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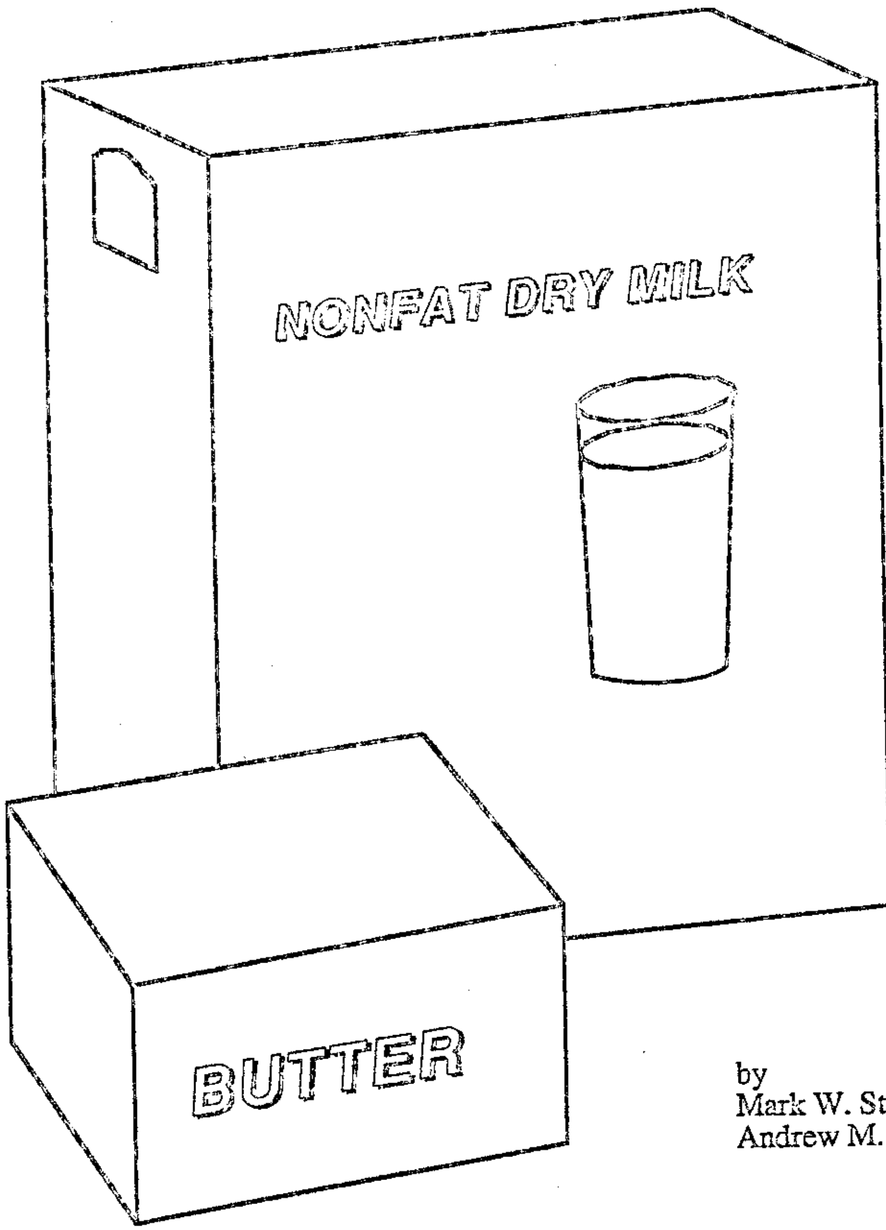
Manufacturing Costs In Ten Butter/Powder Processing Plants



by
Mark W. Stephenson
Andrew M. Novakovic

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

Preface

Mark W. Stephenson is a Doctoral Candidate and Andrew M. Novakovic is an Associate Professor in the Department of Agricultural Economics at Cornell University.

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Additional copies of this publication can be requested from Andrew Novakovic or:

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Report Summary

The dairy marketing group of Cornell University's Agricultural Economics Department has on-going projects to determine the costs of processing hard, or storable, dairy products[1]. This report represents the first of a two part study to determine the cost of processing butter and non-fat dry milk. The second part of the study will use economic engineering models of butter/powder processing to analyze costs and related factors in simulated but realistic plants. This report, on the first phase of the project, summarizes the results of a survey of existing plants. An objective of this phase is to provide information for the selection of modeling parameters and benchmarks of actual processing costs for the economic engineering study which follows.

Ten plants were selected and surveyed for unique combinations of:

—Ownership (cooperative and proprietary)
—Location (major dairy areas across the country)
—Size (varying capacities to process raw products)
—Seasonality (stable and fluctuating processing patterns)
—Marketing Practices (retail butter packaging, CCC sales, bulk blends etc.)

The survey collected information on equipment capacities, product input and output, labor hours by plant center, utility usage and major cost items over a twelve month period from June 1987 through May 1988. Two of the plants were privately owned with the remaining eight being cooperatively owned. The plants are located across the major dairy areas of the country representing the Northeast, the Upper Midwest, the Southwest and the West. They ranged in sustainable processing capacities from approximately 90,000—360,000 pounds of butter and/or powder in a 24 hour period. The seasonal aspect of production varied from plants which produced no product for one or more months to those which

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[1] Three reports on cheese manufacturing are presently available from the Publications Office of the Department of Agricultural Economics, Cornell University: Jens K. Mesa-Dishington, Richard D. Aplin, and David M. Barbano, Economic Performance of 11 Cheddar Cheese Manufacturing Plants in Northeast and North Central Regions, Department of Ag Economics, Cornell University, A.E. Res. 87-2; Jens K. Mesa-Dishington, Richard D. Aplin, and David M. Barbano, Cheddar Cheese Manufacturing Costs Economies of Size and Effects of Different Current Technologies, Department of Ag Economics, Cornell University, A.E. Res. 87-3; John C. Martin, David M. Barbano, and Richard D. Aplin, Diversification of the Cheddar Cheese Industry Through Specialty Cheese Production: An Economic Assessment, Department of Ag Economics, Cornell University, A.E. Res. 89-9.

operated near 100% capacity for the entire 12 month period. A wide spectrum of marketing practices is observed in the ten plants.

It is determined that the average costs of processing in these ten plants are 13.68¢ per pound of butter produced and 13.29¢ per pound of nonfat dry milk powder produced. An analysis of variance on factors affecting these costs indicates that plant ownership had a demonstrable effect on differences in cost with proprietary firms being lower cost processors than cooperatives. Location is also an influential factor with the Northeast firms being high cost processors. The upper Midwest is observed to be low cost processors; everyone else is in between. Size appears to be a factor in butter production although not in powder production with low cost associated with large capacity processors and the higher costs with the smaller processors. Seasonal variation is shown to be highly influential in determining the costs of production. When each of the ten plants are projected as though operating at 100% of capacity, the average annual costs of production are reduced to 5.71¢ per pound of butter and 7.89¢ per pound of nonfat dry milk powder.

Long–run average cost curves for daily processing of butter, nonfat dry milk and cwt of raw milk are estimated from the data. One implication of these is that USDA's present make–allowance for butter/powder processing appears to provides adequate compensation to modern medium to large scale processors for the joint manufacture of butter and powder from farm milk.

