Cheddar plants using 1.2X evaporation, however, even in the largest plant. While economies of scale are present in 1.2X evaporation plants, total manufacturing costs remained higher per cwt than conventional plants for all plant sizes (Table 9). Like 1.5X UF and 1.2X RO, 1.2X evaporation has higher depreciation and interest costs, property taxes and insurance (all of which are tied to the additional capital investment) and lower production material costs than a conventional plant. However, due to the sheer size of the equipment, 1.2X evaporation plants have greater fuel, labor and cleaning requirements (Table 10). These result in higher manufacturing costs per cwt of raw milk than plants using 1.5X UF, 1.2X RO, or conventional methods for all plant sizes and all operating schedules.

Components of Whey Product Manufacturing Cost

As mentioned earlier, using milk fractionation/concentration technologies has the effect of transferring some of the whey processing costs to the cheese plants. Part of the processing that would normally be done in the whey plant (i.e. ultrafiltration when producing WPC, evaporation when manufacturing whey powder) has already been accomplished in the cheese plant through the use of the milk concentration/fractionation technologies. The exception to this is producing whey powder using whey from 1.5X UF cheese plants³. In this case, the UF permeate must be mixed with the whey from the cheese vats before it leaves the Cheddar plant in order to produce standard whey powder. This results in no decrease in whey volumes. Thus, manufacturing costs for whey powder using whey from 1.5X UF cheese plants are the same as costs to manufacture whey powder using whey from conventional cheese plants (Table 7). In general, however, the use of milk fractionation/concentration technologies transfers some of the usual whey processing costs to the cheese plant, reinforcing the need to base comparisons on total cheese and whey manufacturing costs, not solely on differences in cheese or whey manufacturing costs alone.

WPC manufacturing costs range from approximately the same to \$0.011 lower per cwt of raw milk (depending on plant size and operating schedule) in new whey plants constructed to handle whey from Cheddar plants using 1.5X UF, 1.2X RO or 1.2X evaporation than in plants receiving whey from conventional Cheddar plants using no milk fractionation/concentration technologies (Tables 7, 8, & 9). **The lower WPC manufacturing costs result from slightly lower capital costs, particularly in the whey pasteurization center.** This is due to the decreased volume of whey received from cheese plants using these technologies as compared to the whey volume from a conventional cheese plant. The breakdown of the WPC manufacturing costs for the various technologies are illustrated for the 960,000 lb plant in Table 11. Since the lower costs of WPC operations associated with cheese plants using UF, RO or evaporation stem from lower capital investments, these benefits would not be realized if an existing whey plant built to handle whey from a conventional cheese plant was used.

³ Whey from cheese plants using 1.2X RO or 1.2X evaporation has the same total pounds of whey solids as whey from a conventional cheese plant, but less liquid volume due to the concentration process. Whey from a 1.5X UF plant has some of the whey solids (primarily lactose) removed along with the liquid portion, prior to cheese making. This lactose solution is what comprises UF permeate. This UF process in the cheese plant makes it somewhat easier to manufacture WPC, but to make whey powder with whey from a 1.5X UF plant, the permeate must be mixed back with the whey from the cheese vats to achieve the proper ratio of whey solids in the powder. Thus, when making whey powder using whey from a 1.5X UF cheese plant, there would be no reduction in whey volume.

Table 11 Costs of Manufacturing WPC in a Plant Associated with a Conventional Cheddar Plant Compared to Costs in Plants Accompanying Cheddar Plants Using Three Milk Fractionation/concentration Technologies. All WPC Plants Accompany 960,000 Lb Capacity Cheddar Plants^{1,2}

Note: Assumes breakeven on UF permeate. **Bold** cost components are those affected by the fractionation/concentration technologies.

Cost Item	No Concentration	1.5X UF	RO	Evaporation
(\$/Cwt of Milk)				
Labor				
Supervisory	.016	.016	.016	.016
Direct Fixed	.013	.013	.013	.013
Direct Variable	.164	.164	.164	.164
Total Labor	.193	.193	.193	.193
Capital Costs				
Depreciation & Interest	.179	.175	.176	.176
Utilities				
Electricity	.005	.005	.005	.005
Fuel	.093	.093	.093	.093
Water & Sewage	.007	.007	.007	.007
Total Utilities	.105	.105	.105	.105
Materials				
Laboratory	.000	.000	.000	.000
Production	.005	.005	.005	.005
Packaging	.017	.017	.017	.017
Cleaning	.014	.014	.013	.013
Total Materials	.036	.036	.035	.035
Repair & Maintenance	.031	.031	.031	.031
Property Tax & Insurance	.056	.055	.055	.055
Production Inventory	.000	.000	.000	.000
Other Expenses	.006	.006	.006	.006
TOTAL	.606	.601	.601	.601

¹ WPC is assumed to be 34.5% protein, with an assumed yield of 1.64 lbs per cwt raw milk and an annual production of 4 million pounds.

² All plants operating 5 days per week, 24 hours per day.

Whey volume is also reduced when manufacturing whey powder using whey from 1.2X RO or 1.2X evaporation cheese plants. However, in whey powder plants the whey pasteurization center is a part of the evaporator system and the decrease in whey volume is not great enough to reduce the system size required. However, the decreased volume does lower utility costs, reducing total whey powder manufacturing costs by approximately \$.007 per cwt of raw milk (Table 12). The other components of whey powder manufacturing costs across the

technologies are also presented in Table 12. Since there are very little economies of scale in utility costs, this reduction in costs is constant across plant sizes, regardless of operating schedule (Tables 8 & 9). In contrast to WPC operations, these savings in whey powder could be realized either in an existing powder plant or a new plant, as they result from savings in utilities, not capital investment.

Economies of Scale

Economies of scale are large in both Cheddar cheese manufacturing and whey product manufacturing⁴. This is true in conventional plants as well as in plants using milk fractionation/-concentration technologies (Figures 1 & 2).

The total manufacturing costs of producing Cheddar and WPC are essentially the same when using conventional methods, 1.5X UF or 1.2X RO (Figure 1). Only when 1.2X evaporation is used in the cheese plant are total manufacturing costs somewhat higher. Figure 2 presents an identical message for the production of Cheddar and whey powder.

The cost differences between using 1.2X evaporation and 1.5X UF or 1.2X RO or conventional methods are insignificant, however, when compared to the effects of plant size on manufacturing costs. For example, total manufacturing costs for Cheddar and WPC in the 2,400,000 lb capacity plant are \$1.52 to \$1.54 per cwt of milk regardless of technology (Figure 1, and in the Appendix). The same costs for a 720,000 plant are approximately \$2.59 per cwt, or more than \$1.00 per cwt higher⁵.

Conclusions on Manufacturing Costs

Using 1.5X UF, 1.2X RO or 1.2X evaporation in a Cheddar plant in effect transfers some of the costs normally in whey processing to the cheese plant. Thus, compared to a conventional cheese plant, 1.5X UF and 1.2X RO increase Cheddar manufacturing costs per cwt of raw milk slightly (in most cases less than \$0.015) for all but the largest size plant, while 1.2X evaporation increases manufacturing costs for all plant sizes (Tables 7, 8 & 9). On the other hand, whey product manufacturing costs are less than those for conventional operations in all cases except for the production of whey powder using whey from the 1.5X UF cheese plants (Tables 7, 8 & 9). Due to the overall transfer of costs, total cheese and whey manufacturing costs should be the unit of comparison, not cheese or whey manufacturing costs alone.

⁴ While economies of scale are large for both cheese and whey product manufacturing, they are relatively greater for whey product manufacturing.

⁵ Assuming all plants operating 5 days per week, 24 hours per day.

Table 12 Costs of Manufacturing Whey Powder in a Plant Associated with a Conventional Cheddar Plant Compared to Costs in Plants Accompanying Cheddar Plants Using Three Milk Fractionation/Concentration Technologies. All Whey Powder Plants Accompany 960,000 Lb Capacity Cheddar Plants^{1,2}

Note: Assumes permeate is returned to whey in 1.5X UF Cheddar plant. **Bold** cost components are those affected by the fractionation/concentration technologies.

Cost Item	No Concentration	1.5X UF	RO	Evaporation
(\$/Cwt of Milk)				
Labor				
Supervisory	.016	.016	.016	.016
Direct Fixed	.011	.011	.011	.011
Direct Variable	.172	.172	.172	.172
Total Labor	.199	.199	.199	.199
Capital Costs				
Depreciation & Interest	.241	.241	.241	.241
Utilities				
Electricity	.064	.064	.064	.064
Fuel	.072	.072	.068	.068
Water & Sewage	.020	.020	.017	.017
Total Utilities	.156	.156	.149	.149
Materials				
Laboratory	.000	.000	.000	.000
Production	.005	.005	.005	.005
Packaging	.060	.060	.060	.060
Cleaning	.012	.012	.012	.012
Total Materials	.077	.077	.077	.077
Repair & Maintenance	.025	.025	.025	.025
Property Tax & Insurance	.083	.083	.083	.083
Production Inventory	.000	.000	.000	.000
Other Expenses	.006	.006	.006	.006
TOTAL	.787	.787	.780	.780

¹ Whey powder is assumed to be human food grade, with an assumed yield of 5.80 lbs per cwt raw milk and an annual production of 14.5 million pounds.

² All plants operating 5 days per week, 24 hours per day.

FIGURE 1 — COMBINED CHEDDAR & WPC MANUFACTURING COSTS FOR CHEDDAR PLANTS OPERATING 5 DAYS, 24 HOURS AND USING EITHER NO MILK CONCENTRATION TECHNOLOGY OR 1.5X UF, OR 1.2X RO, OR 1.2X EVAPORATION

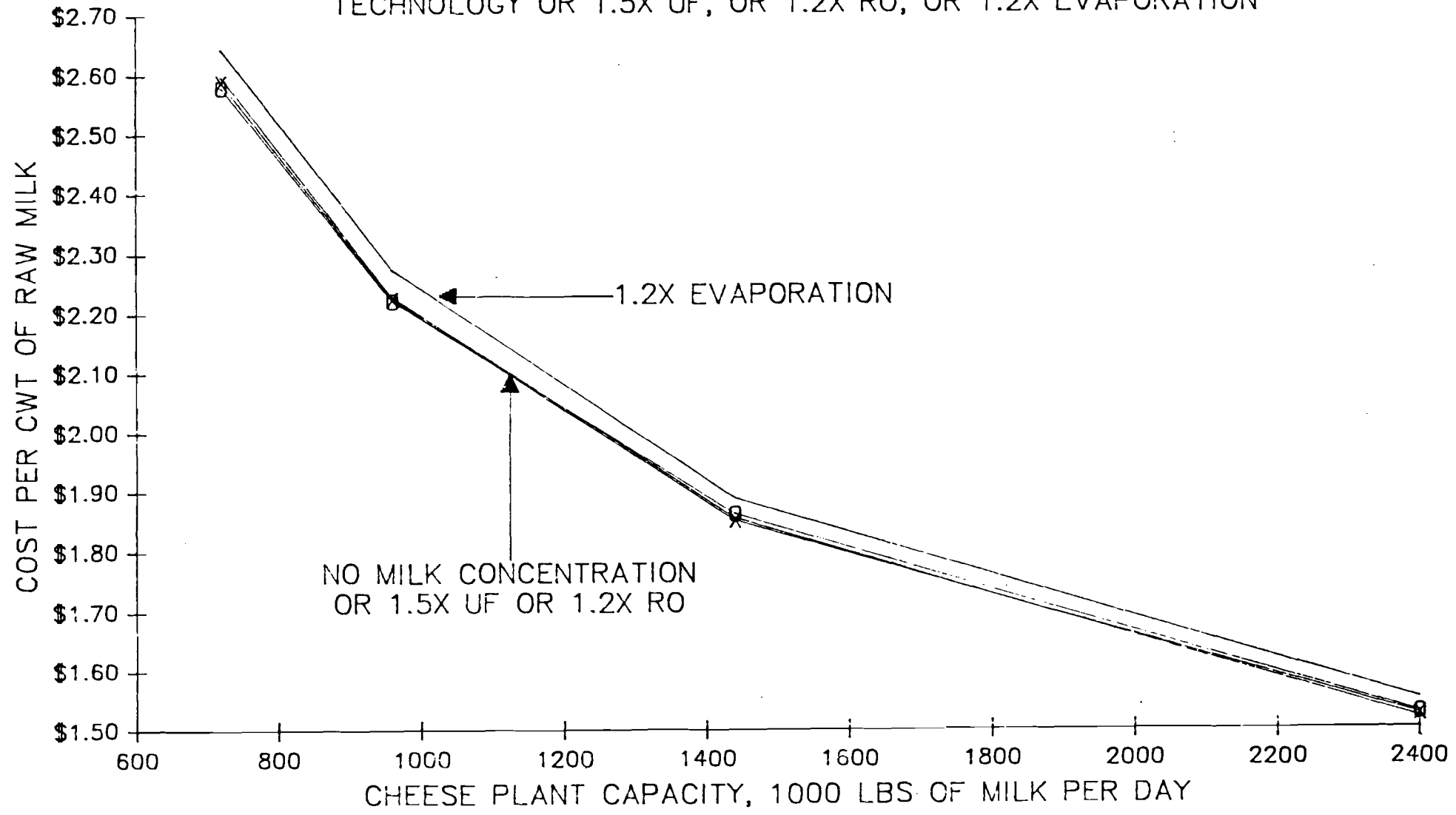
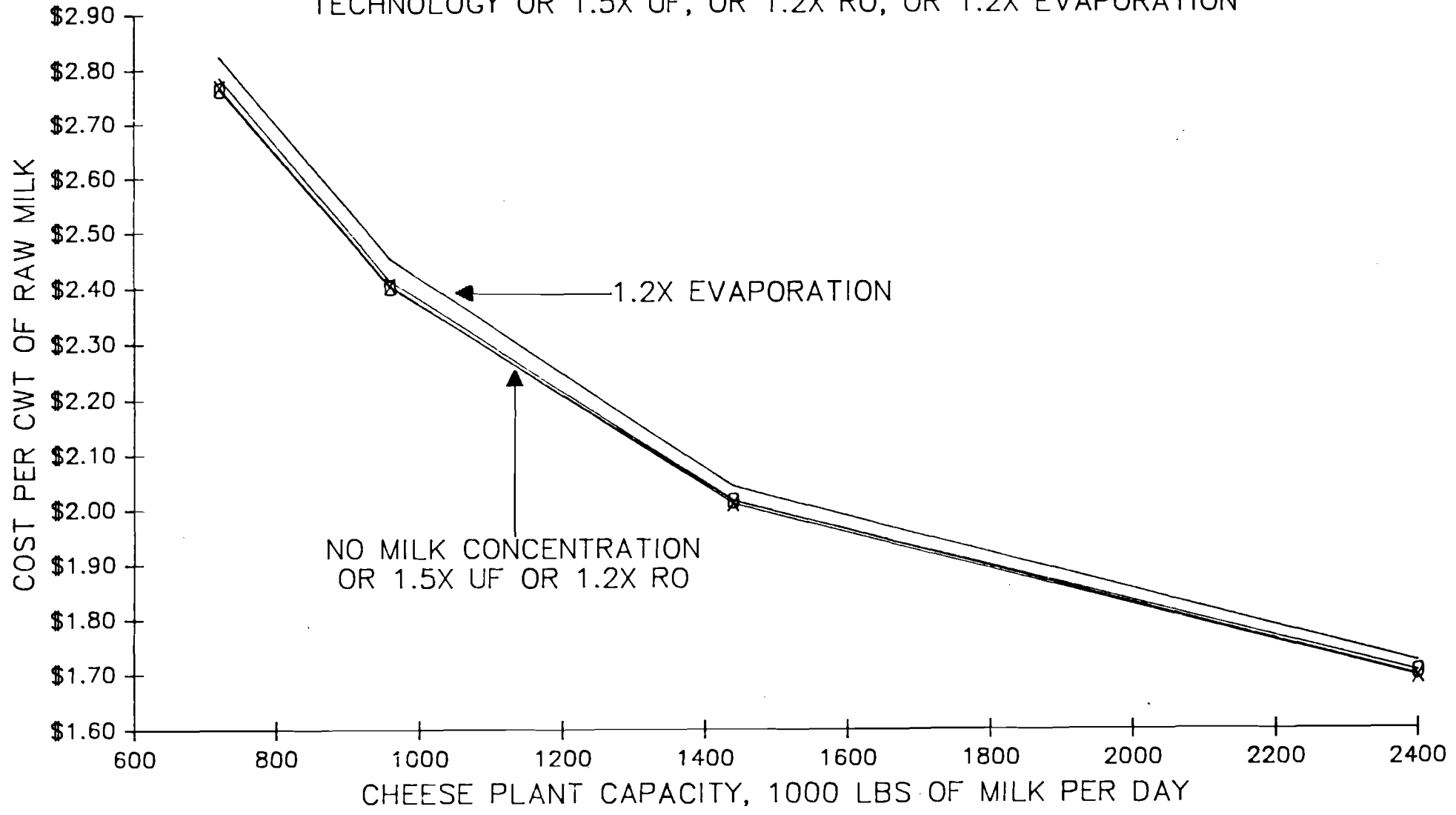


FIGURE 2 – COMBINED CHEDDAR & WHEY POWDER MANUFACTURING COSTS FOR CHEDDAR PLANTS OPERATING 5 DAYS, 24 HOURS USING EITHER NO MILK CONCENTRATION TECHNOLOGY OR 1.5X UF, OR 1.2X RO, OR 1.2X EVAPORATION



The economies of scale are very large in Cheddar cheese and whey product manufacturing, regardless of technologies used.