Structure of the Butter/Powder Industry

Milk has been recognized as a high value food product for more than 6,000 years. With the domestication of the Auroch, and the subsequent breeding for specialization into milk, meat and draft animals, man has relied on the cow for much of his progress through recorded history. Because fluid milk has always been highly perishable, its transformation into products with greater keeping quality has had a high priority. The making of cheese and butter has been practiced for many centuries and was a farm task until only recently. In the later half of the 1800's several changes in dairy processing took place. Centrifugal separators changed the practice of letting milk stand for 24 hours to skim the cream off. This, coupled with steam–powered churns and mechanical refrigeration, helped to move dairy processing off the farm. Vacuum concentration of milk was a new technology at the time of the Civil War. The war effort created a great demand for the sweetened condensed milk which could be stored in tins without refrigeration for some time. Soon after, the Just–Hatmaker process for roller drying of milk was introduced and dairy products had obtained a new status—high value food without the extreme perishability.

Although dairy plants making cheese also provide a large measure of seasonal balancing through the manufacture of a storable product, the flexibility is not as great as plants producing butter and nonfat dry milk powder. Our modern dairy industry produces fairly homogeneous or standardized products. These products have typically been standardized around levels of butterfat and moisture content. Farm milk brought into dairy plants is most often separated into heavy cream (40% butterfat) and skim milk (less than 0.5% butterfat) and then recombined to achieve the desired percentage of butterfat in a great variety of products.[2] This practice leaves the dairy industry with imbalances between the supply and demand of milk's components (those being butterfat and the milk solids–not–fat hereafter referred to as SNF). Plants that process heavy cream and skim milk into storable products play a very important role in balancing fluctuating and unequal supplies of these two basic fractions of milk.

2 Cheese plants have generally been an exception to this practice until recently. Mozzarella and several other part–skim varieties are typically made from standardized milk to produce lower fat products or to achieve greater yields.

In the past, butterfat was the component of greatest value in milk. Dairy farms that were situated some distance from population centers would separate the milk, sell the cream and either dump the skim milk portion or feed it to livestock. Although current trends have placed a lower value on butter in the diet, butter production has suffered only a slight decline since the 1930's. This has not been true of nonfat dry milk (hereafter referred to as NDM or powder). As seen in figure 1, the processing of the SNF component into powdered form rose dramatically from the 1930's to the 1960's and has declined somewhat since then.

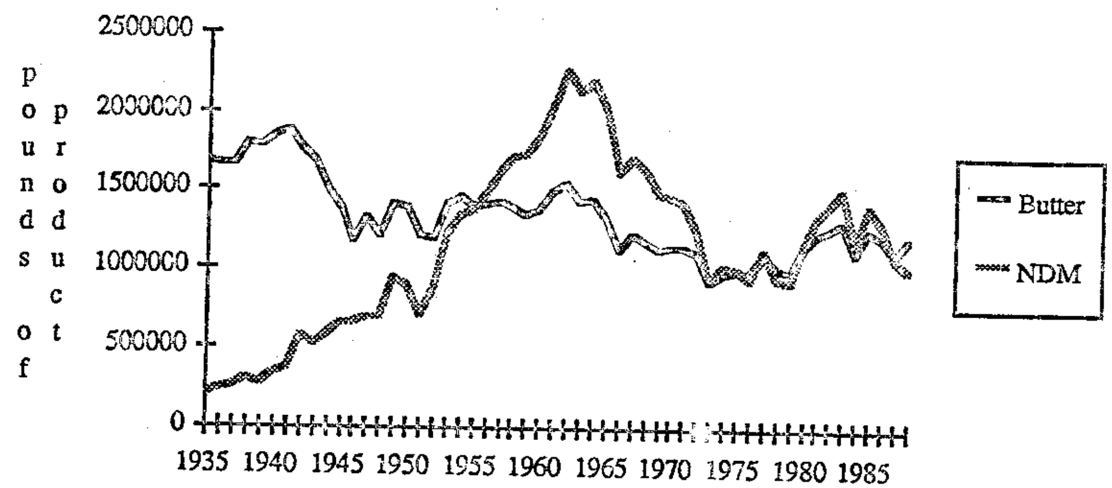

Figure 1. Annual Production of Butter and NDM 1935—1988

During the first half of the century, thousands of creameries existed as individually owned, profit oriented businesses producing butter for sale in the cities. For example, in 1937 more than 4,600 firms reported production of creamery butter.[3] By 1972, the number of firms had dwindled to 475, and in 1987 only 178 reported any production of butter.[4] Plants producing nonfat dry milk for human consumption have also dwindled from 180 in 1972 to 83 plants in 1987. These dramatic changes in plant numbers are indicative of the underlying structural changes that have taken place in the dairy industry during this period of time.

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[3] Alden C. Manchester, The Public Role in the Dairy Economy, Westview Press: Boulder, Colorado, 1983, p. 78.

[4] USDA, Dairy Products, Annual Summary, various years.

The dairy cooperatives that existed during the 1920's and 30's were largely confined to price bargaining for their farmer/members. Throughout the 50's and 60's, bulk movement of milk added supply coordination to the role cooperatives were playing. With this new function came the need to ensure a market for members' milk. The solution was found in cooperative ownership of surplus disposal facilities—usually a butter/powder plant. The result is that the bulk of butter and nonfat dry milk is no longer produced in numerous proprietary firms, but rather in relatively few, cooperatively owned operations (see Figure 2).

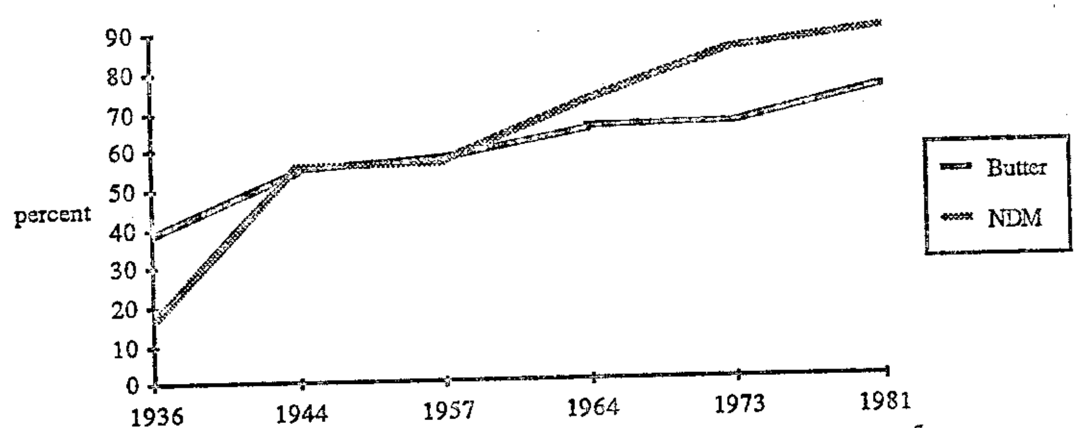

Figure 2. Cooperatives' Share of Total Output[5]

The United States is one of the largest producers of storable dairy products in the world. In 1987, for example, the US ranked third in the production of butter with 501,000 metric tons behind France with 569,000 metric tons and U.S.S.R. with 1,742,000 metric tons. Nonfat dry milk production placed the United States second with 480,000 metric tons behind France's production of 603,000 metric tons.[6] In that year, less than 7 percent of our butter production was exported to other countries while 80 percent of the NDM was shipped out of the the United States. Imports of butter and NDM into US commerce are not significant.

The federal government has played an important role as an exporting agent of these commodities. Through the price support program, the Commodity Credit Corporation stands willing to purchase surplus stores of butter, NDM and cheddar cheese. The CCC

5 U.S. Farmer Coop. Service, Report #7. Marketing Operations of Dairy Cooperatives. 1977.

6 USDA, World Dairy Situation, November 1988.

has often moved a great deal of their NDM purchases out of storage through exports overseas. Averaging over the years 1984–1986, US export of NDM was equivalent to 66% of production while CCC purchases of NDM for those same years were the equivalent of 60% of US production. Not all of the US export of NDM is the result of Federal activity as there always exists some commercial export and CCC purchases of NDM are not always so large. During those same years, the federal government purchases of butter averaged 22% of American production. CCC butter exports are typically not as large as NDM shipments however, in some years, such as 1981, Federal exports of butter have been significant. The CCC has been an important market for surplus disposal of whole milk components.

Commodity Credit Corporation purchases tend to be very seasonal reflecting the patterns of surplus disposal. Production of manufactured products varies significantly over the course of a year, especially for butter and nonfat dry milk. For example, the monthly standard deviations of the indices of cheese, NDM and butter production for the U.S. averaged 0.0581, 0.1761 and 0.1609 respectively over the years 1983–86. This indicates that, relative to cheese production, the manufacture of butter and NDM is much more seasonally variable. The differences between cheese and the other two products are largely due to the fact that butter and NDM serve as the residual claimant on milk components not used in other products.

The major category of milk usage is as fluid milk products, which account for 40% of total U.S. production. Although the standard deviations of milk production and fluid milk consumption are approximately equal (0.0469 and 0.0409 respectively), the large variations for butter and NDM are derived from the nearly counter cyclical patterns of seasonality observed between farm production and fluid demand as shown in Figure 3. If the cycles were exactly parallel, then storable products, manufactured from surplus milk, could be produced in a less seasonal fashion. As it is, the large swings in surplus milk must be handled through annual cycles. The situation in Figure 3 actually understates the complexity of the problem insofar as it only shows how much farm milk is available for manufacturing. The supply of milk for butter/powder processing varies even more.

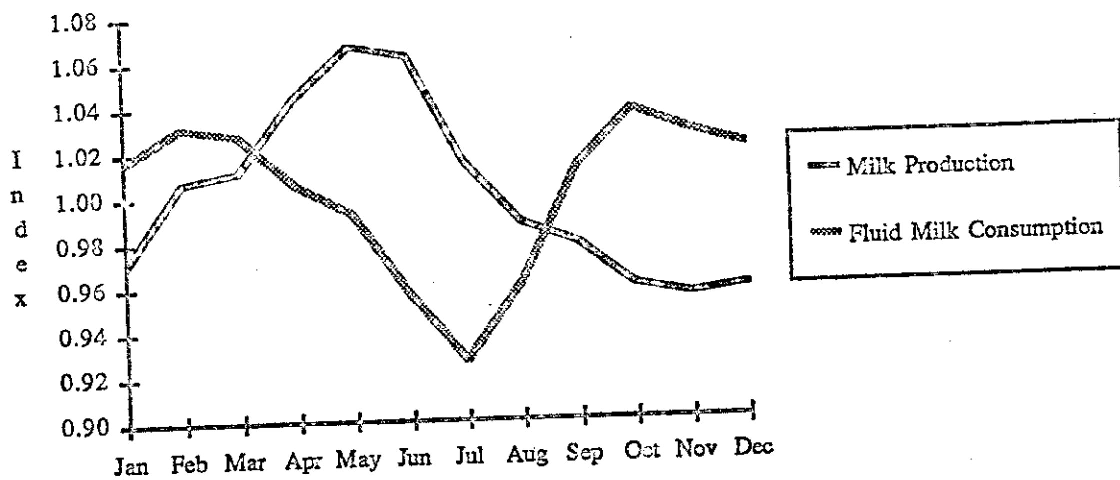

Figure 3. Indices of Average Daily Milk Production and Fluid Milk Consumption[7]

Figure 4 shows the correlation between milk production and the manufacture of fluid milk and storable products. The negative correlation between milk production and fluid consumption quantifies the counter–cyclical patterns observed in Figure 3.

	Milk Production	Fluid Milk Consumption	Cheese Production	NDM Production	Butter Production
Milk Production	1.00				
Fluid Milk Consumption	–0.11	1.00			
Cheese Production	0.90	–0.29	1.00		
NDM Production	0.81	–0.24	0.94	1.00	
Butter Production	0.13	0.35	0.36	0.44	1.00

Figure 4. Correlation of Monthly Milk Production with Product Uses

7 Calculated from monthly averages for the years 1983–86. Taken from USDA's Milk Production, Disposition, and Income and Dairy Products Annual Summary.

The high level of positive correlation (0.90) between milk production and cheese manufacture again illustrates the fundamental differences between cheese plants and butter/powder operations as methods of surplus disposal. Cheese plants make cheese when there is over supply of raw milk relative to fluid uses (see Figure 5), while butter/powder plants process butterfat and/or solids–not–fat that are seasonally in surplus. The negative correlations between fluid milk consumption and cheese and NDM production are intuitive—fluid consumption competes with cheese and NDM for supplies of raw milk. Less intuitive, but expected, is the positive correlation between fluid milk consumption and the production of butter. Fluid milk processors do not use all the butterfat they receive in farm milk for beverage milk products; hence they supply the manufacturing market with surplus cream. Surplus cream is used in many products such as ice cream and table creams, but a large amount goes to the manufacture of butter. These relationships are illustrated graphically in Figure 5.

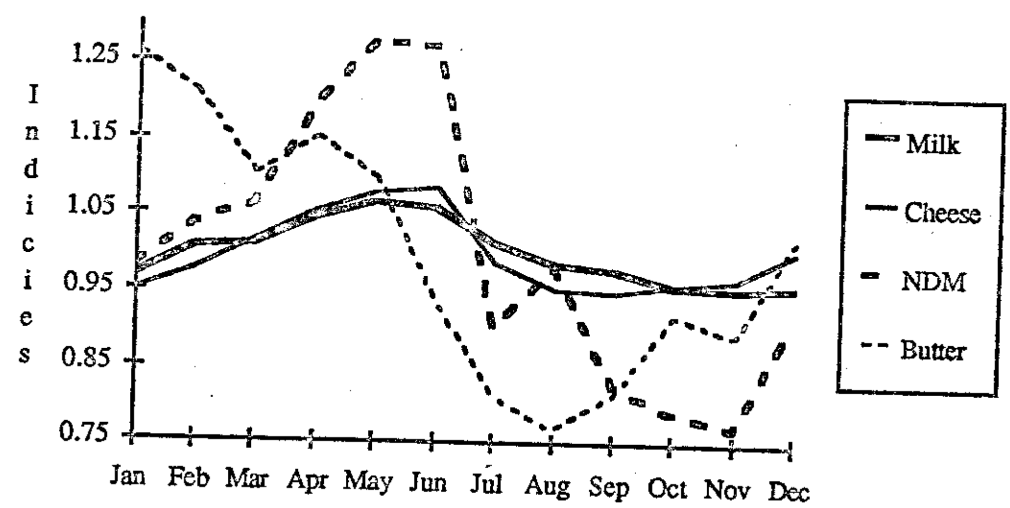

Figure 5. U.S. Average Seasonal Indices of Production[8]

Although current per capita consumption of butter and NDM is less than peak consumption years, their production continues to represent a significant element of dairy processing in the United States. Converting the pounds of butterfat and SNF processed in

[8] Calculated from monthly averages for the years 1983–86. Taken from USDA's Milk Production, Disposition, and Income and Dairy Products Annual Summary.

butter/powder plants from 1980–86 to raw milk equivalent basis, they represent from 13.5% to 20.3% of the U.S. milk supply. Figure 6 illustrates the utilization of raw milk by major products manufactured.