Considering the combined costs of manufacturing either Cheddar and WPC or Cheddar and whey powder, the two smaller plants studied have slightly higher total manufacturing costs when using 1.5X UF or 1.2X RO than with conventional cheese making. In most scenarios, the higher costs are approximately \$0.02 or less per cwt of raw milk for 1.5X UF and \$0.01 or less per cwt for 1.2X RO. On an annual basis for the 720,000 lb capacity plant, the increase in the total cost of manufacturing cheese and whey products ranges from approximately \$49,000 to zero, depending on technology used, operating schedule, and the whey product produced. In the 960,000 lb plants, the net change in manufacturing costs due to using UF or RO ranged from an increase of \$37,000 annually to a savings of \$17,000 a year.

Even for the two largest plants, using 1.5X UF or 1.2X RO may still increase the combined cheese and whey manufacturing costs as compared to conventional operation, particularly for shorter operating schedules. The change in annual combined costs for the 1,440,000 lb plant range from an increase of \$22,000 to a decrease in costs of \$31,000. For the largest plant, (2,400,000 lbs raw milk per day), the net annual difference in costs ranges from an increase of \$12,000 to a decrease of \$114,000, again depending on technology, operating schedule, and whey product produced.

Using 1.2X evaporation in the cheese plant results in higher total cheese and whey product manufacturing costs for all plant sizes and operating schedules studied. The estimated increase in costs ranged from \$0.014 in the 2,400,000 lb plant operating around the clock (\$122,000 annually) to \$0.082 per cwt in the 720,000 lb plant operating only 5 days per week, 18 hours per day, (\$102,000 per year).

Viewpoints Important in Interpreting Profitability Analysis

Regardless of the technology used, the profitability of producing Cheddar and WPC or whey powder is very sensitive to a number of factors, including the raw milk cost, product prices, plant capacity, and plant operating schedule. Based on other work done by the authors, we conclude that it has been very challenging, if not impossible, for a Cheddar cheese plant to maintain profitability under the volatile milk and product price conditions existing during 1987-1990 (6). As raw milk, cheese and whey product prices have varied widely over this time period, so have cheese and whey product profits.

Since a large plant can achieve significantly lower cheese and whey manufacturing costs, the estimated profitability of cheese and whey operations varies directly with the scale of the plant. For example, the difference in profitability for Cheddar and whey product operations between a 720,000 lb capacity plant and a 2,400,000 lb capacity plant was more than \$1.00 a cwt. Actually, it was estimated that the 720,000 lb plant was losing \$0.40 per cwt, while the 2,400,000 lb plant was making a profit of approximately \$0.60 per cwt

(both plants operating 5 days per week, 24 hours per day), (Appendix). This difference in profitability of more than \$1.00 per cwt between the smallest and largest plants studied held regardless of whether the cheese plant used 1.5X UF, 1.2X RO, 1.2X evaporation, or no concentration/fractionation method whatsoever, and was true in Cheddar and whey powder operations as well as for Cheddar and WPC (Appendix).

The profitability analyses of the milk concentration/fractionation technologies will focus on **differences** in profits or losses rather than the estimated profits or losses per se. Whereas in the cost estimation section we focused on the differences in cheese and whey manufacturing **costs** between conventional operations and those using 1.5X UF, 1.2X RO, and 1.2X evaporation, here we will examine the differences in **profitability** between conventional operations and those using UF, RO or evaporation technologies. The actual estimated profits (or losses) for each of plants in the following scenarios are reported in the Appendix.

The basic analyses compare the manufacturing cost of a conventional Cheddar/whey operation with the manufacturing costs of a Cheddar/whey operation using UF, RO or evaporation in the cheese plant, assuming all new Cheddar and whey plants for both the conventional operations and those using milk fractionation/concentration technologies. However, payback periods and IRRs are also calculated based on the assumption that the UF, RO, or evaporation technologies are added to an existing Cheddar and whey operation. Differences in the capital investment required to add UF, RO or evaporation technology to an existing Cheddar/whey plant, particularly for WPC operations, as well as some differences in whey plant manufacturing costs require this additional analysis ⁶.

Since the model plants are losing money in some operating situations, the difference in profitability between a Cheddar plant using a milk fractionation/concentration technology and a conventional operation may actually be a difference in **losses**, rather than profits. In such instances, if the difference in profitability between a Cheddar and whey plant using 1.5X UF, 1.2X RO or 1.2X evaporation and a conventional plant is a **positive** difference, the operating losses for the plant with the new technology are estimated to be that much **less** than the losses in the conventional cheese and whey operation. In other words, the difference indicates the amount per cwt of raw milk that the losses should **decrease** if the milk fractionation/concentration technology were adopted.

The cost estimates include a charge for the cost of money on the additional capital required by the particular milk concentration/fractionation technology. Thus, if a plant using one of the technologies is more profitable than a conventional plant, it means that the technology increases profits even **after** allowing for a return on the additional capital required for the technology. If a technology does not affect the profitability of a plant, it means

⁶ See page 20 for further details.

that the estimated benefits of the technology just equal the added costs of adopting that technology, including a return on investment equal to the assumed cost of capital.

In the following tables, the differences are in bold if they indicate a situation where it was estimated that both the conventional plant and the plant using UF, RO or evaporation are losing money.

Comparisons of Profitabilities Across Technologies
Assuming No Increase in Cheese Yields
and No Increase in Milk Volumes Processed

As described earlier, using milk fractionation/concentration technologies in Cheddar plants prior to cheese making seemingly had a relatively small impact on the combined cheese and whey manufacturing costs. The use of 1.5X UF or 1.2X RO increased the combined cost of manufacturing cheese and whey products in the 720,000 lb per day capacity plant and in the 960,000 lb plant, except when operating at capacity. The increases in costs ranged from a fraction of a cent per cwt of raw milk to over \$0.03 per cwt, depending on the plant size, operating schedule and the whey product produced (Tables 7 & 8).

On the other hand, 1.5X UF and 1.2X RO decreased the total manufacturing cost for cheese and whey for the 1,440,000 and 2,400,000 lb capacity plants in many situations. The reductions in costs in these largest plants, when they occurred, ranged from just a fraction of a cent per cwt to more than \$0.01 per cwt again depending on plant size, operating schedule and the whey product produced (Tables 7 & 8). Using 1.2X evaporation in the cheese plant increased cheese and whey manufacturing costs for all plant sizes across all operating schedules and for both whey products (Table 9).

Assuming no change in cheese yields or cheese quality due to using milk fractionation/concentration, the effects of these technologies on cheese and whey manufacturing costs lead to a decrease in profitability for the 720,000 and 960,000 lb plants as compared to conventional operations, except when using 1.2X RO in the 960,000 lb plant and operating at full capacity, 7 days per week, 24 hours per day (data not shown). Table 13 demonstrates these differences in profitability for plants operating 5 days, 24 hours which is the base case operating schedule in this study. Looking at the two largest plants (1,440,000 and 2,400,000 lbs of milk per day), 1.5X UF and 1.2X RO increased operating profits by approximately \$0.01 per cwt when operating on a 5 day, 24 hour schedule (Table 13). The increase in profits in these larger plants is also somewhat greater per cwt if WPC is produced rather than whey powder. As mentioned earlier, this is primarily due to the benefit from the reduced capital costs required to build new WPC plants to accompany cheese plants using UF, RO, or evaporation as compared to WPC plants with conventional cheese plants. No such reduction in capital costs

Table 13 Amount by Which These Milk Fractionation/Concentration Technologies Change Cheddar and WPC or Whey Powder Operating Profit (or Loss), Model Plants of Four Sizes¹

Note: Relative to a conventional plant, a negative sign indicates that the concentration/fractionation technology reduces profits. A positive sign indicates that the concentration/fractionation technology increases profits. Values in **bold** indicate situations where both the conventional plants and plants using concentration/fraction technologies have operating losses, under assumed product prices. Breakeven is assumed on all UF permeate.

Plant Capacity (Lbs Milk Per Day)	1.5X UF	1.2X RO	1.2X Evaporation
(\$/Per Cwt)			
<u>Cheddar and WPC²</u>			
720,000	-.019	-.008	-.064
960,000	-.006	-.003	-.052
1,440,000	+0.008	+0.006	-.025
2,400,000	+0.008	+0.002	-.025
----- (\$/Per Cwt)			
<u>Cheddar and Whey Powder³</u>			
720,000	-.022	-.004	-.060
960,000	-.011	-.001	-.050
1,440,000	-.001	+0.005	-.026
2,400,000	+0.008	+0.009	-.018

¹ The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar with 93% fat retention. Plants are assumed to be operating 5 days per week, 24 hours per day. A cheese yield of 10.16 lbs is assumed for all methods (including no concentration), with an annual production of 25.4 million lbs.

² Assuming a 1.64 yield for WPC for all methods (including no concentration) with an annual production of 4.1 million lbs.

³ Assuming a 5.80 yield for whey powder for all methods (including no concentration) with an annual production of 14.5 million lbs. for whey powder plants are realized, regardless of milk fractionation/concentration technologies used.

Although an increase in profitability of \$0.01 per cwt of raw milk may seem relatively small, given the volumes of milk processed daily in the two largest plants, this improvement in profitability amounts to approximately \$40,000 per year for the 1,440,000 plant and over \$60,000 annually for the 2,400,000 lb plant, assuming each was operating on a 5 day, 24 hour schedule. The payback periods and rates of return on the investment for 1.5X UF and 1.2X RO for these larger plants might be attractive to management in some situations and are reported in Table 14. In making a judgement on the desirability of the investment, however, management should also consider the additional risk associated with using these milk fractionation/concentration technologies.

The primary risk with 1.5X UF and 1.2X RO stems from the development of small ruptures of the UF or RO membranes and loss of fat and protein prior to cheese making. If this occurred, it would be an additional source of slippage in the plant. While this can be prevented, management must recognize the potential seriousness of the problem and carefully monitor and control the permeate from each membrane module for milk fat and protein. Quality control standards would need to be set for decision making for membrane replacement based on loss of milk fat and protein in the permeate per module per day.

The previous analyses are based on the comparisons of the profitabilities of producing Cheddar and whey products in new cheese and whey plants using UF, RO, and evaporation with the profitabilities of manufacturing Cheddar and whey products in new conventional cheese and whey plants. Of course 1.5X UF, 1.2X RO or 1.2X evaporation could be adopted by modifying existing Cheddar and whey facilities as well. In that case, the profitability of manufacturing Cheddar and WPC with the new technologies as compared to the profitability of manufacturing in a conventional operation would be different, again due to the differences in whey plant capital costs⁷. As seen in Table 15, the investment to modify an existing Cheddar and WPC operation to use 1.5X UF or 1.2X RO in the cheese plant appears to be desirable (based upon the estimated payback periods and IRRs) only for the 2,400,000 lb plant. On the other hand, since the savings, if any, in manufacturing whey powder using whey from a UF or RO cheese plant, stem from lower utility costs (rather than any changes in capital costs), the rates of return are the same regardless of whether new Cheddar and whey plants are assumed or if an existing operation is modified (Tables 14 & 15).

Because of the higher manufacturing costs mentioned earlier, the profitability of using 1.2X evaporation is \$0.02 to \$0.07 lower per cwt than for conventional plants, depending on plant size (Table 13). Thus, no payback periods or rates of return are calculated for this technology.

⁷ See page 20 for further details.

Table 14 Payback Periods and Internal Rates of Return (IRR) on the Added Investment Required for New 1.5X UF or 1.2X RO Cheese and Whey Facilities Compared to New Conventional Cheese and Whey Operations, Assuming No Increase in Cheese Yields Due to UF or RO, Model Plants of Four Sizes¹

Plant Capacity (Lbs Milk Per Day)	1.5X UF		1.2X RO	
	Payback (Years)	IRR ² (%)	Payback (Years)	IRR ² (%)
Cheddar and WPC³				
720,000	U ⁴	U ⁴	U ⁴	U ⁴
960,000	U ⁴	U ⁴	U ⁴	U ⁴
1,440,000	3.9	33	5.4	20
2,400,000	4.8	25	7.6	12
Cheddar and Whey Powder⁵				
720,000	U ⁴	U ⁴	U ⁴	U ⁴
960,000	U ⁴	U ⁴	U ⁴	U ⁴
1,440,000	10.8	5	6.5	16
2,400,000	5.4	21	5.0	24

¹ The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar with 93% fat retention. Plants are assumed to be operating 5 days per week, 24 hours per day. A cheese yield of 10.16 lbs is assumed for all methods (including conventional) with an annual production of 25.4 million lbs.

² Internal rate of return is the percentage rate equating the total capital investment required to add milk fractionation/concentration technology to a Cheddar plant with the present value of the increase in profits (expressed in cash flow terms) from using the technology.

³ Assuming a 1.64 yield for WPC for all methods (including conventional) with an annual production of 4.1 million lbs.

⁴ Undesirable investments for these plant sizes with no increase in cheese yields.

⁵ Assuming a 5.80 yield for whey powder for all methods (including conventional) with an annual production of 14.5 million lbs.

Table 15 Payback Periods and Internal Rates of Return (IRR) on the Added Investment Required for Adding 1.5X UF or 1.2X RO to Existing Cheese and Whey Facilities Assuming No Increase in Cheese Yields Due to UF or RO, Model Plants of Four Sizes¹

Plant Capacity (Lbs Milk Per Day)	1.5X UF		1.2X RO	
	Payback (Years)	IRR ² (%)	Payback (Years)	IRR ² (%)
<u>Cheddar and WPC³</u>				
720,000	U ⁴	U ⁴	U ⁴	U ⁴
960,000	U ⁴	U ⁴	U ⁴	U ⁴
1,440,000	10.8	5	11.5	4
2,400,000	5.4	21	7.7	12

<u>Cheddar and Whey Powder⁵</u>				
720,000	U ⁴	U ⁴	U ⁴	U ⁴
960,000	U ⁴	U ⁴	U ⁴	U ⁴
1,440,000	10.8	5	6.5	16
2,400,000	5.4	21	5.0	24

¹ The Cheddar plants are designed for standard stirred curd process, producing 640 lb blocks of 37% moisture commodity Cheddar with 93% fat retention. Plants are assumed to be operating 5 days per week, 24 hours per day. A cheese yield of 10.16 lbs is assumed for all methods (including conventional) with an annual production of 25.4 million lbs.

² Internal rate of return is the percentage rate equating the total capital investment required to add milk fractionation/concentration technology to a Cheddar plant with the present value of the increase in profits (expressed in cash flow terms) from using the technology.

³ Assuming a 1.64 yield for WPC for all methods (including conventional) with an annual production of 4.1 million lbs.

⁴ Undesirable investments for these plant sizes with no increase in cheese yields.

⁵ Assuming a 5.80 yield for whey powder for all methods (including conventional) with an annual production of 14.5 million lbs.

Permeate Production When Using Milk Fractionation/Concentration Technologies

The total lbs of permeate solids produced when manufacturing WPC are the same regardless of whether the whey came from a conventional cheese plant or one using 1.5X UF, 1.2X RO, or 1.2X evaporation. These milk fractionation/concentration technologies simply start the WPC process in the cheese plants rather than leaving it all to the whey plant as would happen in a conventional cheese/WPC operation. Thus, the effect of permeate handling losses or gains on total profitability is the same for conventional cheese and whey operations as it is for cheese plants using UF, RO, or evaporation. Overall, adding 1.5X UF, 1.2X RO, or 1.2X evaporation to a cheese plant which already has a WPC operation will not change or increase the amount of permeate solids produced or any gains or losses incurred from processing permeate.

Since this is the case, consideration of permeate handling costs should not be an issue when considering adding a milk fractionation/concentration technology to a cheese and whey operation. If the plant is already producing WPC these technologies will not increase the volume of permeate produced. If cheese and whey powder are currently being produced, each of these three technologies (1.5X UF, 1.2X RO and 1.2X evaporation) can be adopted in the cheese plant, while the whey plant continues to produce whey powder. The Appendix contains further details on permeate handling options and sensitivity of profits to possible permeate handling gains or losses.

Comparisons of Profitabilities Across Technologies Assuming Increases in Cheese Yields

Overview of Increased Cheese Yields

As noted earlier, unless a cheese plant has a capacity of 1,440,000 lbs of milk per day or more, using 1.5X UF or 1.2X RO increases total manufacturing costs and reduces Cheddar and whey profitability. Using 1.2X evaporation increases costs and reduces profits even in the largest plant studied (2,400,000 lbs per day). Thus, in many instances, these technologies would have to result in increased cheese revenues both to be profitable and provide a desirable rate of return on the added capital investment and to justify the additional risks associated with using milk fractionation/concentration technologies.

Assuming constant cheese, whey cream, and whey product prices regardless of technologies used, the primary factors that could increase cheese plant revenues are:

- 1) Increased cheese yields resulting from increased fat recovery in the cheese
- 2) Increased cheese yields resulting from increased recovery of nonfat milk solids in the cheese

- 3) Increased volumes of milk processed in the plant (to be discussed in the next section).