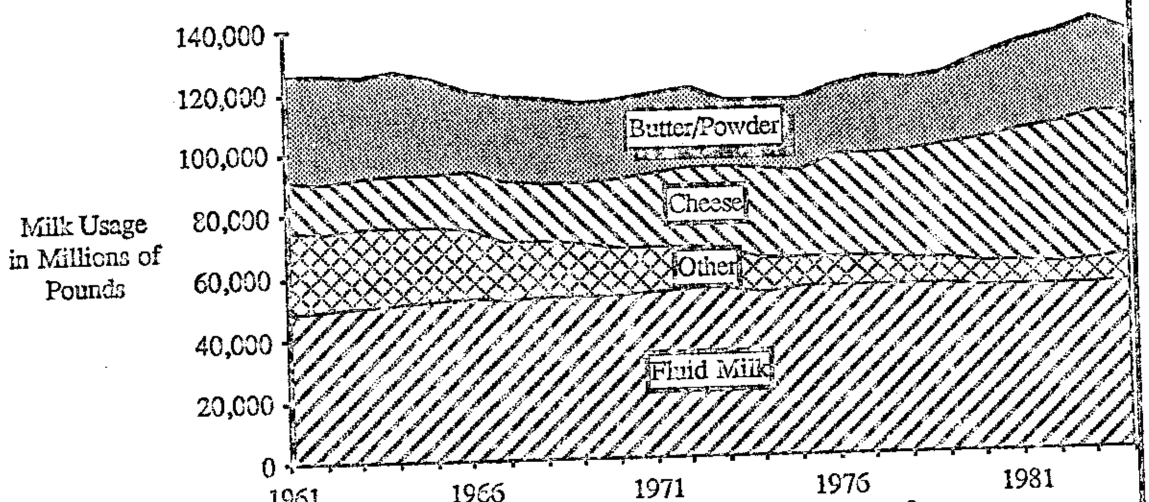

Figure 6. Utilization of Milk from 1961–1984[9]

Objective of the Survey

A survey was prepared and administered for the purpose of assessing dominant processing practices, technologies, input and output mixes, and costs of the major factors of production in butter/powder plants[10]. The overriding objective of this survey is to provide a series of benchmarks by which the costs of processing for butter and nonfat dry milk might be simulated using an economic engineering approach employed in the second phase of a larger research effort.

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9 Calculated from USDA's Milk Production, Disposition, and Income and Dairy Products Annual Summary. The Butter/Powder value represents the highest milk equivalent usage—either butter or NDM and condensed skim milk. In all years, this value was the milk equivalent of butter.

10 The survey questions may be found in Appendix A.

Methodology of the Survey

Survey plants were sought which would be typical or representative of firms, practices and conditions in the business. The characteristics that were identified and used for selection were:

—Ownership (cooperative and proprietary)

—Location (major dairy areas across the country)

—Size (varying capacities to process raw products)

—Seasonality (stable and fluctuating processing patterns)

—Marketing Practices (retail butter packaging, CCC sales, bulk blends etc.)

Ten plants that spanned these criteria were selected and surveyed[11].

The survey requested information over a twelve month period from June 1987 through May 1988. These months were selected as being the most recent contiguous months that covered a one year period and were little affected by major government programs (Dairy Termination Program) or natural disasters (drought).

Format of Reported Analysis

The analysis of the survey is partitioned into the following four sections of this report. First, the overall characteristics of the plants surveyed are enumerated. The following section compares the total capacities of major pieces of equipment in the plants. Next is a section where comparisons of some of the efficiencies of production between the

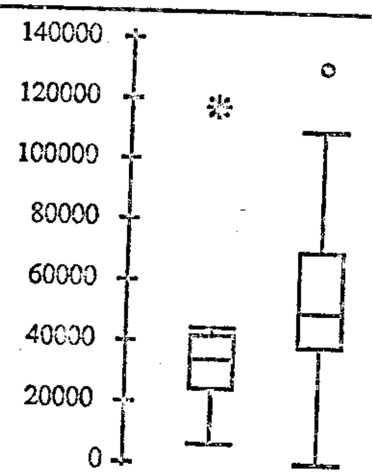
11 See the section entitled "Characteristics of the Survey Plants"

plants are made. And finally, the fourth section compares the costs of production between the plants. The costs of production in this study are defined to lie between receiving and shipping of the raw and finished products. By this it is meant that no purchase price of raw milk or cream has been considered nor has any cost of transportation for the products outside of the plants been included.

Many of the plants that were visited indicated internal accounting problems in dealing with the assignment of costs to various centers within a plant. The very title—'butter/powder'—that we assign to these plants connotes a joint process of production. Even this two–product description of a plant's function is a gross simplification of the observed distribution of inputs and outputs at most operations. On the output side, it would be desirable to be able to say that it costs some number of cents per pound to produce butter or NDM so that comparisons between plants are made on the same basis. However, it becomes problematic to assign, for example, a portion of the cost of steam to butter, condensed milk and powder. Most all plants take in products other than raw milk in varying proportions. As such, on the input side it is not appropriate to simply assign a processing cost per hundredweight of milk either.

To ameliorate some of these problems, in several portions of the survey analysis plant values are converted to a milk equivalent (ME) basis. These milk equivalents are calculated on either a butterfat or a solids–not–fat basis. Surplus cream, as well as raw milk, is often processed at the plants. Further, butter and NDM are not the only end–products sold from plants. Significant volumes of condensed skim milk are sold in bulk, as are blends and mixes of skim milk and cream. The characteristics of plant inputs and outputs is such that most often one conversion factor is appropriate and the other is not. Calculating the butterfat equivalent of NDM is no less meaningless than the solids–not–fat equivalent of butter. When milk equivalent conversions are used, the basis of the conversion will be clearly specified.

Throughout the report, boxplots are used to depict plant information. Boxplots summarize data by showing the median and range of a set of data, and the data range demarcates a central core as well as end points. Figure 7 defines the specific components of a boxplot and explains their interpretation.



Boxplots have three components:

- Extreme data values are plotted individually, usually with a circle. If they are very extreme, they are plotted with a starburst.
- The outlined central box depicts the middle half of the data between the 25th and the 75th percentiles. The horizontal line across the box marks the median value in the data.[12]
- The "whiskers" extend from the top and bottom of the box to depict the extent of the "main body" of the data.

Figure 7. Explanation of Boxplots.

Regression analysis[13] is used in this report as a means of statistically distributing costs to the various products. In the main, estimates are statistically good when the data are grouped for all plants, and fairly good when data from individual plants are used separately. Thus, one can more accurately estimate the average performance of a group of plants than the performance of any one plant. There are a few instances where the lack of data, the spread of the data, or the intractability of the data yield weak results for certain variables and plants. Such instances are pointed out in the body of the report and weak results are not used for purposes of comparison.

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[12] The median value in a string of numbers or data is that midpoint at which half of the observed values are above and half below. This is usually not the same as the mean or average value, which is more sensitive to extreme endpoints.

[13] Regression analysis is a statistical technique that uses the pattern of real, observed relationships to estimate how one or more factors (e.g. labor, utilities, etc.) affect the level or outcome of another variable (e.g. cost).

Characteristics of the Survey Plants

Relation to National Markets

During the twelve months of the survey, the ten plants processed raw milk and surplus cream into 228,867,996 pounds of butter, 204,922,453 pounds of NDM, and 232,408,362 pounds of condensed skim milk. This represents 20%, 19% and 25% respectively of the United States production of those products[14].

Size

Plant managers were asked to estimate their maximum sustainable capacity to produce butter and NDM in a 24 hour period[15]. The milk equivalents on a butterfat and solids–not–fat basis are also calculated for each of the twelve months on every plant. From these, daily milk equivalent processing averages over the year are determined. As measures of size, these indicators are shown in Figure 8. The median 24 hour capacities to produce butter and NDM are 176,500 and 151,500 respectively and the ratios of largest to smallest plants are 4.0 and 4.65 respectively.

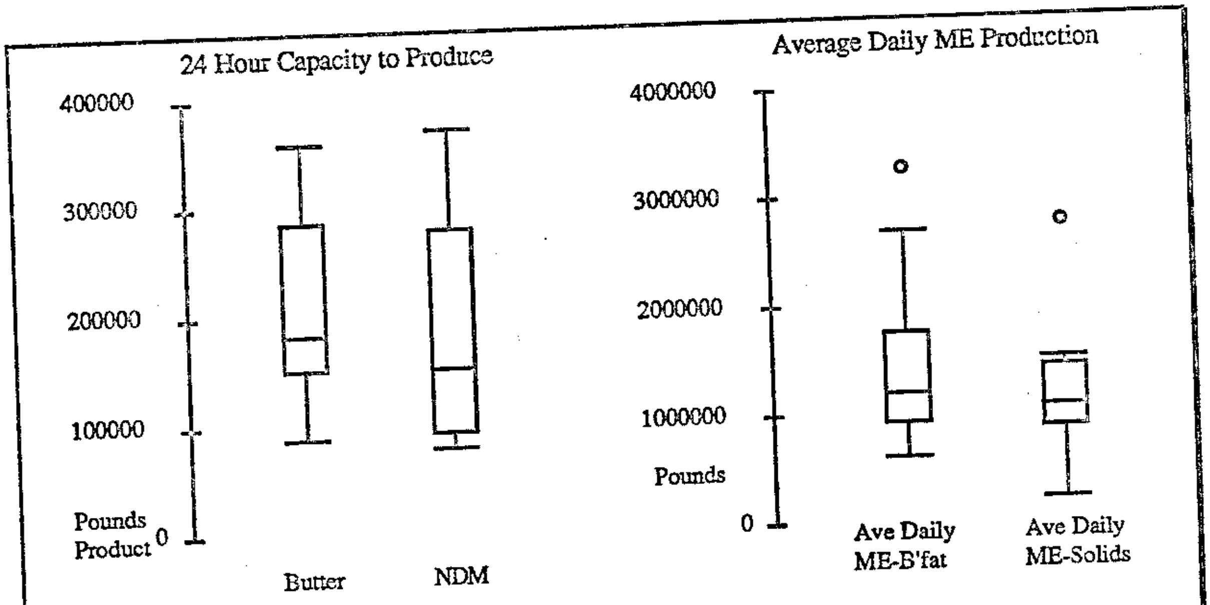

Figure 8. Size of the Plants

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14 U.S. production numbers taken from USDA's Dairy Products Annual Summary.

15 This question was posed to reflect an ongoing, sustained operation, not a 24 hour burst of continuous churning and drying. CIP time was to be factored into the answer. Further, if churn or dryer size were not the limiting factor, but rather some other plant center, then the obstruction should be reflected in the answer. There may be different limiting bottlenecks for different plants. See question 19 of the survey.

Ownership and Location

Of the ten plants surveyed, ownership is divided into two privately owned plants with the remaining eight being cooperatively owned. The plants are located across the major dairy areas of the country representing the Northeast, the Upper Midwest, the Southwest and the West. The majority of plants were located in the Northeast and Upper Midwest.

Seasonality

We did not survey plants for inter–week fluctuations in butter/powder processing. However, the challenges posed by seasonality in some plants is a question of interest. Two statistical measures of seasonal variation are calculated, as shown in Figure 9. On the left side, the standard deviation of monthly milk equivalent processing on a butterfat and solids–not–fat bases are calculated for each of the twelve months. Although it is difficult to place a sensible interpretation on the actual values of standard deviation, the range in values would descriptively span from "non–seasonal" to "very seasonal", indicating plants that operate near capacity all year round to plants that processed no product for at least one month. Without exception, plants in the Northeast have the most seasonally variable output. Another measure of seasonality shown in Figure 9 uses the ratio of the highest production month to the lowest production month on a milk equivalent basis for each plant. Again by this measure, Northeast plants have the most seasonal output in the country.

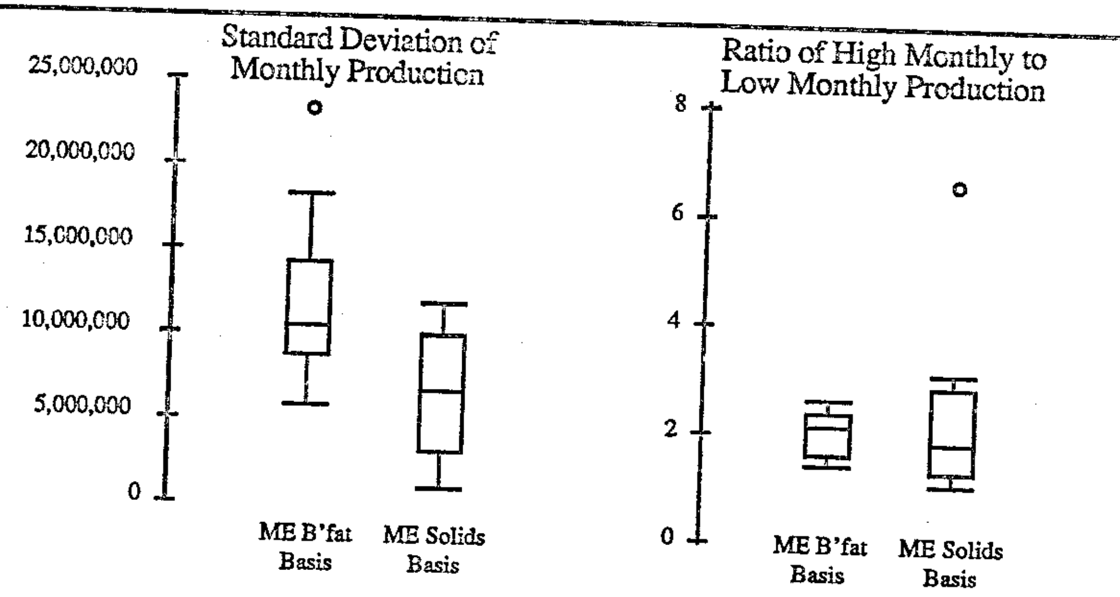

Figure 9. Seasonality of the Plants

Plant Utilization

The plants vary widely in their use of potential plant capacity, as defined in Figure 8. Over the year, more than one plant averages using less than 10% of their available capacity to process a given dairy product. Figure 10 displays the spread in plant usage. On the whole, plants greatly underutilize their ability to churn butter. It is not clear whether ①this over capacitization is intentional, ②much larger churns are not much more expensive, ③churn size is geared to a daily peak load not reflected in our monthly data, or ④there are some other rational reasons.