Effect of Fat Recovery on Profitability

Fat recovery or retention has a dramatic effect on cheese yields and consequently, revenues (Table 16). High levels of fat recovery are achievable without using milk concentration/fractionation technologies. By increasing fat retention from 88% to 93%, cheese yields increase more than 3% without any additional capital investment or new technology required. This is 6 times the size of the most optimistic yield increase predicted from using 1.5X UF, and nearly 4 times the size of the most optimistic yield increase predicted from 1.2X RO or 1.2X evaporation. An increase in cheese yields of 3% would increase profitability by more than \$0.20 per cwt of raw milk, regardless of plant size, assuming cheese and whey cream prices of \$1.32 and \$0.52 per lb, respectively (Table 17).

Increases in Cheese Yields Due to Fractionation/Concentration Technologies

Since high fat recovery can be achieved without using milk fractionation/concentration technologies, a constant fat recovery in the cheese of 93% was assumed in our analyses for all technologies. Thus, cheese yield increases per cwt of raw milk that can be totally credited to milk fractionation/concentration technologies are due to increased retention of nonfat milk solids.

Based on theoretical yield calculations, the 1.5X UF process could increase cheese yield by as much as 0.5%, while 1.2X RO and 1.2X evaporation have the potential to raise cheese yields by up to 0.8%.

In both cases, the increase in cheese yield is due to the retention of non-fat, non-casein, milk solids that are dissolved in the water phase of the cheese. When milk is fractionated using 1.5X UF prior to cheese making, the concentration of protein and minerals in the skim phase of the milk increases, however, the lactose concentration remains about the same. Thus, the increase in cheese yield with 1.5X UF is primarily due to increased retention of whey protein and to a lesser extent milk minerals. When milk is concentrated using 1.2X RO or evaporation, the concentration of all non-fat, non-casein milk solids is increased, including lactose. This results in a slightly higher cheese yield than with 1.5X UF.

At the low levels of milk fractionation/concentration used in this study, the additional amount of lactose in the cheese produced using milk concentrated with 1.2X RO or evaporation is not expected to cause quality defects, particularly in current Cheddar varieties, as are assumed here. A study of using RO prior to aged Cheddar cheese manufacture indicated that 10% to 15% milk volume reduction (i.e. 1.1X to 1.8X) is possible with minimal risks of product defects (4).

Table 16 Effects of Different Fat Retention Levels on Cheddar Cheese and Whey Cream Yields in Conventional Cheddar Plants Using No Concentration Method¹

	Percent Fat Retained in the Cheese			
	93	91.5	90	88
Cheddar Yield (Lbs Per Cwt Raw Milk)	10.16	10.06	9.97	9.84
Whey Cream Yield (Lbs Per Cwt Raw Milk)	.58	.70	.83	.99

¹ Milk composition based on 1984 Wisconsin survey, 3.68% fat, 3.27% protein. WPC and whey powder yields are not affected by changes in fat retention rates.

Table 17 Effects of Increased Yields Due to Higher Fat Retention Levels on Profitability of Cheddar and Whey Product Operations in Conventional Plants Using No Milk Concentration/Fractionation Method for All Plant Sizes¹

Change in Fat Retention Levels	Increase in Profitability Per Cwt of Raw Milk
	(Dollars)
From 88% to 90%	+.09
From 90% to 91.5%	+.05
From 91.5% to 93%	+.07

¹ Based on Cheddar and whey cream yields calculated in Table 14. WPC and whey powder yields are not affected by changes in fat retention rates.

The effects of possible yield increases on the profitability of Cheddar/whey product manufacturing operations were analyzed for 1.5X UF, 1.2X RO, and 1.2X evaporation based on two yield assumptions:

- 1) Realization of the full theoretical yield increase (i.e. 0.5% yield increase for 1.5X UF, 0.8% yield increase for 1.2X RO, and 1.2X evaporation).
- 2) Realization of half of the full yield increase (i.e. 0.25% yield increase for 1.5X UF, 0.4% yield increase for 1.2X RO, and 1.2X evaporation).

For each yield increase scenario the estimated profits of the model plants using milk fractionation/concentration technologies were compared with the estimated profits of the conventional model plants which were assumed to have no yield increase.

As will be detailed shortly, if the full theoretical cheese yield increases were realized, the increase in profits over those in a conventional plant would be sizeable and would result in fairly short payback periods and favorable returns on the investment. In fact, if only half of the full yield increase were realized, the adoption of 1.2X RO would appear to be desirable for all four plant sizes studied and 1.5X UF would also be desirable for all but the smallest plant size studied (i.e. 720,000 lbs milk per day). On the other hand, if only half of the theoretical yield increase were realized, 1.2X evaporation appears to be feasible for just the two largest plants (i.e. 1,440,000 and 2,400,000 lbs of milk per day).

Analyzing Investment Worth

Besides comparisons of operating profits, the economic desirability of investing in milk fractionation/concentration if increased cheese yields were realized is evaluated using the payback period and internal rate of return (IRR) measures of investment worth. Again, the payback periods and rates of return are estimated for both types of circumstances in which decisions are made concerning adoption of a milk fractionation/concentration technology:

- 1) Choosing between a new cheese and whey operation using a milk fractionation/concentration technology and a new conventional cheese and whey facility.
- 2) Choosing between continuing to use an existing conventional cheese and whey plant as is or modifying the existing cheese plant to incorporate a milk fractionation/concentration technology.

Adoption of UF, RO or evaporation in a situation with no existing facilities (i.e. where new Cheddar and WPC operations will be established regardless of whether a fractionation/concentration technology is chosen) appears to be a slightly more desirable circumstance than when considering adoption in an existing Cheddar/WPC plant. In the scenario assuming modification of an existing facility, the existing WPC plant would remain as is, with no benefit from the decreased whey volumes. Assuming all new

operations, slightly smaller WPC plants could be constructed if cheese plants using UF, RO or evaporation were built rather than a new conventional cheese plant.

The decreases in WPC plant capital costs based on the assumption of new operations are quite variable, depending on plant size and the configuration of equipment inside the WPC plants. Thus, it was estimated that based on changes in whey volumes and the actual pieces of equipment in the WPC plants accompanying the 1,440,000 and 2,400,000 lb cheese plants, the decrease in WPC capital costs would be much larger for the 1,440,000 cheese and whey operation than for the biggest plant. This is due to the fact that the equipment is ordinarily only available in certain fixed sizes, and the decrease in whey volume was not estimated to be large enough to step down an entire size for most of the equipment in the largest size plant. This results in UF or RO appearing to be somewhat better investments for the 1,440,000 lb cheese and WPC operation than for the 2,400,000 lb plant (Table 14).

Whey powder plants are assumed to require the same capital investment regardless of the scenario assumed, since the decrease in whey volumes from cheese plants using RO, or evaporation is not great enough to result in lower capital costs, even if all new plants are assumed. As discussed earlier, whey volumes would not decrease at all in whey powder plants using whey from a 1.5X UF cheese plant, due to the return of permeate to the UF whey before it leaves the cheese plant.

1.5X UF With Increased Cheese Yields

If retention of nonfat milk solids in the 1.5X UF plants increased cheese yields by 0.25% (from 10.16 lbs to 10.185 lbs per cwt of raw milk, half the theoretical yield increase), profitabilities in all but the smallest plant would be \$0.01 to \$0.04 greater per cwt of milk than in conventional plants with no concentration technology (Table 18). Due to higher manufacturing costs per cwt, the smallest 1.5X UF plant, (720,000 lbs capacity) would only realize the same profit as a conventional plant of the same size, with a 0.25% increase in cheese yields in the UF plant. The apparent conflict between no increase in profit and a positive payback period and IRR for the smallest plant (Table 18) is due to two things: 1) the new technology increased profits by less than \$0.005 per cwt and thus was rounded to zero; 2) while there was no increase in net profit from the new technology, it did cover the assumed capital costs and thus would eventually payback the capital investment, albeit over a relatively long time frame (approximately 7 to 8 years).

Depending on plant size, the increased profitability for the three larger 1.5X UF plants would result in a fairly quick recovery of capital (i.e. a 2 to 5 year payback on the investment) and substantial returns on the added capital invested in the technology (i.e. a 22% to more than 100% internal rate of return) (Table 18). Investment in 1.5X UF in the three larger plants would appear to be desirable if a 0.25% increase in cheese yield were achieved, regardless of which whey product is produced or whether new plants

Table 18 Estimated Increases in Cheddar Cheese Operating Profits (or Decreases in Losses), Payback Periods, and Internal Rates of Return (IRR) on the Added Investment Required if Increased Cheese Yields are Realized from Using 1.5X UF^{1 2}

Note: With our assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the technology used. Thus, the figures in **bold** represent estimated decreases in losses for the plants.

Plant Capacity (Lbs Milk Per Day)	Cheddar Yield Increases (Lbs per Cwt Raw Milk)					
	0.25% (10.16 to 10.185)			0.50% (10.16 to 10.21)		
	Profit Increase (\$/Cwt)	Payback Period (Years)	IRR ³ (%)	Profit Increase (\$/Cwt)	Payback Period (Years)	IRR ³ (%)
Cheddar & WPC - Comparing New 1.5X Plants to New Conventional Plants						
720,000	0	6.8	14	.03	3.8	36
960,000	.02	3.9	34	.05	2.2	81
1,440,000	.04	1.5	216	.07	0.9	VL ⁴
2,400,000	.03	1.9	108	.06	1.2	495
Cheddar & WPC - Modifying Existing Plants for 1.5X UF						
720,000	0	7.9	11	.03	4.3	29
960,000	.02	5.3	22	.05	3.1	47
1,440,000	.04	3.4	41	.07	1.8	130
2,400,000	.03	2.1	91	.06	1.3	296
Cheddar & Whey Powder - Same Results, Both Scenarios						
720,000	.01	7.2	13	.04	3.8	35
960,000	.02	4.8	24	.05	2.8	56
1,440,000	.03	3.2	46	.06	1.8	122
2,400,000	.03	2.0	99	.06	1.2	435

¹ All plants receive the same amount of milk and are assumed to be operating 5 days per week, 24 hours per day with 93% fat retention.

² If Cheddar yields increased by 0.25% or 0.5% per cwt due to using 1.5X UF in the cheese plant, whey product yields would decline slightly. This is taken into account in the profitability calculations.

³ Internal rate of return is the percentage rate equating the total capital investment required to add milk fractionation/concentration technology to a Cheddar plant with the present value of the increase in profits (expressed in cash flow terms) from the increase in cheese yields.

⁴ The internal rates of return, while not calculated exactly for this case, is estimated to be greater than 500%.

were assumed or existing operations were modified.

If the full theoretical yield increase of 0.5% (a cheese yield of 10.21 lbs per cwt raw milk) were realized in the 1.5X UF plants, profitability would increase by \$0.03 to \$0.07 per cwt of milk over that of conventional plants, again depending on plant size (Table 18). Realization of the full theoretical yield increase would make adoption of 1.5X UF an attractive investment possibility even for the 720,000 lb plant. This increase in cheese yield due to milk fractionation/concentration would shorten the payback periods to 1 to 4 years and raise returns on investment to 36% to 495%, depending on plant size (Table 18).

Here, as will be seen later with evaporation and RO, the larger the plant the greater the benefits from the milk fractionation/concentration technology, particularly if they increase cheese yields.

1.2X RO With Increased Yields

While both the 1.2X RO and 1.5X UF plants had essentially the same costs and profitabilities as conventional plants when yields were constant, 1.2X RO plants could theoretically retain more nonfat milk solids in the cheese than 1.5X UF plants and thus have the potential for greater yield increases. The full theoretical yield increase is approximately 0.8% for 1.2X RO, compared to 0.5% for 1.5X UF. Cheese yields would be 10.24 lbs per cwt of raw milk for the full yield increase, and 10.20 lbs per cwt if half of that increase were realized (a yield of 10.16 lbs is assumed for a conventional plant with no milk fractionation or concentration technologies). If a 0.4% yield increase were realized, profitabilities in 1.2X RO plants would be \$0.03 to \$0.05 per cwt of milk higher than in conventional plants with no concentration technology. If the full 0.8% yield increase occurred, profitabilities in the 1.2X RO plants would be \$0.08 to \$0.10 greater per cwt of milk than in conventional plants, depending on plant size (Table 19).

These higher profits from increased cheese yields result in 1 to 3 year paybacks for the added investment, while returns on investment would range from about 50% to over 500% (Table 19). Both payback periods and internal rates of return vary according to plant size and the amount of yield increase.

1.2X Evaporation with Increased Yields

Cheese operations using 1.2X evaporation had higher manufacturing costs than conventional plants, or plants using 1.5X UF or 1.2X RO, and the same potential cheese yield increase as 1.2X RO. Assuming a 0.4% increase in cheese yields, (half of the potential 0.8% yield increase), only the two largest 1.2X evaporation plants would be more profitable than conventional plants of the same size

Table 19 Estimated Increases in Cheddar Cheese Operating Profits (or Decreases in Losses), Payback Periods, and Internal Rates of Return (IRR) on the Added Investment Required if Increased Cheese Yields are Realized from Using 1.2X RO^{1 2}

Note: With our assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the technology used. Thus, the figures in bold represent estimated decreases in losses for the plants.

Plant Capacity (Lbs Milk Per Day)	Cheddar Yield Increases (Lbs per Cwt Raw Milk)					
	0.4% (10.16 to 10.20)			0.8% (10.16 to 10.24)		
	Profit Increase (\$/Cwt)	Payback Period (Years)	IRR ³ (%)	Profit Increase (\$/Cwt)	Payback Period (Years)	IRR ³ (%)
Cheddar & WPC - Comparing New 1.2X Plants to New Conventional Plants						
720,000	.03	2.8	54	.08	1.5	216
960,000	.05	1.7	143	.09	0.9	VL ⁴
1,440,000	.05	1.2	497	.10	0.7	VL ⁴
2,400,000	.05	1.5	204	.09	0.8	VL ⁴
Cheddar & WPC - Modifying Existing Plants for 1.2X RO						
720,000	.03	3.1	48	.08	1.6	168
960,000	.05	2.7	58	.09	1.4	265
1,440,000	.05	1.9	112	.10	1.1	VL ⁴
2,400,000	.05	1.7	154	.09	0.9	VL ⁴
Cheddar & Whey Powder - Same Results, Both Scenarios						
720,000	.05	2.6	64	.09	1.4	246
960,000	.05	2.2	85	.09	1.2	528
1,440,000	.05	1.6	156	.10	0.9	VL ⁴
2,400,000	.05	1.3	304	.10	0.8	VL ⁴

¹ All plants receive the same amount of milk and are assumed to be operating 5 days per week, 24 hours per day with 93% fat retention.

² If Cheddar yields increased by 0.4% or 0.8% per cwt due to using 1.2X RO in the cheese plant, whey product yields would decline slightly. This is taken into account in the profitability calculations.

³ Internal rate of return is the percentage rate equating the total capital investment required to add milk fractionation/concentration technology to a Cheddar plant with the present value of the increase in profits (expressed in cash flow terms) from the increase in cheese yields.

⁴ The internal rates of return, while not calculated exactly for these cases, are estimated to be greater than 500%.

with no concentration technology and no yield increase (Table 20)⁸. These two largest plants would have payback periods of approximately 4 years and internal rates of return of 25% or more (Table 20).

If, however, using 1.2X evaporation increased Cheddar yields by the full 0.8%, all four sizes of evaporation plants would be more profitable than conventional plants. These increases in profitability range from \$0.02 to \$0.07 per cwt of milk, depending on plant size (Table 20). Payback periods for 1.2X evaporation plants achieving a 0.8% increase in cheese yields would range from 2 to 5 years, with a 26% to 252% return on the added investment (Table 20). Again, returns are greatest for larger sized plants.

Overall, the potential increases in profitability appear to be greater for 1.5X UF and 1.2X RO than for 1.2X evaporation, assuming estimated yield increases are realized uniformly. However, evaporation could be viewed as a lower risk technology than either UF or RO from a sanitation and cheese quality perspective. Moreover, as discussed on page 44, another risk of 1.5X UF and 1.2X RO stems from the possible mechanical rupture of the UF or RO membranes. If this occurred, fat and protein would be lost into the permeate prior to cheese making, and substantial decreases in profitability would result.

Summary of Profitability With an Increase in Cheese Yields

Increased Cheddar yields are theoretically possible using 1.5X UF, 1.2X RO, and 1.2X evaporation, due to increased retention of nonfat milk solids in the cheese. Based on theoretical yield calculations, 1.5X UF could increase cheese yields by as much as 0.5% (from 10.16 to 10.21 lbs per cwt of raw milk), and 1.2X RO and 1.2X evaporation by up to 0.8% (from 10.16 to 10.24 lbs per cwt of raw milk).

If cheese yields increased by only half as much as these theoretical limits (from 10.16 to 10.185 lbs per cwt raw milk for 1.5X UF and to 10.20 lbs per cwt of raw milk for 1.2X RO and 1.2X evaporation), profitabilities for all plants other than the smallest 1.5X UF plant (i.e. 720,000 lbs capacity) and the two smallest 1.2X evaporation plants (i.e. 720,000 and 960,000 lbs) would be greater than for conventional plants with no concentration technology. Except for these instances, the investments in fractionation/concentration appear profitable, with relatively short paybacks of capital and good returns on the added investment required.