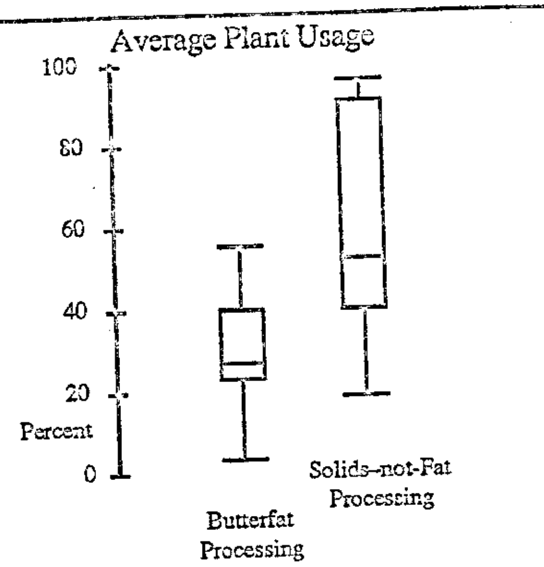

Figure 10. % Use of Plant Capacity

Marketing Practices

The final plant characteristic that is explicitly probed in the survey is the mix of products that are being manufactured in what is considered to be a "butter/powder" plant. All plants churn sweet cream and fill 68 pound commercial boxes. The survey attempted to determine the prevalence of other practices. It was found that several plants also churn some whey cream, and many package the butter in various retail packages. Figure 11 shows the number of plants having various packaging options. It is determined that on average, 33% of the butter churned is packaged as 1 pound solids and 33% is packaged as 1/4 pound prints. These values differ from annual national averages as reported in a survey of butter packaging conducted by USDA's Agricultural Statistics Board.[16] In USDA's study, it is determined that 55% of butter was packaged in 68 pound bulk containers, 20% in 1 pound solids and 20% as 1/4 pound prints during 1988.

Both skim milk and buttermilk are commonly sold as a condensed product. Less commonly, whole milk and whey products are condensed and sold in tanker loads. Another outlet for both fat and solids-not-fat are custom blends and mixes. Figure 11 also demonstrates the prevalence of this practice. All of the condensed products, with the exception of blends and mixes, are further processed and sold as a dry product in 50 pound bags.

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16 USDA, Dairy Products, Annual Summary, April 1988 through March 1989.

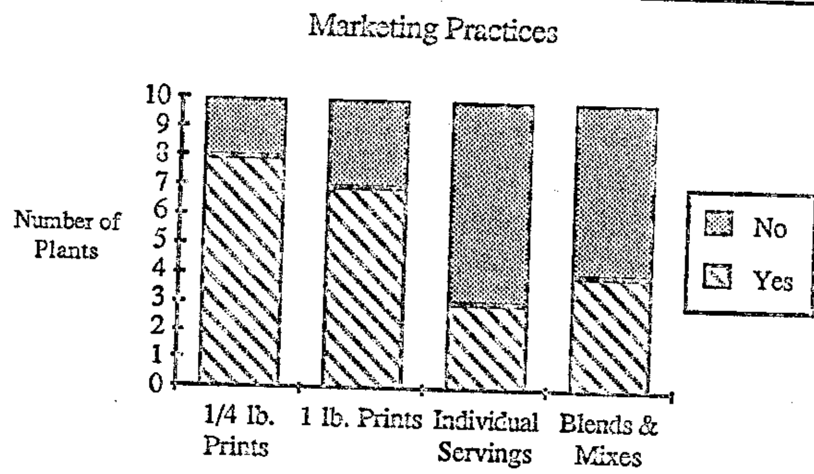

Figure 11. Alternative Marketing of Plant Products

Equipment Capacities

Although plants do market cream and skim milk through sales of condense and blends, their primary outlet for processed butterfat and solids–not–fat is as butter and NDM powder. The major pieces of equipment used in the manufacture of these products are the churn, evaporator and dryer. Figure 12 depicts the spread in plant capacities of these three centers in the ten survey plants. It is a common practice in the surveyed plants to have multiple units of any equipment type, two or three churns for example; it is the sum of equipment capacities that is listed here[17].

There are no real differences between any of the plants in the churn technology employed—all are modern continuous churns. There are some differences in the evaporators. Singly or in combination, TVR (thermal vapor recompression) and MVR (mechanical vapor recompression) units are being used. The number of effects varied from one to eight and turbo fans are in place in some evaporators. Spray dryers are exclusively

[17] Capacities for the plants were taken from question 3 of the survey.

in use. However, there are tall and short form dryers, box dryers, and filter mat dryers with one or more stages. The most common type of dryer employed in the plants is a two–stage, tall form dryer.

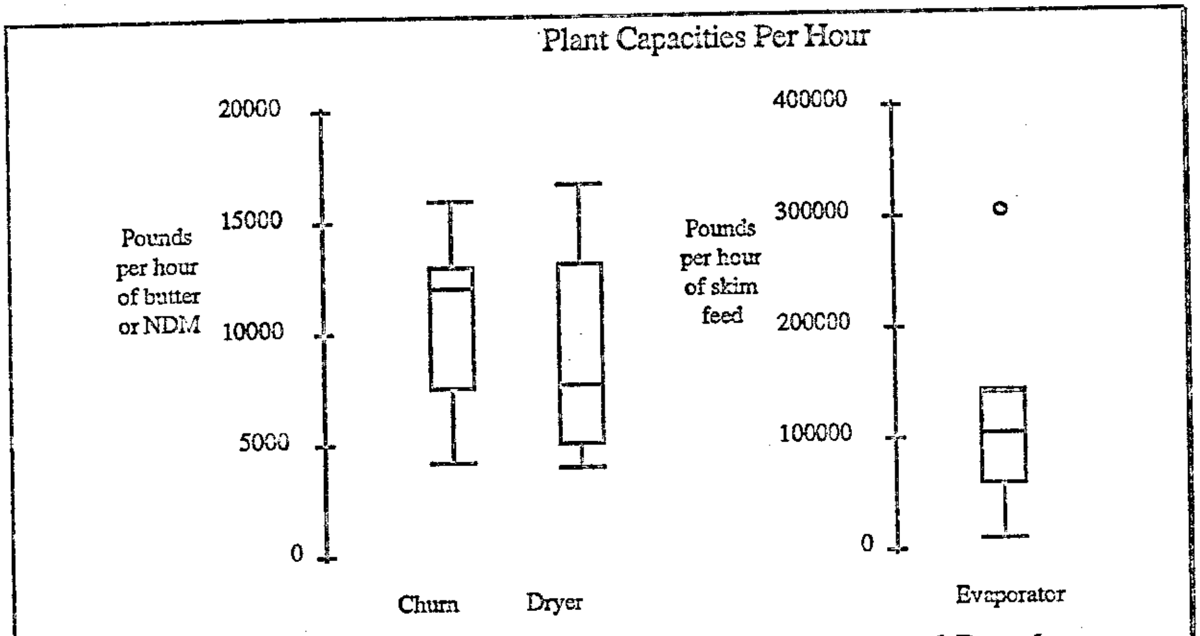

Figure 12. Plant Capacities to Churn, Evaporate and Powder

In general, plants have a 68 pound commercial bag–in–box filler capable of handling the total churn output. It is not true however, that the largest volume of butter is packaged in these commercial containers. On average, more pounds of butter are printed as one pound solids or $^1/_4$ pound sticks than in the 68 pound box. Although there are many different kinds of individual, restaurant–type packages represented in the plants surveyed, the most common is a continental wrap. Of the plants printing butter in continentals, 6% of their output is typically put up in these packages. Figure 13 demonstrates the capacities of the plants to print $^1/_4$ pound and one pound packages.