⁸ The apparent conflict in Table 20 between no increase in profit and a positive payback period and IRR for the 960,000 lb plant is due to two things: 1) the new technology increased profits by less than \$0.005 per cwt and thus was rounded to zero; 2) while there was no increase in net profit from the new technology, it did cover the assumed capital costs and thus would eventually payback the capital investment, albeit over a long time frame (Table 20).

Table 20 Estimated Increases in Cheddar Cheese Operating Profits (or Decreases in Losses), Payback Periods, and Internal Rates of Return (IRR) on the Added Investment Required if Increased Cheese Yields are Realized from Using 1.2X Evaporation^{1 2}

Note: With our assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the technology used. Thus, the shaded figures represent estimated decreases in losses for the plants.

Plant Capacity (Lbs Milk Per Day)	Cheddar Yield Increases (Lbs per Cwt Raw Milk)					
	0.4% (10.16 to 10.20)			0.8% (10.16 to 10.24)		
	Profit Increase (\$/Cwt)	Payback Period (Years)	IRR ³ (%)	Profit Increase (\$/Cwt)	Payback Period (Years)	IRR ³ (%)
Cheddar & WPC - Comparing New 1.2X Plants to New Conventional Plants						
720,000	-.02	NA ⁴	NA ⁵	.02	4.8	26
960,000	0	16.5	1	.04	2.8	57
1,440,000	.02	3.9	34	.07	1.6	176
2,400,000	.02	3.8	36	.06	1.5	186
Cheddar & WPC - Modifying Existing Plants for 1.2X Evaporation						
720,000	-.02	NA ⁴	NA ⁵	.02	4.7	27
960,000	0	122.0	NA ⁵	.04	3.3	43
1,440,000	.02	5.2	23	.07	2.1	92
2,400,000	.02	4.8	26	.06	1.7	135
Cheddar & Whey Powder - Same Results, Both Scenarios						
720,000	-.01	25.8	NA ⁵	.04	4.2	31
960,000	0	12.4	6	.05	3.0	49
1,440,000	.02	4.3	30	.07	1.9	116
2,400,000	.02	3.0	49	.07	1.4	252

¹ All plants receive the same amount of milk and are assumed to be operating 5 days per week, 24 hours per day with 93% fat retention.

² If Cheddar yields increased by 0.4% or 0.8% per cwt due to using 1.2X evaporation in the cheese plant, whey product yields would decline slightly. This is taken into account in the profitability calculations.

³ Internal rate of return is the percentage rate equating the total capital investment required to add milk fractionation/concentration technology to a Cheddar plant with the present value of the increase in profits (expressed in cash flow terms) from the increase in cheese yields.

⁴ No payback period can be calculated as there is no benefit from the evaporation process, thus it can never pay for itself.

⁵ No IRR can be calculated as there is no benefit from the evaporation process in these cases.

In general, when comparing these three technologies, assuming each achieves half of the theoretically possible yield increase, 1.2X RO achieves higher rates of return and faster payback periods than either 1.5X UF or 1.2X evaporation.

If the full theoretical yield increases were realized, the increase in profits over those in a conventional plant would be sizeable, resulting in fairly short payback periods and favorable returns on investment, making the adoption of RO, UF, or evaporation profitable for all plant sizes. In this case, 1.2X RO again achieves higher rates of return and faster payback periods than either 1.5X UF or 1.2X evaporation, assuming that each technology achieves all of the theoretically possible yield increase.

However, the projected benefits from increasing cheese yields using these technologies are predicated upon the assumption that all cheese manufactured is of equal quality to that produced in conventional plants and that it would sell for the same price.

Moreover, despite the potential gains in profitability from increasing cheese yields through milk fractionation/concentration technologies, there are two things that have much larger effects on profitability. Cheddar cheese profitability is influenced much more by differences in plant capacities (assuming equal operational performance) and by differences in fat retention in the cheese (which is unrelated to the milk fractionation/concentration technologies) than by using 1.5X UF, 1.2X RO, or 1.2X evaporation.

Conclusions Assuming an Increase in Cheese Yields

In short, the research results underscore the following:

- 1) The profitability of Cheddar cheese and whey product production increases dramatically as scale increases, regardless of technology. Increasing plant capacity can have a much greater effect (up to \$1.00 per cwt of raw milk) on profitability than adopting milk fractionation/concentration technologies. Assuming no increase in milk volumes processed, increased cheese yields from using fractionation/concentration technologies increase profitability by \$0.10 per cwt of raw milk, at most.
- 2) At any plant size, increasing fat recovery will significantly improve cheese yields and hence profitability without any added investment. For example, with the price of cheese at \$1.32 per lb and whey cream at \$0.52 per lb of cream, increasing fat recovery from 88% to 93% will increase profitability by \$0.21 per cwt of raw milk, which is more than twice the increase in profitability achievable from increased cheese yields due solely to milk fractionation/concentration.

Comparisons of Profitabilities Across Technologies
if They Permit Increased Volumes of Milk to be Processed
with No Increase in Cheese Yields

Overview of Increasing Milk Volumes Processed

If a plant were operating at 100% capacity, 7 days a week, 24 hours a day during a significant portion of the year and needed to increase capacity even further, the use of 1.5X UF, 1.2X RO or 1.2X evaporation would allow up to 10% more milk to be processed daily, effectively operating at 110% of capacity. This would increase the plant's production of cheese and whey products by 10% with very little modification in the rest of the cheese making process.

Note that while these milk fractionation/concentration technologies could be used to increase milk volumes processed by more than 10%, this would require extensive remodeling of the downstream cheese making equipment to handle the increased loads of cheese. However, flexibility to accommodate up to a 10% increase is usually within cheese manufacturing equipment capacities. Therefore, minimal remodeling of the existing cheese plant would be required to take advantage of these fractionation/concentration technologies if total milk volumes were increased only up to 10%.

Major Points

Operating 7 days per week, 24 hours per day, Cheddar and WPC plants using 1.5X UF or 1.2X RO in the cheese plant have approximately the same daily operating profits as conventional plants also operating around the clock (Table 21). However, even operating 7 days per week, 24 hours per day, plants using 1.2X evaporation have lower daily operating profits than conventional plants, due to higher fuel, labor, and cleaning requirements.

For Cheddar and whey powder operations, running 7 days, 24 hours results in essentially the same or slightly increased daily operating profits for all 1.2X RO plants and 1.5X UF plants, each relative to a conventional plant also running 7 days, 24 hours (Table 21). Again, all plant sizes using 1.2X evaporation have lower operating profits than conventional plants.

If using 1.5X UF, 1.2X RO or 1.2X evaporation enabled a plant to process 10% more raw milk per day and thus increase its daily cheese and whey production, the plant's total daily operating profit would be significantly higher (or in the case of the smaller plants, operating losses would be lower) on those days than that of a conventional plant operating at 100% of capacity (Table 22). This is true for both WPC and whey powder, for all technologies and all plant sizes. The increase in daily operating profits by increasing throughput 10% ranges from \$600 to more than \$4,500, depending on whey product, plant size, and technology (Tables 23, 24, 25). In fact, plants with 1.5X UF, 1.2X RO, or 1.2X evaporation would actually be more profitable than larger conventional plants built to handle the same volume of milk without using fractionation/concentration technologies (Table 22). This is due to the

Table 21 Total Daily Operating Profits of Cheddar Cheese and Whey Operations for Conventional Plants and Plants Using 1.5X UF, 1.2X RO or 1.2X Evaporation for Four Plant Sizes When Milk Volumes are Not Increased but All Plants are Operating at Full Capacity¹

Note: Assumes breakeven on UF permeate.

Plant Capacity (Lbs Milk Per Day)	Conventional Plant	1.5X UF	1.2X RO	1.2X Evap.
(\$ Per Day)				
<u>Cheddar & WPC^{2,3}</u>				
720,000	-1,327	-1,399	-1,359	-1,738
960,000	1,302	1,321	1,326	884
1,440,000	6,702	6,849	6,811	6,379
2,400,000	18,504	18,802	18,647	18,021

(\$ Per Day)				
<u>Cheddar & Whey Powder^{2,4}</u>				
720,000	-3,458	-3,550	-3,457	-3,836
960,000	-1,509	-1,537	-1,461	-1,903
1,440,000	2,823	2,881	2,954	2,522
2,400,000	11,562	11,838	11,861	11,235

¹ All plants operating 7 days per week, 24 hours per day.

² A 10.16 lb cheese yield per cwt is assumed.

³ A 1.64 lb WPC yield per cwt of raw milk is assumed.

⁴ A 5.80 lb whey powder yield per cwt of raw milk is assumed.

Table 22 Total Daily Operating Profits (or Losses) of Cheddar Cheese and WPC or Whey Powder Production in Conventional Plants Compared to Plants with Milk Volumes Increased 10% Through Using 1.5X UF, 1.2X RO or 1.2X Evaporation, Four Plant Sizes¹

Note: Assumes breakeven on UF permeate.

Original Plant Capacity	Conventional Plant	Plant With Increased Capacity ²	Larger Conventional	1.5X UF	1.2X RO	1.2X Evap.
(Lbs Milk/Day)	(\$ Per Day)	(Lbs Milk/Day)	-----(\$ Per Day)-----			
<u>Cheddar & WPC^{3,4}</u>						
720,000	-1,327	792,000	-764	-177	-157	-532
960,000	1,302	1,056,000	2,203	2,959	2,964	2,527
1,440,000	6,702	1,584,000	8,373	9,347	9,308	8,881
2,400,000	18,504	2,640,000	22,007	23,016	22,864	22,243
(Lbs Milk/Day)	(\$ Per Day)	(Lbs Milk/Day)	-----(\$ Per Day)-----			
<u>Cheddar & Whey Powder^{3,5}</u>						
720,000	-3,458	792,000	-3,114	-2,438	-2,469	-2,844
960,000	-1,509	1,056,000	-878	-118	-35	-472
1,440,000	2,823	1,584,000	3,751	5,065	5,147	4,720
2,400,000	11,562	2,640,000	14,172	15,526	15,568	14,947

¹ The fractionation/concentration methods allow 10% more milk to be processed daily, with daily cheese, whey powder, and WPC production each increasing by 10% accordingly. The conventional plants have no concentration methods and thus cannot increase their milk volumes. All plants operating 7 days per week, 24 hours per day.

² The larger conventional plant is assumed to be 10% larger than the regular conventional plant, and have the same milk capacity as the plants using fractionation/concentration methods.

³ A 10.16 lb cheese yield per cwt is assumed.

⁴ A 1.64 lb WPC yield per cwt of raw milk is assumed.

⁵ A 5.80 lb whey powder yield per cwt of raw milk is assumed.

Table 23 Estimated Increases in Cheddar Cheese Operating Profits (or Decreases in Losses), Payback Periods, and Internal Rates of Return (IRR) on the Added Investment Required if Milk Throughput is Increased by 10% from Using 1.5X UF¹

Note: With our assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the technology used. Thus, the figures in **bold** represent estimated decreases in losses for the plants.

Increased Plant Capacity (Lbs Milk Per Day)	Profit Increase (\$/Day)	Payback Period (Years)	IRR ² (%)
Cheddar & WPC - Comparing New 1.5X Plants to New Conventional Plants³			
792,000	1,150	1.2	448
1,056,000	1,657	0.8	VL ⁴
1,584,000	2,645	0.4	VL ⁴
2,640,000	4,512	0.5	VL ⁴
Cheddar & WPC - Modifying Existing Plants for 1.5X UF³			
792,000	1,150	1.4	258
1,056,000	1,657	1.1	828
1,584,000	2,645	0.8	VL ⁴
2,640,000	4,512	0.6	VL ⁴
Cheddar & Whey Powder - Same Results, Both Scenarios			
792,000	1,020	1.2	457
1,056,000	1,391	0.9	VL ⁴
1,584,000	2,242	0.7	VL ⁴
2,640,000	3,964	0.5	VL ⁴

¹ UF plants are the same size as conventional plants, but plants using 1.5X UF receive and process 10% more milk each day, and produce 10% more cheese and whey products. All plants are assumed to be operating 7 days per week, 24 hours per day with 93% fat retention and a 10.16 lb cheese yield.

² Internal rate of return is the percentage rate equating the total capital investment required to add milk fractionation/concentration technology to a Cheddar plant with the present value of the increase in profits (expressed in cash flow terms) from the increase in milk throughput.

³ See page 20 for further details on the two WPC scenarios.

⁴ The internal rate of return, while not calculated exactly for this case, is estimated to be greater than 1000%.

Table 24 Estimated Increases in Cheddar Cheese Operating Profits (or Decreases in Losses), Payback Periods, and Internal Rates of Return (IRR) on the Added Investment Required if Milk Throughput is Increased by 10% from Using 1.2X RO¹

Note: With our assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the technology used. Thus, the figures in **bold** represent estimated decreases in losses for the plants.

Increased Plant Capacity (Lbs Milk Per Day)	Profit Increase (\$/Day)	Payback Period (Years)	IRR ² (%)
Cheddar & WPC - Comparing New 1.2X Plants to New Conventional Plants³			
792,000	1,170	0.8	VL ⁴
1,056,000	1,662	0.6	VL ⁴
1,584,000	2,606	0.4	VL ⁴
2,640,000	4,360	0.5	VL ⁴
Cheddar & WPC - Modifying Existing Plants for 1.2X RO³			
792,000	1,170	1.0	VL ⁴
1,056,000	1,662	0.8	VL ⁴
1,584,000	2,606	0.6	VL ⁴
2,640,000	4,360	0.5	VL ⁴
Cheddar & Whey Powder - Same Results, Both Scenarios			
792,000	989	0.9	VL ⁴
1,056,000	1,474	0.7	VL ⁴
1,584,000	2,324	0.6	VL ⁴
2,640,000	4,006	0.5	VL ⁴

¹ RO plants are the same size as conventional plants, but plants using 1.2X RO receive and process 10% more milk each day, and produce 10% more cheese and whey products. All plants are assumed to be operating 7 days per week, 24 hours per day with 93% fat retention and a 10.16 lb cheese yield.

² Internal rate of return is the percentage rate equating the total capital investment required to add milk fractionation/concentration technology to a Cheddar plant with the present value of the increase in profits (expressed in cash flow terms) from the increase in milk throughput.

³ See page 20 for further details on the two WPC scenarios.

⁴ The internal rate of return, while not calculated exactly for this case, is estimated to be greater than 1000%.

Table 25 Estimated Increases in Cheddar Cheese Operating Profits (or Decreases in Losses), Payback Periods, and Internal Rates of Return (IRR) on the Added Investment Required if Milk Throughput is Increased by 10% from Using 1.2X Evaporation¹

Note: With our assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the technology used. Thus, the figures in **bold** represent estimated decreases in losses for the plants.

Increased Plant Capacity (Lbs Milk Per Day)	Profit Increase (\$/Day)	Payback Period (Years)	IRR ² (%)
Cheddar & WPC - Comparing New 1.2X Plants to New Conventional Plants³			
792,000	795	1.6	160
1,056,000	1,225	1.0	VL ⁴
1,584,000	2,179	0.7	VL ⁴
2,640,000	3,739	0.5	VL ⁴
Cheddar & WPC - Modifying Existing Plants for 1.2X Evaporation³			
792,000	795	1.6	161
1,056,000	1,225	1.2	488
1,584,000	2,179	0.9	VL ⁴
2,640,000	3,739	0.7	VL ⁴
Cheddar & Whey Powder - Same Results, Both Scenarios			
792,000	614	2.0	98
1,056,000	1,037	1.4	255
1,584,000	1,897	1.0	VL ⁴
2,640,000	3,385	0.8	VL ⁴

¹ Evaporation plants are the same size as conventional plants, but plants using 1.2X evaporation receive and process 10% more milk each day, and produce 10% more cheese and whey products. All plants are assumed to be operating 7 days per week, 24 hours per day with 93% fat retention and a 10.16 lb cheese yield.

² Internal rate of return is the percentage rate equating the total capital investment required to add milk fractionation/concentration technology to a Cheddar plant with the present value of the increase in profits (expressed in cash flow terms) from the increase in milk throughput.

³ See page 20 for further details on the two WPC scenarios.

⁴ The internal rate of return, while not calculated exactly for this case, is estimated to be greater than 1000%.

combination of slightly greater capital investment costs for the larger conventional plants as well as the substantial reduction in production materials expenses that is possible for plants using milk fractionation/concentration technologies.

Return on Investment and Payback Periods

The desirability of making an investment in 1.5X UF, 1.2X RO, or 1.2X evaporation in order to allow for increased throughput depends on the number of days a plant already operates at 100% of capacity, 7 days per week, 24 hours per day and whether it is in a position to increase its volume of milk processed by 10% (i.e. can it obtain this much extra milk on a daily basis). In the extreme case, where a plant would operate at 110% of capacity 365 days per year, the investment in 1.5X UF, 1.2X RO and 1.2X evaporation all appear to be very desirable, even for the smallest plant studied (720,000 lbs of milk per day). The payback periods would be short, with high rates of return on the investment. This is true for both scenarios with cheese and WPC (i.e. assuming a new whey plant versus remodeling an existing plant), as well as for a Cheddar and whey powder operation (Tables 23, 24, 25).

Most plants do not operate at full capacity throughout the entire year, however, but more commonly only during certain peak periods. Thus, only during these periods would most plants be able to take advantage of the opportunity to increase milk volumes processed (throughput) by using UF, RO or evaporation. To take this into account, the number of days per year were calculated that a plant would have to operate at 110% of capacity to payback the investment in these technologies in 4 years. A shorter payback period could be achieved by operating more days with increased throughput. The same tack was taken with rate of return on investment (IRR). Here, it was estimated the number of days per year of increased throughput required with each technology to achieve two specific rates of return: 20% and 30%. Again, the more days operated with increased throughput per year, the higher the rate of return (IRR).

In all cases, the advantage of larger scale plants can be seen in the fewer number of days required to payback the investment or to reach a desired rate of return for each technology. The plants were assumed to still use the milk fractionation/concentration technologies on all days, even those when milk volumes processed were not increased.

Only the case of all new plants was assumed in Tables 26-30. If modifications to existing operations were assumed, it would not affect the payback periods and IRRs for the cheese and whey powder operations. However, more days would be required to reach these payback and IRR targets under the assumption of modifying an existing operation for cheese and WPC plants, due to not receiving any credit for decreased capital investment to the whey plant in this circumstance.

Table 26 shows the number of days of increased throughput required to payback the investment of using 1.5X UF, 1.2X RO, or 1.2X

Table 26 Number of Days Per Year Plants Would Have to Operate at 110% of Capacity to Payback the Investment in 1.5X UF, 1.2X RO, or 1.2X Evaporation in 4 Years¹

Note: With our assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the technology used. Thus, the figures in bold represent estimated decreases in losses for the plants.

Increased Plant Capacity ² (Lbs Milk Per Day)	1.5X UF	1.2X RO	1.2X Evaporation
(Days Per Year)			
<u>Cheddar and WPC</u>			
792,000	137	92	206
1,056,000	84	59	151
1,584,000	30	35	85
2,640,000	35	42	95
----- (Days Per Year)			
<u>Cheddar and Whey Powder</u>			
792,000	159	107	243
1,056,000	122	79	183
1,584,000	76	55	110
2,640,000	43	37	98

¹ Cheese, WPC, and whey powder yields are assumed to be 10.16, 1.64, and 5.80 lbs per cwt raw milk, respectively.

² The concentration methods allow 10% more milk to be received daily, with daily cheese, whey powder, and WPC production each increasing by 10% accordingly.

evaporation in 4 years in either a Cheddar/WPC or a Cheddar/whey powder operation. Across all plant sizes, fewer days are required to payback the investment in Cheddar/WPC operations than Cheddar and whey powder plants. This is due to the benefit from the decreased whey plant capital costs for the WPC plants under the assumption of all new plants, as mentioned above. Also, the large economies of scale are seen clearly here, with the smallest 1.5X UF plant requiring approximately 4 1/2 to 5 months of increased throughput annually to payback the investment (depending on the whey product produced), versus little more than a month for the two largest 1.5X UF operations.

The reason the 1,584,000 lb cheese and WPC plant (the 1,440,000 plant operating at 110% of capacity) requires fewer days to payback the investment than the largest operation refers back to the credit received for the smaller WPC plant capital costs under the assumption of all new plants. As mentioned in an earlier section, the 1,584,000 lb plant receives a much larger credit for reduced capital costs than the largest plant due to the fixed nature of the standard equipment sizes in the whey plant that were used in this study. This larger credit is reflected in the fewer number of days required to payback the investment and also reach a target rate of return, discussed next.

Looking at the rates of return, (Tables 27 & 28), the same observations naturally hold true as in the analysis of payback periods. Fewer days of increased throughput are required to reach an IRR of 20% or 30% in Cheddar/WPC operations than in Cheddar and whey powder plants. Larger plants also require fewer days of increased throughput than smaller plants, and evaporation always requires more days to reach the target IRR than UF or RO.

To take advantage of increased throughput, however, additional milk supplies would be necessary. How much additional milk would be required on an annual basis, assuming that the plants operated with increased throughput (110% of capacity) only on enough days to meet the payback goal of 4 years? In answering this question, the plants are assumed to operate on a 5 day, 24 hour per day schedule (71% of capacity) during the rest of the year. For example, the 720,000 lb capacity Cheddar and WPC operation using 1.5X UF would require 137 days of increased throughput to pay back the additional capital investment (Table 26). Thus, instead of operating 260 days per year at 720,000 lbs of milk per day, this plant would now need 792,000 lbs of milk for 137 days, while still requiring 720,000 lbs for the remaining 123 days.

On an annual basis, 9,864,000 lbs of additional milk would be necessary for those days of increased throughput (72,000 lbs per day for 137 days). However, this is still just 5% of the total 187 million lbs of milk required for the plant per year (720,000 lbs per day for 260 days). Table 29 details the additional milk required to meet the 4 year payback period for all plants sizes using 1.5X UF, 1.2X RO or 1.2X evaporation and the percentage that this is of the total annual milk utilization for the plants before increasing throughput.

Table 27 Number of Days Per Year Plants Would Have to Operate at 110% of Capacity to Achieve a 20% Return on Investment in 1.5X UF, 1.2X RO, or 1.2X Evaporation¹

Note: With our assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the technology used. Thus, the figures in **bold** represent estimated decreases in losses for the plants.

Increased Plant Capacity ² (Lbs Milk Per Day)	1.5X UF	1.2X RO	1.2X Evaporation
(Days Per Year)			
<u>Cheddar and WPC</u>			
792,000	120	80	187
1,056,000	73	51	138
1,584,000	24	29	77
2,640,000	28	35	85

(Days Per Year)			
<u>Cheddar and Whey Powder</u>			
792,000	140	92	220
1,056,000	106	67	166
1,584,000	64	45	99
2,640,000	34	29	86

¹ Cheese, WPC, and whey powder yields are assumed to be 10.16, 1.64, and 5.80 lbs per cwt raw milk, respectively.

² The concentration methods allow 10% more milk to be received daily, with daily cheese, whey powder, and WPC production each increasing by 10% accordingly.

Table 28 Number of Days Per Year Plants Would Have to Operate at 110% of Capacity to Achieve a 30% Return on Investment in 1.5X UF, 1.2X RO, or 1.2X Evaporation¹

Note: With our assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the technology used. Thus, the figures in **bold** represent estimated decreases in losses for the plants.

Increased Plant Capacity ² (Lbs Milk Per Day)	1.5X UF	1.2X RO	1.2X Evaporation
	(Days Per Year)		
<u>Cheddar and WPC</u>			
792,000	161	110	230
1,056,000	101	71	168
1,584,000	40	45	96
2,640,000	45	52	109
	----- (Days Per Year)		
<u>Cheddar and Whey Powder</u>			
792,000	187	129	273
1,056,000	145	96	206
1,584,000	92	69	126
2,640,000	55	49	113

¹ Cheese, WPC, and whey powder yields are assumed to be 10.16, 1.64, and 5.80 lbs per cwt raw milk, respectively.

² The concentration methods allow 10% more milk to be received daily, with daily cheese, whey powder, and WPC production each increasing by 10% accordingly.

Table 29 Additional Milk Required for Increased Throughput Necessary to Meet 4 Year Payback Periods for the Additional Investment for 1.5X UF, 1.2X RO, and 1.2X Evaporation¹

Plant Capacity (Lbs of Milk Per Day)	Annual Lbs Milk with No Inc. in Throughput ²	Additional Lbs of Milk Required if Throughput is Increased and the Percent that the Additional Milk is of the Annual Total					
		1.5X UF		1.2X RO		1.2X Evaporation	
	Annual Milk (Mill. Lbs)	Add Milk (Mill. Lbs)	%	Add Milk (Mill. Lbs)	%	Add Milk (Mill. Lbs)	%
<u>Cheddar and WPC</u>							
720,000	187.2	9.9	5.3	6.6	3.5	14.8	7.9
960,000	249.6	8.1	3.2	5.7	2.3	14.5	5.8
1,440,000	374.4	4.3	1.2	5.0	1.3	12.2	3.3
2,400,000	624.0	8.4	1.3	10.1	1.6	22.8	3.7
<u>Cheddar and Whey Powder</u>							
720,000	187.2	11.4	6.1	7.7	4.1	17.5	9.3
960,000	249.6	11.7	4.7	7.6	3.0	17.6	7.0
1,440,000	374.4	10.9	2.9	7.9	2.1	15.8	4.2
2,400,000	624.0	10.3	1.7	8.9	1.4	23.5	3.7

¹ Payback periods for Cheddar and whey powder and Cheddar and WPC operations are reported in Table 26 for all plant sizes and technologies.

² Annual lbs of milk required are calculated assuming all plants are operating 5 days per week, 24 hours per day, for a total of 260 days per year.

The percent of additional milk required for the days of increased throughput (to achieve a 4 year payback target) ranges from approximately 9% to 1%, based on plant size, technology, and whey product produced (Table 29). As plant size increases, the additional milk required represents an ever decreasing percentage, due to the effects of economies of scale, with fewer days of increased throughput required per year to reach the target payback period of 4 years. Thus, although additional milk would be required to increase plant throughput, it appears that it may be feasible in some situations, particularly for larger plants.

Comparisons of Profitabilities Across Technologies
Assuming Both Increased Cheese Yields and Increased Milk Volumes
Were Realized

Overview of Increasing
Cheese Yields and Milk Volumes

If both increased yields and increased milk volumes were achieved through using 1.5X UF, 1.2X RO, or 1.2X evaporation in the cheese plant, operating profits of these plants would be much greater than those of conventional plants with no milk concentration technologies, (i.e. from a decrease in operating losses by \$1,042 per day for the smallest cheese and whey powder plant using 1.2X evaporation and achieving a 10.20 lb cheese yield (i.e. -\$3,458 - - \$2,416) to an increase in operating profit of \$6,767 per day for the largest Cheddar and WPC plant using 1.2X RO with a 10.24 lb cheese yield) (i.e. \$25,271 - \$18,504) (Table 30).

As increasing the throughput alone decreased losses by \$614 per day for the smallest cheese and whey powder operation using 1.2X evaporation (Table 25), the remaining \$428 from the example above (\$1,042-\$614) is due to the increased cheese yield (10.16 lbs to 10.20 lbs, an increase of 0.4%). For the largest Cheddar & WPC plant using 1.2X RO mentioned above, \$4,360 of the increased profits is due to increased throughput (Table 24), so the remaining \$2,407 can be attributed to the yield increase (in this case from 10.16 lbs per cwt to 10.24 lbs, a 0.8% increase). Thus, it can be generalized that somewhat more than half of the increased profits (or decreased losses) reported in Table 30 are due to the plant's ability to process 10% more milk per operating day, while slightly less than half is due to the increased cheese yields resulting from using milk fractionation/concentration technologies. However, it must be reiterated here that Table 30 presents only the most extreme case, where each plant is operating at 110% of capacity 7 days per week, year round.

Return on Investment

While not reported here, the payback periods and IRRs under these extreme circumstances would be significantly improved over those for increased throughput alone (Tables 23, 24, 25), which in themselves are already quite favorable. Thus, a Cheddar and whey powder operation operating at 110% of capacity 365 days per year with increased cheese yields would have a payback period of less than 2

Table 30 Total Daily Operating Profit of Cheddar Cheese and WPC or Whey Powder When Throughput and Cheese Yields are Each Increased in Plants Using 1.5X UF, 1.2X RO, or 1.2X Evaporation, Compared to Two Conventional Plants Using No Concentration Technology¹.

Note: Assumes breakeven on permeate in 1.5X UF cheese and WPC plants.

Original Plant Milk Capacity (1000 Lbs Per Day)	Convent. Plant	Plant with Increased Milk Cap. (1000 Lbs Per Day)	Larger Conventional Plant ²	Cheddar Yields (Lbs per Cwt Raw Milk)					
				1.5X UF	Reverse Osmosis	Evaporation	10.16	10.185	10.21
Cheddar (\$ Per Day)				(\$ Per Operating Day)					
& WPC									
720	-1,327	792	-764	40	255	202	566	-173	191
960	1,302	1,056	2,203	3,248	3,536	3,443	3,927	3,005	3,490
1,440	6,702	1,584	8,373	9,780	10,211	10,024	10,752	9,597	10,325
2,400	18,504	2,640	22,007	23,736	24,456	24,058	25,271	23,437	24,650
Cheddar (\$ Per Day)				(\$ Per Operating Day)					
& Whey Powder									
720	-3,458	792	-3,114	- 2,258	-2,024	-2,041	-1,670	-2,416	-2,045
960	-1,509	1,056	-878	195	508	462	956	24	519
1,440	2,823	1,584	3,751	5,535	6,004	5,892	6,634	5,465	6,207
2,400	11,562	2,640	14,172	16,307	17,089	16,809	18,046	16,188	17,425

¹ Cheese yield increases are assumed due to increased non-milk fat solids in the cheese. Whey cream yields are assumed to remain constant but WPC and whey powder yields would decrease slightly. The 1.5X UF plant is assumed to have potential cheese yield increases of 0.25% and 0.5%, (i.e. 10.185 and 10.21 lbs). Yield increases for the reverse osmosis and evaporation plants are assumed to be 0.4% and 0.8%, (i.e. 10.20 and 10.24 lbs). All plants operating 7 days per week, 24 hours per day.

² The larger conventional plant is assumed to have 10% more capacity than the regular conventional plant, but does not use any concentration methods and is not assumed to have any yield increases.

years to 6 months, depending on plant size, technology used, and cheese yield achieved. Cheddar and WPC plants, under the same conditions would have payback periods ranging from less than 18 months to less than 6 months, again depending on plant size, technology used, and cheese yield. In the same vein, IRRs would range from greater than 98% to over 1000% for Cheddar and whey powder and from more than 160% to over 1000% for Cheddar and WPC, based on plant size, technology used, and cheese yield. This suggests that a firm planning on building a new manufacturing facility for commodity Cheddar should seriously consider incorporating one of these milk fractionation/concentration technologies into the plant.

Based on the number of days required to pay back the capital investment with increased throughput alone (Table 26), the plants achieving increased cheese yields year round from using UF, RO or evaporation would require fewer days of increased throughput annually to pay back the investment in four years time. Thus, both Cheddar and WPC and Cheddar and whey powder operations should be able to meet that 4 year payback goal by running increased throughput (with increased cheese yields) in less than one to eight months, depending on technology, plant size, whey product produced, and cheese yields, (i.e. increased throughput would be required for less than 243 days for the smallest Cheddar and whey powder plant using 1.2X evaporation if cheese yields were increased year round, Table 26).

Looking at IRRs, under these same circumstances of both increased throughput and increased cheese yields, increased throughput would be necessary for considerably less than one to seven months to achieve a 20% return on investment and for considerably less than one and a half to nine months to achieve a 30% return on investment, based on the results from increased throughput alone. Again, this range depends on plant size, technology used, whey product produced, and cheese yields realized. For example, the largest Cheddar and WPC plant could achieve an IRR goal of 30% by operating with increased throughput less than 45 days annually if increased cheese yields were realized year round (Table 28).

MEDIUM CONCENTRATION FACTOR UF (6.5X) IN CHEDDAR CHEESE OPERATIONS

Overview of Manufacturing Costs

As was true for the milk fractionation/concentration techniques reported earlier (1.5X UF, 1.2X RO, and 1.2X evaporation), using 6.5X UF in a Cheddar plant increases cheese manufacturing costs while decreasing WPC manufacturing costs. Again, one reason for these changes is the transfer of some of the whey processing costs to the cheese plant, reinforcing the necessity to look at total cheese and whey costs, not either alone. (Note: for a brief explanation of the 6.5X UF process, refer to page 9.) For 6.5X UF, the net effect of using the technology was an increase in total cheese and WPC manufacturing costs per cwt of raw milk for all plant sizes and most operating schedules when compared to conventional plants (Table 31). Due to economies of scale, the increase in total cheese and WPC

Table 31 **Differences in the Manufacturing Costs of Cheddar and WPC Between Conventional Cheese Plants and Those Using 6.5X UF for Four Plant Sizes Using Four Operating Schedules**^{1 2}

Notes: 1) A negative sign indicates that the manufacturing cost for cheese or whey products is lower in plants using 6.5X UF.
2) Breakeven is assumed on the UF permeate.

Manufacturing Cost & Plant Capacity ³	Plant Operating Schedules			
	5 Days 18 Hours	6 Days 18 Hours	5 Days 24 Hours	7 Days 24 Hours
	(\$/Cwt of Milk)			
Cheddar				
720,000	.234	.186	.148	.100
960,000	.206	.163	.128	.084
1,440,000	.149	.114	.085	.052
2,400,000	.114	.085	.058	.031
WPC				
720,000	-.084	-.075	-.063	-.056
960,000	-.075	-.068	-.056	-.051
1,440,000	-.066	-.060	-.049	-.046
2,400,000	-.054	-.049	-.041	-.038
Cheddar & WPC				
720,000	.150	.111	.085	.044
960,000	.131	.095	.072	.033
1,440,000	.083	.054	.036	.006
2,400,000	.060	.036	.017	-.007

¹ The Cheddar plants are designed for automatic Cheddaring using a DMC and producing 640 lb blocks of 37% moisture commodity Cheddar with 93% fat retention. A cheese yield of 10.16 lbs per cwt is assumed for the conventional plant. Due to the concentration process, the 6.5X UF plant is assumed to have a yield of 10.57 lbs (a 4% increase).

² See the Appendix for the actual Cheddar and WPC manufacturing costs.