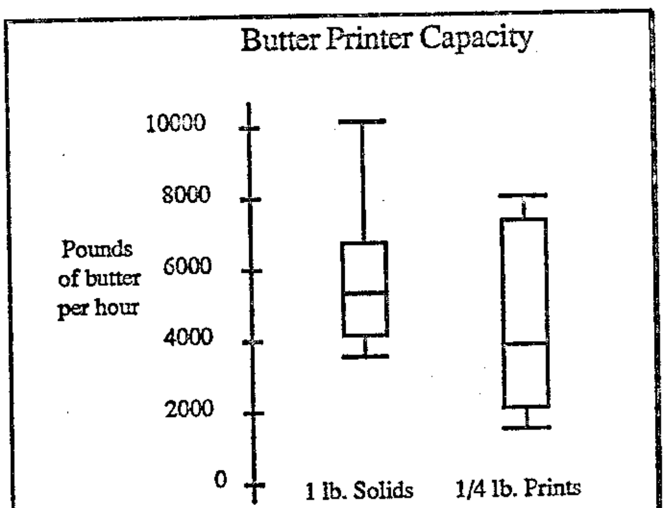

Figure 13. Butter Printer Capacities

Figure 14 shows that plants vary greatly in their capacity to unload and store raw products. By way of explanation, it must be noted that transfers of raw milk are an important activity in some plants. Also, plants with a large percentage of cream receipts relative to raw milk need not have as extensive unload and raw product storage facilities.

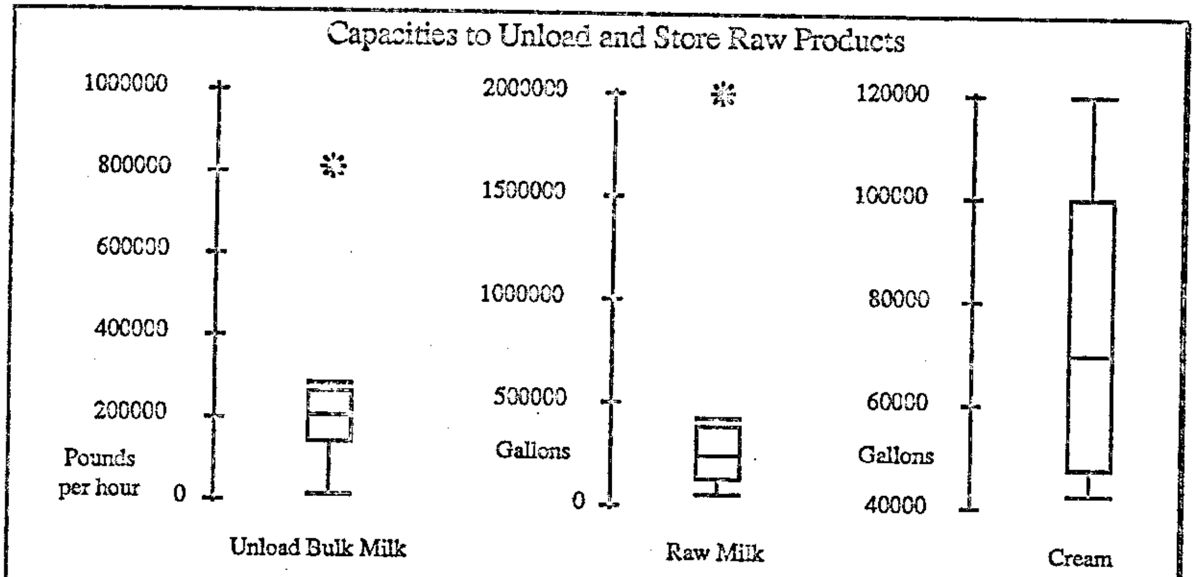

Figure 14. Capacities to Handle Raw Products

Like the variability between the plants in their ability to handle raw inputs, there is a large spread in the capacity to store finished products as shown in Figure 15.

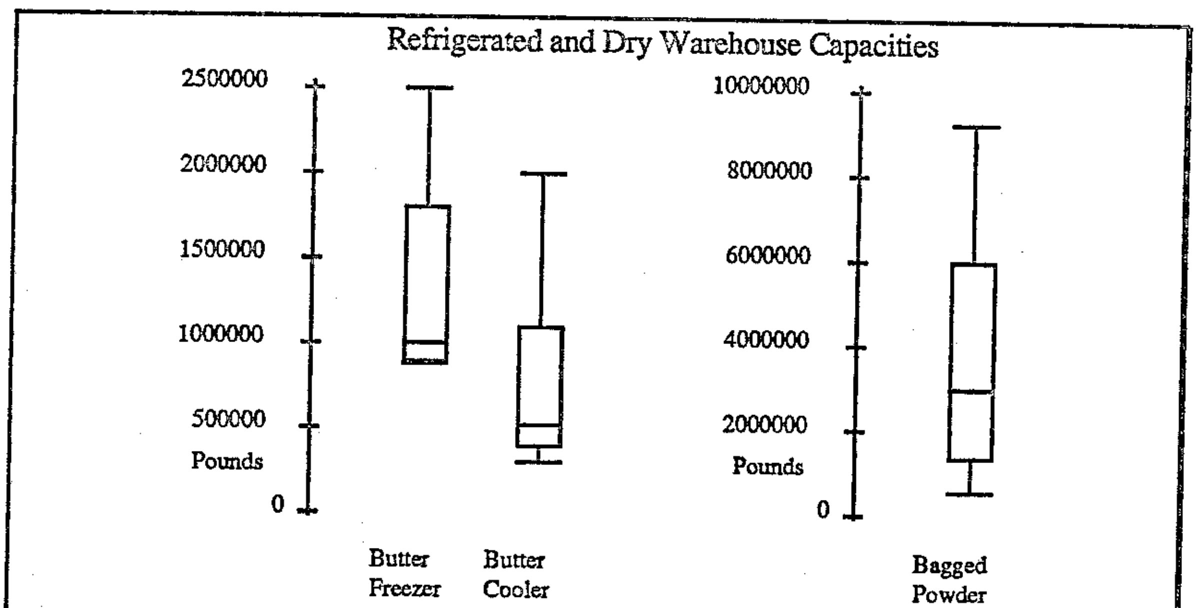

Figure 15. Warehouse Capacities

Most of the disproportion between plants is in the dry product warehouse. Some organizations have cavernous storage which is being used to take a speculative position in the market, others having large storage warehouses hold the space largely unused or partially filled with processing supplies and other products.