³ Plant capacities are in terms of pounds of raw milk received per day.

manufacturing costs is the least per cwt of milk for the largest sized plants, however, which is the same as we've seen all along.

Depending on plant size and operating schedule, 6.5X UF increased **cheese** manufacturing costs from \$0.031 per cwt of raw milk in the largest plant (operating at 100% of capacity) to more than \$0.23 per cwt of milk in the smallest plant, (operating at 50% of capacity) (Table 31). On the other hand, using 6.5X UF decreased WPC manufacturing costs by \$0.038 to \$0.084 per cwt of raw milk, depending on plant size and operating schedule (Table 31). This transfer of costs occurs because the 6.5X UF process concentrates the UF "whey" to such a degree in the cheese plant that a UF center is no longer required in the WPC plant⁹. Overall though, using 6.5X UF in the Cheddar plants **increases total cheese and WPC** manufacturing costs by approximately \$0.01 to \$0.15 per cwt of raw milk compared to conventional plants, depending on plant size and operating schedules (Table 31). Only in the largest plant, operating around the clock, was the combined cheese and WPC manufacturing cost **less** in a 6.5X UF plant than in conventional operation.

Components of Cheddar Cheese Manufacturing Costs Using 6.5X UF

As indicated above, using 6.5X UF increases Cheddar cheese manufacturing costs regardless of plant size or operating schedule. What factors lead to these higher costs?

The 960,000 lbs capacity plant is used to illustrate in more detail the effects that using 6.5X UF has on the components of cheese manufacturing cost (Table 32). While the magnitudes of the technology's effect on individual cost items depend on plant size, the directions are the same regardless of plant size.

Using 6.5X UF in the Cheddar plants raises the level of capital investment over that of conventional plants due to the need for a UF center and entirely different cheese making equipment. This larger capital investment leads to significantly higher depreciation and interest charges (i.e. an increase of \$0.11 or more per cwt), as well as higher property taxes and insurance costs (Table 32). Maintenance and repair costs are also somewhat higher in 6.5X UF plants, due to the addition of the extra equipment as well as the maintenance and replacement of UF membranes which are not found in conventional cheese plants. The new technology leads to slightly increased labor and electricity costs, as well. Due to the assumed higher cheese yield, costs for packaging materials are also higher per cwt of milk when using 6.5X UF than in a conventional plant (Table 32).

⁹ In fact, the whey from a 6.5X UF cheese plant is too concentrated to make standard 34.5% protein WPC, and some of the permeate must be added back with the whey before it is transferred to the whey plant for final processing into WPC. This is also the reason manufacturing whey powder is not considered an option with this technology.

Table 32 **Cheddar Manufacturing Costs With Medium Concentration Factor UF (6.5X) Compared to No Concentration Method.** Both Plants Have a Capacity of 960,000 Lbs of Raw Milk Per Day^{1,2}

Note: Assumes breakeven on UF permeate. Cost components in **bold** are those affected by the 6.5X UF process.

Cost Item	No Concentration	6.5X UF
	(\$/Cwt of Milk)	
Labor		
Supervisory	.048	.048
Direct Fixed	.052	.050
Direct Variable	.479	.487
Total Labor	.579	.585
Capital Costs		
Deprecation & Interest	.306	.466
Utilities		
Electricity	.018	.023
Fuel	.092	.081
Water & Sewage	.009	.009
Total Utilities	.119	.113
Materials		
Laboratory	.007	.007
Production	.170	.056
Packaging	.278	.289
Cleaning	.039	.035
Total Materials	.494	.387
Repair & Maintenance	.024	.062
Property Tax & Insurance	.102	.144
Production Inventory	.021	.021
Other Expenses	.026	.026
TOTAL	1.671	1.799

¹ Both Cheddar plants are designed for automatic cheddaring using a DMC and producing 640 lb blocks of 37% moisture commodity Cheddar with 93% fat retention with capacities of 960,000 lbs of raw milk per day. The plant with no concentration is assumed to have a cheese yield of 10.16 lbs per cwt raw milk. Due to the concentration process, the yield in the 6.5X UF plant is assumed to increase 4% to 10.57 lbs per cwt of raw milk. Annual Cheddar production is 25.4 million lbs for the plant using no concentration and 26.4 million lbs for the plant with 6.5X UF concentration.

² Both cheese plants are assumed to be operating 5 days per week, 24 hours per day.

Cheddar plants using 6.5X UF have much lower production materials costs (i.e. rennet and starter media) than conventional cheese plants (Table 32). The starter culture center differs from one in a conventional plant in that a portion of the 6.5X UF retentate is used to grow the starter culture rather than using starter media ¹⁰. The increased concentration of the cheese milk through the UF process also allows the quantity of rennet to be reduced by 50% compared to a conventional cheese plant. As starter media and rennet together account for over 85% of production material costs, the elimination of the starter media and 50% of the rennet reduces total production materials costs by 67% compared to a conventional cheese plant (Table 32). Fuel and cleaning materials costs are also slightly lower in the 6.5X UF plants than in conventional cheese plants using no milk concentration technology.

Economies of scale play a large role in nearly all the cost items that are higher for 6.5X UF plants than conventional plants (i.e. depreciation, interest, property taxes, maintenance, repair, and labor). Thus, the estimated increases in these expenses due to 6.5X UF are less per cwt of milk in larger plants than in smaller plants. On the other hand, the decrease in production material costs per cwt is constant across all plant sizes. Thus, as plant size increases, the savings in production material costs from using 6.5X UF in the Cheddar plant remains the same per cwt while higher costs due to using the technology decrease per cwt. These combine to narrow the gap in cheese manufacturing costs between 6.5X UF Cheddar plants and conventional plants down to \$0.031 per cwt of raw milk for the largest plant size (i.e. 2,400,000 lbs per day) operating 7 days, 24 hours per day (Table 31).

Components of WPC Manufacturing Costs When Using 6.5X in the Cheddar Plant

Evaluation of the economic impacts of whey processing for a 6.5X UF Cheddar plant is difficult. First, the UF "whey" is already the equivalent of liquid WPC, with a higher protein content on a solids basis than 34.5%, (the industry standard for WPC). Thus, to market this whey product "as is" would require development of a market for a new WPC product and determination of a value. To overcome this problem, it was assumed that some of the permeate from the ultrafiltration of the milk in the cheese plant would be mixed back with the "whey" after it leaves the modified DMC, diluting the protein content and thus permitting production of standard 34.5% WPC. This allows for evaluation of WPC manufacturing costs and estimation of potential revenues based on a standard product, commonly produced and purchased. While this addition of permeate back into the "whey" after it leaves the modified DMC may not conform to current federal standards for WPC, the process is technically feasible.

The amount of 34.5% WPC produced will depend on the amount of whey protein not retained in the cheese. As cheese yield increases due to higher retention of whey protein in the cheese, the amount of permeate that will be used to dilute the UF "whey" will decrease.

¹⁰ See page 9 for more detail on the starter center.

Thus, as the cheese yield increase, the amount of permeate solids that must be processed will increase. As in the earlier analyses, breakeven on permeate processing is assumed, but a sensitivity analysis is performed on the potential profit or loss resulting from a range of values on the permeate solids.

Using these assumptions, WPC manufacturing costs (using "whey" from a 6.5X UF Cheddar plant) were estimated to range from \$0.299 per cwt of raw milk in the largest capacity plant (i.e. 2,400,000 lbs of milk per day) to \$0.682 per cwt of raw milk in the smallest capacity plant (i.e. 720,000 lbs of milk per day), each operating 5 days per week, 24 hours per day (Appendix). These are \$0.041 to \$0.063 per cwt of milk lower than WPC manufacturing costs associated with conventional plants of the same sizes. However, it must be reiterated that these are not so much cost savings, but rather a **transferral** of part of the whey processing costs to the cheese plant.

The decrease in WPC manufacturing costs stem primarily from the concentration of the UF "whey" that occurs during the 6.5X UF process in the Cheddar plants. The "whey" is concentrated to such a degree in the cheese plants that it can be evaporated and dried directly as 34.5% WPC powder, with no UF center needed in the WPC plant. This transfer of whey processing from the whey plant to the cheese plant reduces the whey plant's capital investment costs (i.e. depreciation, interest, property taxes, and insurance), as well as labor, cleaning, and repair and maintenance costs. Packaging costs are also lower per cwt of milk since using 6.5X UF in the cheese plant decreases WPC yield while it increases Cheddar yields. WPC yields in plants using no concentration method or 1.5X UF, 1.2X RO, or 1.2X evaporation are assumed to be 1.64 lbs per cwt of milk. With 6.5X UF, WPC yields are assumed to decrease to 1.41 lbs per cwt of raw milk with a 4% increase in cheese yields. The various WPC cost components are shown in Table 33, which compares WPC manufacturing costs for two WPC plants each serving 960,000 lbs capacity Cheddar plants, one being a conventional cheese plant and the other using 6.5X UF, each operating 5 days, 24 hours per day.

Increased Cheddar Yields Due to Using 6.5X UF

Since using 6.5X UF increases Cheddar manufacturing costs more than it decreases WPC manufacturing costs (for all plant sizes, each on a per cwt of raw milk basis), higher total revenues would have to be realized to justify the investment in the technology and compensate for the additional risks involved. **Assuming that an acceptable quality cheese could be produced using 6.5X UF which would sell for the same price as cheese produced in a conventional plant, the higher revenues must come from higher cheese yields.**

One result of the 6.5X UF process is that more nonfat milk solids (particularly whey proteins) are retained in the cheese. This, plus the additional fat available from the fresh cream, results in a higher cheese and whey cream yield. However, the exact

Table 33 **WPC Manufacturing Costs** in Two Plants Accompanying 960,000 Lb Capacity Cheddar Plants, One Using No Milk Fractionation, the Other Using **Medium Concentration Factor UF (6.5X)**^{1,2}

Note: Assumes breakeven on UF permeate. Cost components in **bold** are those affected by the 6.5X UF process.

Cost Item	No Concentration	6.5X UF
(\$/Cwt of Milk)		
Labor		
Supervisory	.016	.016
Direct Fixed	.013	.013
Direct Variable	.164	.159
Total Labor	.193	.188
Capital Costs		
Depreciation & Interest	.179	.155
Utilities		
Electricity	.005	.005
Fuel	.093	.093
Water & Sewage	.007	.007
Total Utilities	.105	.105
Materials		
Laboratory	.000	.000
Production	.005	.005
Packaging	.017	.015
Cleaning	.014	.012
Total Materials	.036	.032
Repair & Maintenance	.031	.015
Property Tax & Insurance	.056	.050
Production Inventory	.000	.000
Other Expenses	.006	.006
TOTAL	.606	.551

¹ WPC yield is assumed to be 1.64 lbs per cwt raw milk in the plant accompanying the Cheddar plant using no concentration, with an annual production of 4 million lbs. In the 6.5X UF plant, permeate is assumed to be added back to UF whey after it leaves the cheese vats to produce standard 34.5% protein WPC. Due to the 4% increase in cheese yields in the 6.5X UF plants, however, WPC yields decrease to 1.41 lbs per cwt raw milk, with an annual production of 3.5 million lbs.

² Both WPC plants are assumed to be operating 5 days per week, 24 hours per day.

magnitude of this increase in cheese yields is far from certain and depends greatly on plant management as well as technical skill. Thus, the profitabilities of producing Cheddar and WPC using 6.5X UF in the model plants were estimated for three possible increases in cheese yields; 4%, 6%, and 8% (i.e. 10.57, 10.77, and 10.97 lbs per cwt of raw milk, respectively). The Appendix provides the details of the Cheddar and WPC yield calculations, including the assumed composition of the milk, cream, cheese and whey for each level of yield increase.

Profitability of Using 6.5X UF

The estimated profitabilities for 6.5X operations are based on the milk and product prices in Table 4 (page 19) and the milk composition and product yields found in Table 34. The approach for calculating total Cheddar and WPC profitability when using 6.5X UF in the cheese plant is illustrated in Table 35. Note that using 6.5X UF, as compared to conventional plants with no concentration technologies, affects several aspects of overall profitability, including the required purchase of fresh cream to standardize the milk at a higher fat level, increases in cheese and whey cream yields, reductions in WPC yields, and an increase in permeate solids per cwt of raw milk.

If using 6.5X UF increased cheese yields by 4% (i.e. from 10.16 to 10.57 lbs per cwt of raw milk), total Cheddar and WPC profitability would improve by \$0.02 to \$0.09 per cwt of raw milk compared to a conventional plant (Table 36), depending on plant size and assuming the average input and product prices in Table 4. A 6% yield increase would improve profitability by \$0.10 to \$0.17 per cwt of raw milk while an 8% increase would improve profitability by \$0.18 to \$0.24 per cwt, again depending on plant size (Table 36). However, under the milk and cheese price conditions existing during 1989 and 1990, the smallest plant might not be profitable even with a 8% increase in cheese yields.

Return on Investment

While a 4% yield increase does improve profitability somewhat (as compared to a conventional operation) measures of investment worth such as payback period and IRR suggest that 6.5X UF would probably not be an attractive investment if this were the highest level of cheese yield expected (Table 37). Thus, fairly large increases in cheese yields would be needed to justify the investment in 6.5X UF technology and provide adequate compensation for the additional risk, particularly for the smaller plants. An adequate return is especially necessary given the substantial risks involved in using 6.5X UF to manufacture Cheddar.

Table 34 Average Milk Composition (Wisconsin) and Assumed Dairy Product Yields for Cheddar & WPC in Conventional Operations Compared to Using 6.5X UF in the Cheddar Plants Assuming Three Levels of Cheese Yield Increases.

	Conventional Plant No Yield Increase	6.5X UF Plant 4% Inc.	6.5X UF Plant 6% Inc.	6.5X UF Plant 8% Inc.
Milk Composition ¹				
Percent Fat	3.68	3.68	3.68	3.68
Percent Protein	3.27	3.27	3.27	3.27
Fresh Cream Required (Lbs Per Cwt Raw Milk) ²	0	.52	.72	.90
Cheddar Yield (Lbs Per Cwt Raw Milk)	10.16	10.57	10.77	10.97
Whey Cream Yield (Lbs Cream Per Cwt Raw Milk) ³	.58	.68	.69	.70
34.5% Protein WPC (Lbs Per Cwt Raw Milk)	1.64	1.41	1.30	1.19
Whey Powder (Lbs Per Cwt Raw Milk)	5.80	NA ⁴	NA ⁴	NA ⁴
Permeate Solids (Lbs Per Cwt Raw Milk) ⁵	3.64	4.07	4.15	4.23

¹ Milk composition based on 1984 Wisconsin survey.

² Fresh cream is required for the 6.5X UF plants in order to maintain the ratio of fat to protein with the increased retention of whey protein so that the increased cheese yields will be realized.

³ Assumes 93% fat retention in the cheese and 90% recovery of the fat not recovered in the cheese for both the conventional plants and the 6.5X UF plants.

⁴ Whey powder production is not an option when using 6.5X UF in the Cheddar plant due to the removal of whey protein from the whey.

⁵ Permeate solids increase as cheese yields increase due to the retention of more of the whey protein in the cheese, thus reducing the amount of permeate that is blended back with the "whey" from cheese making to produce 34.5% WPC.

Table 35 Sample Worksheet to Calculate the Profitability of a 960,000 Lbs Capacity Cheddar Cheese and WPC Operation Using Medium Concentration Factor Ultrafiltration (6.5X), Assuming a 4% Increase in Cheese Yields¹

Note: Assumes breakeven on UF permeate.

Item			\$/Cwt Milk
REVENUES			
Cheddar Cheese			
Yield (Lbs/Cwt Raw Milk)	10.57		
Price (\$/Lb Cheese)	1.32		
Revenue			13.95
Whey Cream			
Yield (Lbs/Cwt Raw Milk) ²	.68		
Price (\$/Lb Cream) ³	.52		
Revenue			.35
Total Revenues			<u>14.30</u>
COSTS			
Cheese Manufacturing Cost			
Raw Milk Cost			1.80
Fresh Cream			
Amount Used (Lbs/Cwt Raw Milk)	.52		
Cost (\$/Lb Cream) ³	.60		
Cost of Cream Used			.31
Total Costs			<u>14.81</u>
<u>OPERATING PROFIT FROM CHEESE</u>			<u>-.51</u>
REVENUES			
WPC Yield (Lbs/Cwt Raw Milk) ⁴	1.41		
WPC Price (\$/Lb WPC)	.72		
Total Revenues			<u>1.02</u>
COSTS			
Whey Manufacturing Costs			
			<u>.55</u>
<u>OPERATING PROFIT FROM WHEY</u>			<u>.47</u>
<u>PROFIT FROM CHEESE & WHEY</u>			<u>-.04</u>

¹ The Cheddar plant uses automatic cheddaring and a DMC and is assumed to operate 5 days per week, 24 hours per day.

² Assumes 93% fat retention in the cheese and 90% recovery of fat not retained in the cheese.

³ Whey cream price \$1.30 per lb fat, fresh cream \$1.50 per lb fat.

⁴ Assumes permeate is mixed back with "whey" to produce 34.5% WPC.

Table 36 Estimated Increases in Cheddar/WPC Operating Profits (or Decreases in Losses) from Using Medium Concentration Factor UF (6.5X) to Increase Cheese Yields Compared to Standard Cheddar Plants With No Concentration Method and No Yield Increase^{1,2,3}

Note: Assumes breakeven on UF permeate. With assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the cheese yield increase. Thus, the figures in **bold** represent the estimated decrease in losses by using 6.5X UF.

Plant Capacity (Lbs Milk/Day)	Cheddar Yield Increases (Lbs per Cwt Raw Milk)		
	4%	6%	8%
10.97	10.16 to 10.57	10.16 to 10.77	10.16 to
	(\$/Cwt)		
720,000	.02	.10	.18
960,000	.05	.12	.20
1,440,000	.07	.15	.23
2,400,000	.09	.17	.24

- ¹ This assumes the same amount of milk would be received in both the standard and the 6.5X UF plants, but due to the concentration process, Cheddar yields would be increased by either 4%, 6%, or 8% per cwt respectively in the UF plants. Automatic Cheddaring and a DMC with 93% fat retention in the cheese are assumed for both plants. Profitability for the 6.5X UF plant includes the cost of fresh cream required and increased whey cream revenues. Permeate is assumed to be added back into the UF whey to make 34.5% protein WPC. WPC yields decrease with increases in cheese yields. Assumed WPC yields are 1.64 lbs per cwt of raw milk for the no concentration plant and 1.41, 1.30, and 1.19 lbs per cwt of raw milk, respectively for the 6.5X UF plant.
- ² All plants are assumed to operate 5 days per week, 24 hours per day.
- ³ For estimated operating profits and losses for each plant size and cheese yield, see the Appendix.

Table 37 Payback Periods and Internal Rates of Return for the Increased Investment from Building a **New Medium Concentration Factor UF (6.5X) Plant** Compared to a New Conventional Plant with No Concentration Technology, If 6.5X UF Results in 4%, 6%, or 8% Increases in Cheese Yields, Four Plant Sizes^{1,2,3}

Note: Assumes breakeven on UF permeate. With assumed raw milk and product prices, the two smallest plants lose money in most situations, regardless of the cheese yield increase. Thus, the figures in **bold** represent the estimated decrease in losses by using 6.5X UF.

Plant Capacity (Lbs Milk Per Day)	Cheddar Yields (Lbs per Cwt Raw Milk) Medium CF Ultrafiltration (6.5X)		
	10.57 (4% Increase)	10.77 (6% Increase)	10.97 (8% Increase)
	(Payback Period, Years)		
720,000	8.2	5.6	4.2
960,000	7.6	5.4	4.0
1,440,000	5.7	3.9	3.0
2,400,000	4.8	3.4	2.7
	(Internal Rate of Return, Percent)		
720,000	6	16	27
960,000	8	18	30
1,440,000	16	31	49
2,400,000	22	40	59

¹ This assumes the same amount of milk would be received in both the standard and the 6.5X UF plants, but due to the concentration process, Cheddar yields would be increased by either 4%, 6%, or 8% per cwt respectively in the UF plants. Automatic Cheddaring and a DMC with 93% fat retention in the cheese are assumed for both plants. Profitability for the 6.5X UF plant includes the cost of fresh cream required and increased whey cream revenues. Permeate is assumed to be added back into the UF whey to make 34.5% protein WPC. WPC yields decrease with increases in cheese yields. Assumed WPC yields are 1.64 lbs per cwt of raw milk for the no concentration plant and 1.41, 1.30, and 1.19 lbs per cwt of raw milk, respectively for the 6.5X UF plant.

² All plants are assumed to operate 5 days per week, 24 hours per day.

³ Internal rate of return is the percentage rate which equates the additional capital investment required to build a new medium CF UF plant (over and above the costs of building a new conventional plant) with the present value of the increase in profits (expressed in cash flow terms) from the increase in cheese yields.

The three primary risks with 6.5X UF are:

- 1) It is not a common practice and cheese quality problems may result.
- 2) Large losses of milk solids could occur if the membranes developed leaks, seriously compromising cheese yield. This is a solvable problem, however, if the potential seriousness is recognized by management and the loss of milk fat and protein into the permeate is closely monitored and controlled.
- 3) Fouling and a decline in flux during UF processing of milk can be a major challenge and result in the inability of the UF system to operate at its rated process capacity throughout the course of an operating day or over the full life-span of the membranes. Actual performance of the UF system is also affected by the characteristics of the milk and will be variable.

The analysis suggests that using 6.5X UF probably would have to result in a yield increase of 6% in the larger plants (i.e. 1,440,000 lbs of milk per day or more) and approximately 8% in the smaller plants to justify the large investment involved and compensate for the substantial added production risks. If these levels of yield increases were not expected to be realized, the expected investment payback period may be too long, and the IRR too low, to make the investment in 6.5X UF attractive to many cheese plant managers (Table 37).

Sensitivity of Results to Changes in Product Prices

While the 6.5X UF process increases cheese yields, it simultaneously reduces WPC yields. A 4% increase in cheese yields (i.e. from 10.16 lbs to 10.57 lbs per cwt of raw milk) results in a 14% decline in WPC yields (i.e. from 1.64 lbs to 1.41 lbs per cwt of raw milk). By the time cheese yields have risen 8% (to 10.97 lbs per cwt), WPC yields have dropped 27% (to 1.19 lbs per cwt). Considering these changes in yields, sensitivity analysis was performed to determine how changes in product prices would affect total cheese and WPC profitability.

To do this, monthly Cheddar and WPC prices were collected from January 1987 through December 1990. The highest historical Cheddar price for that period (based on the National Cheese Exchange block price) was \$1.60, occurring in November and December of 1989. The lowest historical Cheddar price for that same period was \$1.12, occurring during November and December 1990. The highest and lowest WPC prices during that period were \$0.88 (December, 1989) and \$0.47 (February, 1987) respectively.

These Cheddar and WPC prices were used to calculate total profitability comparing two scenarios. The first uses the base case cheese yield for 6.5X UF (10.57 lbs per cwt of raw milk or a 4% increase over the 10.16 lbs per cwt assumed with no concentration technique), with a WPC yield of 1.41 lbs per cwt of raw milk. The

second assumes a 10.97 lbs per cwt cheese yield using 6.5X UF (an 8% increase in cheese yield over no concentration), WPC yield of 1.19 lbs per cwt. Comparing the profitability of these two scenarios using the highest WPC price (\$0.88) and the lowest Cheddar price (\$1.12), it was determined that it is always more profitable to increase cheese yields, even at the expense of WPC yields. It was estimated that profitability would improve by approximately \$0.05 per cwt if cheese yields increased from 10.57 to 10.97 lbs per cwt, even with WPC yields decreasing from 1.41 to 1.19 lbs per cwt. This is due to the fact that even under this extreme price situation, the additional cheese yield is worth \$0.45, while the lost WPC yield is only worth \$0.19. Changes in production costs, fresh cream requirements and whey cream yields make up the rest of the difference¹¹.

As 6.5X UF also requires the addition of fresh cream to the milk (in increasing amounts as cheese yield increases), the sensitivity of 6.5X UF profitability to changes in the fresh cream price was also analyzed. In the base case, fresh cream was assumed to cost \$0.60 per lb of cream, while whey cream was assumed to be worth approximately 87% as much or \$0.52 per lb of cream (\$1.50 and \$1.30 per lb of fat, respectively). If the fresh cream price decreased by \$0.10 to \$0.50 per lb of cream, whey cream values were assumed to fall accordingly by \$0.09, for a total of \$0.43 per lb of cream.

At the lowest assumed level of cheese yield increase, 4%, this decrease in cream prices would actually decrease profitability by approximately \$0.01 per cwt of raw milk. This is due to the fact that .68 lbs of whey cream are produced per cwt of raw milk, while only .52 lbs of fresh cream are required (Table 35). Thus, the decrease in whey cream value outweighs the reduced cost of the fresh cream. However, at the two higher levels of cheese yield (10.77 and 10.97 lbs per cwt of raw milk, respectively), more fresh cream is required proportionally than whey cream is produced. Thus, the decreased cost of the increased fresh cream requirements outstrips the loss from the whey cream. If cheese yields were increased 6%, decreasing the fresh cream price by \$0.10 per lb of cream (and whey cream by \$0.09 per lb of cream) would result in an additional net gain of \$0.01 per cwt of raw milk. Under these same conditions with an 8% increase in cheese yields, the additional net gain would be \$0.03, again per cwt of raw milk.

In each of these sensitivity analyses, only the product prices in question were changed. While some price movements tend to be fairly highly correlated (i.e. raw milk and cheese), in other cases little correlation is apparent (i.e. WPC and whey powder). In the case of the cream price sensitivity, a decline in the price of cream might also be related to decreases in milk and cheese prices, as well as whey cream.

¹¹ Cheese prices would have to be less than \$0.50 per lb before producing WPC at \$0.88 per lb would be more profitable than the additional cheese yield.

Sensitivity of Results to Breakeven Assumption on Permeate

As was true in the earlier analyses of 1.5X UF, 1.2X RO and 1.2X evaporation, it has been assumed that all costs of handling the permeate produced, including capital costs, would be covered by revenues received for the permeate (i.e. a breakeven situation). Setting aside this assumption, this sensitivity analysis examines the effect on total cheese and whey profitability of either gaining \$0.02 per lb of permeate solids, or conversely, losing \$0.02 to \$0.12 per lb of permeate solids.

Permeate from a 6.5X UF cheese plant is very similar to permeate from the cheese and whey operations discussed earlier. Permeate from a conventional Cheddar and WPC operation with no concentration technology is assumed to contain 3.64 lbs of permeate solids per cwt of raw milk. For a 6.5X UF operation, assuming a 4% cheese yield increase, permeate solids are assumed to be 4.07 lbs per cwt of raw milk, this rises to 4.15 lbs per cwt and 4.23 lbs per cwt assuming a 6% and an 8% cheese yield increase respectively (Table 38, and the Appendix). This increase in permeate solids per cwt of raw milk occurs because cheese yields increase as more whey protein is retained in the cheese, which conversely decreases the yield of 34.5% WPC. As the yield of 34.5% WPC decreases with increasing cheese yields, less permeate per cwt of raw milk needs to be added back into the 6.5X UF "whey", resulting in a need to handle more lbs of permeate solids per cwt of original milk.

As with any of the technologies discussed earlier that produce WPC, the effects on 6.5X UF profitability of possible gains or losses from permeate handling would be large, depending on the amount of profit or loss realized from each lb of permeate solids (Table 38). Because the amount of permeate solids remains constant per cwt of raw milk for each level of cheese yield increase, the effect of either a gain or loss of revenues from permeate is also constant per cwt of raw milk, regardless of plant size.

Pounds of permeate solids per cwt of milk are higher when using 6.5X UF, however, so the profitability of a 6.5X UF cheese and WPC operation is slightly more sensitive to permeate losses or gains than conventional plants or plants using other technologies (Table 39).

Despite the increase in permeate solids per cwt with higher cheese yields, the risk of losing money due to permeate processing expenses is present for any operation manufacturing WPC, not just those considering investing in 6.5X UF. Any cheese plant planning to manufacture WPC, including one using 6.5X UF (WPC being the only whey processing option available if using 6.5X UF) must find a method that will utilize UF permeate while breaking even or providing a gain. This is not an easy task. As plant location can substantially affect permeate handling costs, the permeate utilization method should be considered when deciding whether to build a WPC plant which would necessarily generate large quantities of UF permeate or a whey powder plant, which would not.

Table 38 Effects on Total Cheddar and WPC Profitability of Gains or Losses per Lb of Permeate Solids for Plants Using Medium Concentration Factor UF (6.5X) Assuming Three Cheese Yield Levels, Compared to Conventional Operations for All Plant Sizes¹

Permeate Handling Gain or Loss (Dollars/Lb Permeate Solids)	Conventional Plant No Yield Inc.	6.5X UF Plant 4% Yield Inc.	6.5X UF Plant 6% Yield Inc.	6.5X UF Plant 8% Yield Inc.
	----- 3.64 Lbs/Cwt ²	----- 4.07 Lbs/Cwt	----- 4.15 Lbs/Cwt	----- 4.23 Lbs/Cwt
			(\$/Cwt)	
\$0.02 <u>Gain</u>	+\$0.07	+\$0.08	+\$0.08	+\$0.09
<u>Breakeven</u>	0	0	0	0
\$0.02 <u>Loss</u>	-\$0.07	-\$0.08	-\$0.08	-\$0.09
\$0.06 <u>Loss</u>	-\$0.22	-\$0.24	-\$0.25	-\$0.25
\$0.12 <u>Loss</u>	-\$0.44	-\$0.49	-\$0.50	-\$0.51

¹ Assumes Cheddar yields of 10.16 lbs, 10.57 lbs, 10.77 lbs, and 10.97 lbs per cwt of raw milk for the conventional plant and the three cheese yield levels of the 6.5X UF plants respectively. WPC Yields are assumed to be 1.64 lbs, 1.41 lbs, 1.30 lbs, and 1.19 lbs per cwt of raw milk for the same plants respectively.

² Lbs of permeate solids per cwt of raw milk. If a WPC plant is already being used to

Table 39 Sensitivity of Total Cheddar & Whey Operating Profits or Losses to Costs of Handling Permeate, Conventional Cheddar and Whey Powder Plant Compared to 6.5X UF Operation Assuming a 4% Cheese Yield Increase^{1,2,3}

Cheddar Plant Capacity, Lbs Raw Milk Received Per Day	Conventional Cheddar & Whey Powder	6.5X UF Cheddar & WPC Operation				
		Permeate Handling Loss or Gain Per Pound of Solids ⁴				
		<u>Gain</u> \$.02	<u>Breakeven</u>	<u>Loss</u> \$.02 \$.06 \$.12		
		(Profit, \$/Cwt)				
720,000	-.71	-.35	-.43	-.51	-.67	-.92
960,000	-.35	.04	-.04	-.12	-.28	-.53
1,440,000	.04	.46	.38	.30	.14	-.11
2,400,000	.36	.83	.75	.67	.51	.26

¹ Assumes Cheddar and whey powder yields of 10.16 lbs and 5.80 lbs per cwt of raw milk respectively for the conventional plants. Cheddar and WPC yields are 10.57 lbs and 1.41 lbs per cwt of raw milk respectively for the 6.5X UF plants.

² Product prices are assumed to be \$1.32, \$0.72, and \$0.18 for the cheese, WPC, and whey powder respectively.

³ All plants operating 5 days per week, 24 hours per day.

⁴ Assuming a 4% increase in cheese yield using 6.5X UF, permeate solids are 4.07 lbs per cwt of raw milk.

If a WPC plant is already being used process whey, however, the risk of additional permeate processing costs from investing in 6.5X UF is rather small, adding at most an additional .59 lbs of permeate solids per cwt of raw milk (assuming the maximum cheese yield increase of 8%, 10.97 lbs of cheese per cwt of raw milk). Thus, if a 960,000 lb capacity conventional cheese and WPC operation is already processing up to 35,000 lbs of permeate solids daily (i.e. 3.64 lbs per cwt of raw milk) while maintaining overall profitability, it should also be able to process an additional 5,500 lbs by switching over to 6.5X UF while increasing cheese yields by 8%.

Avoidance of the risk of permeate processing losses altogether requires that whey powder must be produced rather than WPC. Comparing total cheese and whey profitability and ignoring the added risks associated with using 6.5X UF, manufacturers could afford to lose approximately \$0.08 to \$0.09 per lb of permeate solids before using 6.5X UF (assuming a 4% cheese yield increase) would be less profitable than making Cheddar and whey powder in a conventional operation, assuming \$1.32, \$0.72 and \$0.18 as product prices for cheese, WPC, and whey powder, respectively (Table 39). Of course as the price of WPC declines relative to whey powder, the level of permeate losses manufacturers could sustain would decrease.

Conclusions on Using 6.5X UF

In summary, it is important for cheese and whey plant managers to have an understanding of the potential benefits and risks of using medium concentration factor UF (i.e. 6.5X) before undertaking new plant construction.

Potential benefits from using 6.5X UF in the cheese plant:

- 1) An increase in Cheddar yield of 4% to 8% (i.e. compared to 10.16 lbs per cwt of raw milk in a conventional plant with no concentration technology). A 4% increase due to using 6.5X UF would be 10.57 lbs of cheese per cwt of raw milk, an 8% increase would be 10.97 lbs of cheese per cwt. Depending on plant size, cheese yield increases of 6% to 8% would probably be needed to justify the capital investment required for 6.5X UF and provide adequate compensation for the potential risks involved in the technology.
- 2) Depending on plant management, using 6.5X UF may improve the consistency of cheese quality, by way of careful milk standardization and increased focus on quality control.

Potential risks from using 6.5X UF in the cheese plant:

- 1) Inability to make acceptable quality commodity Cheddar.
- 2) Federal regulations may not permit mixing UF permeate with the UF "whey" from the 6.5X cheese making prior to production of 34.5% WPC. If permeate is not added back to the UF "whey", it would contain 39.6% to 42.8% protein. At this point two options are possible; 1) use UF to further

fractionate this UF "whey" to produce a high protein WPC, or 2) use ion exchange technology to produce whey protein isolate.

- 3) Given our assumed WPC and whey powder prices (i.e. \$0.72 and \$0.18 per lb, respectively), permeate handling losses of greater than \$0.08 to \$0.09 per lb of permeate solids would make using 6.5X UF (assuming a 4% cheese yield increase) less profitable than a conventional cheese and whey operation making whey powder. This level of sustain-able losses on permeate would also decrease as the price of WPC declines.
- 4) A large capital investment is required and payback periods may be long and returns on investment relatively low, particularly at the 4% yield increase level, for all but the largest operations.

ON-FARM UF (2X)

Background

Ultrafiltration of milk can be done at the individual farm level rather than at the cheese plant, as has been assumed in the analyses reported thus far. The technical feasibility of on-farm ultrafiltration has already been demonstrated (7) (8). Several studies have also examined the economic feasibility of on-farm UF, one of the more comprehensive of which was done by Novakovic and Alexander (9).

These studies have shown that using UF on farms is technically feasible but, not surprisingly, that it also increases net on-farm costs. Using UF and thermalization (UF/T) on farms requires a sizeable additional capital investment. For example, Novakovic and Alexander estimated in 1985 that the total capital investment required per farm for UF/T equipment would be approximately \$20,000 for a 50 cow herd, \$27,000 for a 100 cow herd, and \$42,000 for a 400 cow herd (8).

Thermalization is a sub-pasteurization high-temperature, short-time heat treatment that is done prior to on-farm UF. Thermalization of the milk prior to UF on the farm is necessary to maintain the quality of the retentate. It inactivates native milk lipases so that they do not break down the milk fat and produce rancid off-flavors in the retentate prior to cheese making.

Not considering inflation, this level of investment per farm is still very large. For example, the average capital investment for using 1.5X UF in the cheese plant was estimated at \$4,000 on a per farm basis. This was based on the total capital investment required to equip a 960,000 lbs of milk per day plant with 1.5X UF technology, (approximately \$464,000), and assuming half of the milk equivalent was received in the form of 2X retentate from 100 cow herds with an average production level of 15,000 lbs per cow.

The increased capital investment for on-farm UF/T results in increased depreciation, interest, property tax and insurance expenses, as well. Other on-farm expenses also rise from using UF/T, including maintenance and repairs, electricity, labor, and cleaning materials. In addition, costs are incurred to replace UF membranes. However, using UF/T on farms also provides two potential sources of savings on the farm: the feed value of permeate and decreased milk cooling costs due to lowered milk volumes. Because of economies of size, the increase in on-farm costs are larger per cwt of milk for smaller farms. Even for very large farms though, the increase in costs due to using UF outweighs the potential on-farm savings.

The net increase in on-farm costs per cwt of milk from using on-farm UF/T depends on a number of factors including herd size and production per cow, as well as cost of the UF/T equipment, farm labor and electricity rates, and corn and soybean prices (for which permeate will be substituted as a feed source). The approximate increases in net on-farm costs from using UF/T were estimated for various herd sizes and milk production levels using Novakovic and Alexander's data from 1984-85 for Wisconsin (Table 40).

Using Novakovic and Alexander's results, the estimated net increase in on-farm costs from using UF/T would range from \$0.94 per cwt of raw milk for a 50-cow farm with an average annual per cow milk production of 13,000 lbs to \$0.16 per cwt for a 400-cow farm with an average production of 19,000 lbs per cow (Table 40). In the case of a 100-cow farm with a 15,000 lb average production, the net increase in costs over on-farm benefits was approximately \$0.50 per cwt of raw milk. While costs decrease per cwt as production per cow increases, net added costs were always more using on-farm UF/T, even with the largest farm size and highest production level per cow, than on a farm with no UF unit (Table 40).

Thus, a producer would require additional "off-farm" compensation to justify investment in UF/T equipment. This compensation for producers' increased costs would have to come either from savings in hauling, plant premiums, or some combination of the two.

Possible Savings in Hauling Charges from Using UF/T On-Farm

The analysis of possible savings in hauling charges from using UF/T on farms as presented in other studies range from \$0.05 per cwt of milk equivalent to 50% of normal farm-to-plant hauling costs. This could amount to more than \$0.25 per cwt of milk equivalent in some cases (8). Expecting that using on-farm UF/T would decrease hauling charges by 50% seems overly optimistic, however, in part because it is based on at least two questionable assumptions: 1) that UF retentate and regular whole raw milk could be commingled in the same tanker during pick-up; and 2) that retentate could be picked up at the farm only every fourth day, rather than every-other day. The on-farm 2X UF retentate cannot be commingled in a tanker with raw whole milk because the protein content of the mixture going into the cheese vats must be tightly controlled to allow regulation of the cheese making process.

Table 40 **Net Increase in On-Farm Costs From Using On-Farm UF/T for Various Herd Sizes and Cow Production Levels** ¹

Production Per Cow Per Year (Lbs)	Herd Sizes				
	50	75	100	200	400
	(\$/Cwt)				
13,000	0.94	0.73	0.57	0.39	0.23
15,000	0.84	0.65	0.50	0.33	0.19
17,000	0.78	0.60	0.46	0.30	0.17
19,000	0.72	0.56	0.43	0.28	0.16

¹ Estimated from data in Novakovic, A.M. and C.S. Alexander. "The Economic Feasibility of Ultrafiltration and Thermalization of Milk on Wisconsin Farms", a report to the Wisconsin Milk Marketing Board, 1985.

The potential savings in hauling costs due to adopting on-farm UF will depend on a number of factors including the following:

- 1) The size and locations of farms and the density of production.
- 2) The rate of on-farm UF adoption.
- 3) The necessary frequency for picking up UF retentate on farms to avoid quality problems (i.e. every third or fourth day).
- 4) Whether or not UF retentate can be assembled in the same tanker, using separate compartments for retentate and regular whole raw milk ¹² or whether a separate route would be required for retentate pick-up.

Moreover, hauling rates paid by farmers often do not accurately reflect actual hauling costs, primarily due to hauling subsidies. Also, hauling rates may be based on average or pooled costs, rather than reflecting the costs of assembling an individual farm's milk. To the extent that the economic costs of milk hauling are not reflected in hauling charges paid by farmers, cost savings in hauling resulting from on-farm UF/T would probably also not be reflected back to farmers.

Even with optimistic assumptions on possible reductions in hauling charges that farmers might realize from using UF/T on the farm, only the very largest farms (400 cows or more) would have a positive return unless premiums were paid by cheese plants for the retentate. For farms with 200 cows or less, plant premiums would be required as well as maximum savings in hauling to breakeven or have a positive return on the investment in on-farm UF/T. For a 100-cow farm, even allowing for large savings in hauling, feed value of permeate, and decreases in milk cooling expenses, the net return

¹² In order to ensure consistency in cheese manufacturing, retentate and raw milk cannot be commingled.

would still be significantly negative.

Novakovic and Alexander conclude, "Clearly only a very small percentage of farms would have an incentive to adopt UF if on-farm and hauling savings are the only sources of income from adoption. This places critical importance on dairy plants perceiving that farm retentate represents a value added to milk, a value for which they are willing to pay farmers." (9, pg 62). This value added stems from the savings or added profit a cheese plant could realize by receiving some of their milk in the form of UF retentate, processed on the farm.

Plant Savings from Using 2X UF Retentate, Processed On-Farm

Earlier sections of this study indicate some potential benefit to using UF milk in a cheese plant, depending upon many factors, including plant size, operating schedule, type of whey product produced, and particularly if increased cheese yields or milk throughput are realized. All of these factors remain the same regardless of whether the milk is fractionated using UF in the cheese plant or if the plant receives UF retentate processed on the farm. Also, the same benefits of increased cheese yield and/or increased milk throughput can be achieved using 1.5X UF in the plant with a much lower total capital cost. Thus, these benefits cannot be construed as adding value to UF/T retentate processed on-farm.

The increased value of 2X retentate to the cheese plant operator over original raw milk stems from two sources. The first is the savings in cheese manufacturing costs that could be realized by receiving half of the milk as 2X UF retentate (all milk can't be 2X or else it would overload the downstream equipment) rather than raw whole milk. In order to estimate these savings, the cheese and WPC manufacturing costs in a plant receiving half the milk equivalent as 2X UF retentate (fractionated on-farm) were compared with the plant operator's lowest cost alternative means of manufacturing (either a conventional cheese plant using no milk fractionation/concentration technology or a plant using 1.5X UF in-plant, depending on plant size). (Note: only WPC can be produced when using retentate produced on-farm as the permeate necessary to add back into the UF whey to produce whey powder is left on the farm.) This difference between the manufacturing costs of a plant using retentate produced on-farm and the lowest cost alternative represents the **maximum** amount available to the cheese and whey operation for sharing with the producers as compensation for the additional costs of using UF/T on-farm.

The extent to which these savings from fractionating milk on-farm would be shared with producers, however, would depend on the competitive situation.

The second source of saving would be the possible avoidance of losses involved in handling permeate if the milk were fractionated on the farm rather than at the plant. However, of the total permeate produced in an in-plant 1.5X UF Cheddar and WPC operation, over 42% (e.g. 1.54 lbs of permeate solids per cwt of raw milk) would still be produced in a WPC plant using 2X retentate processed on-farm. Thus,

using on-farm UF will **reduce** the permeate solids to be processed (by 58%), permeate processing will still be a factor and must be considered. To totally **eliminate** permeate processing, whey powder must be produced and as discussed earlier, this is not an option with on-farm UF.

Savings in Cheese Manufacturing Costs

A 1.5X UF blend can be achieved two ways. The first (reported in earlier sections of this study) uses a UF unit in the cheese plant to fractionate all raw milk into 1.5X retentate and permeate. The second method, examined here, blends half raw milk and half 2X UF retentate (processed on-farm) to achieve the same results. No UF unit is required in the cheese plant and all permeate from the fractionation is left on the farm. However, permeate is still generated in the WPC plant, although not as much as in a conventional Cheddar and WPC operation, due to the reduction in whey volume from the on-farm UF. As mentioned above, whey powder cannot be produced by these cheese plants when using on-farm UF, as the permeate from the milk fractionation is needed to add back to the UF whey before processing into whey powder.

The savings in Cheddar cheese manufacturing costs that could be realized from using milk fractionated on the farm were estimated to determine the maximum amount available for premiums to compensate producers for their investment in UF/T technology. Manufacturing costs were estimated for the four model plant sizes, assuming half of the milk received each day was original raw milk of the same composition as reported in Table 2 (page 12), and the other half was milk of this same composition fractionated to 2X by on-farm UF/T. No increased cheese yields or increased throughput were assumed.

To estimate the additional value of 2X UF on-farm retentate, the manufacturing costs for a plant receiving half of its milk equivalent as 2X UF retentate processed on-farm were compared with either the combined cheese and WPC manufacturing cost for a plant using 1.5X UF in the cheese plant on all milk received or the total cheese and WPC manufacturing cost for a conventional plant with no milk fractionation/concentration technology, whichever was lower. As shown in Table 41, the cost of manufacturing cheese in a conventional plant is less than using 1.5X UF in-plant in the two smaller plants. Thus, the savings that could be realized from using on-farm UF/T is based on comparisons with a conventional plant for the the two smaller plants, and in comparison to the 1.5X in-plant UF for the largest two plant sizes.

The savings in cheese and whey manufacturing costs by using milk fractionated on-farm ranged from \$0.046 per cwt of raw milk in the 960,000 lb plant to \$0.031 per cwt in the 2,400,000 lb plant, each operating 5 days per week, 24 hours per day (Table 41). These are the in-plant savings on all the milk equivalent, not just the one-half received as 2X UF retentate. If all savings are attributed to the 50% of the milk equivalent received as on-farm retentate, the implied value of the retentate would range from \$0.062 in the largest plant to \$0.092 in the 960,000 lb plant, each on a per cwt of milk equivalent basis.

Table 41 Comparison of Combined Cheese and WPC Manufacturing Costs in Plants Using UF In-Plant with Plants Receiving UF Retentate Processed On-Farm, Four Model Plant Sizes¹

Note: Assumes breakeven on permeate and includes no additional receiving or assembly costs for plants using retentate processed on-farm.

Plant Capacity (Lbs Milk/Day)	Conventional Plant	In-Plant UF (1.5X)	On-Farm UF (2X) ²	In-Plant Savings From On-Farm UF ³
(\$/Cwt Raw Milk)				
720,000	2.578	2.597	2.533	.045
960,000	2.220	2.226	2.174	.046
1,440,000	1.860	1.852	1.811	.041
2,400,000	1.526	1.518	1.487	.031

¹ All plants are designed for standard stirred curd, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all plants, with 93% fat retention in the cheese. Plants are assumed to operate 5 days per week, 24 hours per day.

² The on-farm UF plant is assumed to receive 1/2 of its daily milk supply as 2X UF retentate, processed on-farm, and the other 1/2 of the milk as original raw milk. These combined, form the same concentration as 1.5X UF on all the milk.

³ The estimated plant savings from on-farm UF are the difference between the cheese manufacturing costs in a plant using on-farm retentate and the lowest cost option (either a conventional plant or a plant using in-plant 1.5X UF, depending on plant size).

Table 42 compares the components of cheese manufacturing costs for the 960,000 lb plant for both the 1.5X in-plant UF and the plant using UF/T retentate generated on-farm. A significant portion of the savings in the plant from using on-farm UF retentate is due to lower capital investment (i.e. no UF center is needed in the cheese plant). This leads not only to lower depreciation and interest charges, but also to lower property tax and insurance expenses as well. Other expenses related to the UF center, such as labor, fuel, cleaning materials, and repair and maintenance, are also lower (Table 42).

Avoiding Possible Losses in Handling Permeate

The comparison of cheese manufacturing costs from using 2X retentate generated on-farm with using 1.5X UF to process milk in the plant is based on the assumption that the operator using in-plant UF breaks even on the permeate handling, (i.e. costs of processing or handling permeate are equaled by revenues received for it).

Whether a plant breaks even, makes a gain, or suffers a loss in handling permeate produced from using 1.5X UF in a cheese plant varies according to individual situations. To the extent that a operation losses money on handling permeate produced by in-plant 1.5X UF, the value of the 2X UF retentate generated on-farm is greater than simply the savings in cheese and WPC manufacturing costs outlined in Table 41. Thus, an additional benefit (if losses are expected) of using on-farm UF/T is the absence of some of the permeate to process or handle. However, as mentioned earlier, a significant amount of permeate solids (e.g. 1.54 lbs per cwt of raw milk) will still be generated in the WPC plant, which must be dealt with in some way. If any profits are thought to be made from handling permeate, though, using on-farm UF/T would negate all but those generated from the WPC permeate.

Possible Profitability of On-Farm UF/T

As discussed earlier, the possible desirability or profitability of farmers using UF/T depends on a number of factors including herd size, average milk production per cow, capital investment requirements on the farm, savings in hauling charges realized by the farmer, and the amount of premium paid by the cheese plant for receiving UF/T retentate as opposed to whole milk.

This analysis estimates only the potential benefits to the plant operator of receiving half the milk equivalent as 2X UF retentate processed on-farm. These benefits appear fairly small, (i.e. \$0.06 to \$0.09 per cwt) especially when compared to plant premiums suggested by other studies (8) as necessary for all but the largest farmers for adoption of on-farm UF/T. Small or even average-sized farms would probably adopt on-farm UF/T only if they are isolated and have very high hauling charges.

There are also other more intangible factors to be considered when considering using on-farm UF/T. These include: the technical difficulty and time requirements of operating this equipment on-farm; training necessary; new licensing or inspection requirements; difficulty in achieving quality retentate; membrane replacement

Table 42 Cheddar Manufacturing Costs In-Plant Using 1.5X UF Compared to Using UF Retentate Processed On-Farm. Both Plants Have a Capacity of 960,000 Lbs of Raw Milk Per Day^{1,2}

Note: Assumes breakeven on UF permeate for in-plant UF.

Cost Item	In-Plant UF (1.5X)	On-Farm UF (2X) ²	In-Plant Savings From On-Farm UF
(\$/Cwt of Milk)			
Labor			
Supervisory	.048	.048	0
Direct Fixed	.052	.052	0
Direct Variable	.484	.479	.005
Total Labor	.584	.579	.005
Capital Costs			
Deprecation & Interest	.292	.272	.020
Utilities			
Electricity	.018	.018	0
Fuel	.084	.074	.010
Water & Sewage	.009	.009	0
Total Utilities	.111	.101	.010
Materials			
Laboratory ³	.007	.007	0
Production	.139	.139	0
Packaging	.278	.278	0
Cleaning	.040	.039	.001
Total Materials	.464	.463	.001
Repair & Maintenance	.032	.021	.011
Property Tax & Insurance	.095	.090	.005
Production Inventory	.021	.021	0
Other Expenses	.026	.026	0
TOTAL	1.625	1.573	.052

¹ Both plants are designed for standard stirred curd, producing 640 lb blocks of 37% moisture commodity Cheddar. A cheese yield of 10.16 lbs is assumed for all plants, with 93% fat retention in the cheese. Plants are assumed to operate 5 days per week, 24 hours per day, with an annual production of 25.4 million lbs.

² The on-farm UF plant is assumed to receive 1/2 of its daily milk supply as 2X UF retentate, processed on-farm, and the other 1/2 of the milk as original raw milk. These combined, form the same concentration as 1.5X UF on all the milk.

³ Does not include producer and payroll testing costs, which would be higher for a plant using 2X UF retentate processed on-farm.

decisions and costs; problems of balancing levels of retentate and raw milk receipts at the plant, particularly with different pick-up schedules; new milk testing and payment procedures which would have to be developed; and the continued risk of fat and protein losses from the membrane into the permeate, which could conceivably be worse with on-farm UF.

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