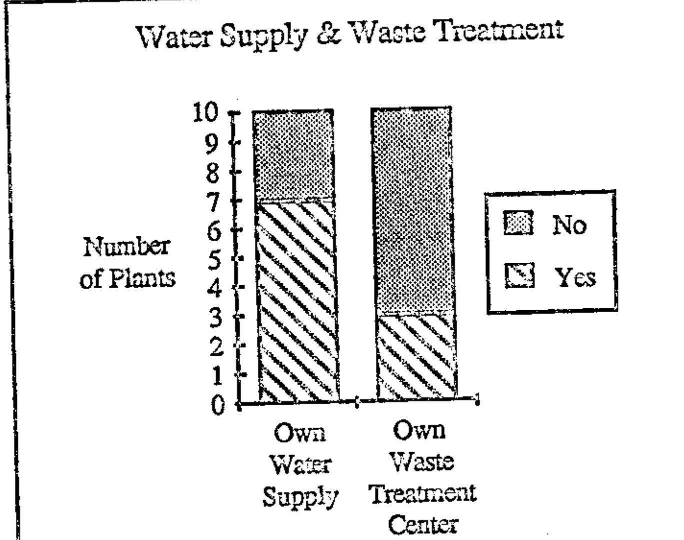

Figure 16. Frequency of Waste Treatment

It is clear that the survey respondents are acutely aware of the problems of waste disposal at the plants. Most of the plants that are performing some level of waste treatment have only begun to do so recently. Virtually all of the other plants indicate that consideration will need to be given to installation of a waste treatment facility in the near future. The facilities in place vary from pre–treatment centers where waste is cooled and/or buffered before discharge in the city sewer to complete neutralization facilities with stream discharge. Figure 16 shows the number of plants having internal water supplies and extensive waste treatment facilities[18].

Inter–Plant Efficiencies of Production

Two of the largest categories of expenses in a butter/powder plant are labor and utility costs. They affect the bottom line through both per unit costs (dollars per hour, kwh or therm) and number of units used. Averaging over the ten plants surveyed, labor

[18] See questions 4 and 5 in the survey.

costs[19] account for 36% of the total costs of production[20] while utility costs average 17%. These two categories are examined for comparisons of productivity between the plants in order to determine how many hours of labor are used to produce a pound of butter or NDM.

Regression analysis is employed to predict the hours of labor used in the plant based on the pounds of products produced. Two types of regressions are used and reported here. The first type of regression is one that is run for each plant where, for example, it might be assumed that labor hours for plant #1 are a function of plant #1's production of butter, powder, condensed skim milk, etc. These were run for each of the ten plants and the results are displayed in Figure 17. The second type of regression is one that is run on the data aggregated over all plants. This type of regression also has butter, powder, and condensed skim milk as independent variables but further includes binary variables for each of the ten plants in the survey (the standard intercept term is suppressed). This provides an "average" value over all the plants for the variable hours required to produce a pound of butter or powder as well as the unique number of fixed hours of labor for each plant. These results can be seen in Figure 18.

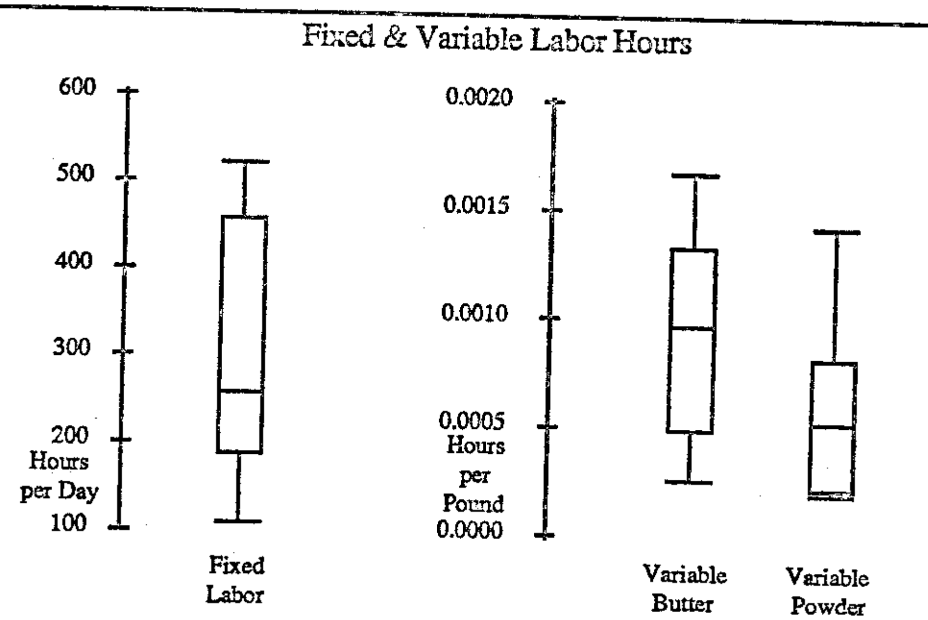

Figure 17. Individual Plant Allocations of Labor Hours to Fixed, Butter and Powder

[19] Labor costs include both wages paid and the value of the benefits package.
[20] Note that total costs does not include the cost of raw material, i.e. milk and cream. Total costs refer to all other costs involved in the manufacture of butter and NDM.

Figure 17's regressions on each plant separately, also have labor hours allocated to a fixed component. The fixed component would be the typical number of labor hours employed at the plant daily, regardless of the products produced. The variable hours are of course those directly attributable to the production of a pound of butter or powder. If the data from a plant is adequate, and if an accurate portrayal of labor usage in a plant is described by a fixed value and variable values for pounds of butter and powder produced, then a given plant should be able to predict the daily hours of labor used by knowing a fixed value and the pounds of butter and powder produced[21]. It should be noted that these allocations of hours must not be compared directly with churn or dryer operator hours, they are the allocated hours for all personnel, including those working as office and support staff, needed to operate the plant.

The regression results for the aggregate data found in Figure 18 are quite good[22]. Thus, the proportion of variable to fixed labor hours used by the plants can be stated with some confidence. Total aggregated labor hours, over the ten plants, for the twelve months of the survey equal 1,409,243. The sum of the variable hours for these same plants are calculated to be 204,179. This implies that on average only 14.5% of labor is variable with the remaining 85.5% being fixed.

$R^2 = 99.6\%$		97 degrees of freedom
Variable	Coefficient	t–ratio
Butter	0.000568 hr/lb	2.83
Powder	0.000362 hr/lb	2.01
Fixed hours—(varies from 171 to 546 hours per day and averages 307 hours per day)		

Figure 18. Aggregate Allocations of Labor Hours to Fixed, Butter and Powder

The amount of fixed labor in the survey plants differs by a magnitude of more than five (based on Figure 17). Variable hours for the production of butter and powder span an even greater range. There is a negative correlation (-44%) between fixed and variable hours, illuminating a typical tradeoff[23]. One might surmise that there would be a high

21 For example, suppose daily fixed hours are 250 and per pound hours for butter and powder are 0.0010 and 0.0005 respectively. Further, daily production of butter and NDM is 175,000 and 150,000 respectively. Then predicted labor hours would be 250 + (0.0010 x 175,000) + (0.0005 x 150,000) = 500 hours per day.
22 A measure of the "goodness of fit" in a regression is the R^2 value. A value of 100% would be a perfect fit. I.e., you would be able to exactly predict the hours of labor used by knowing the values to apply to the coefficient estimates.
23 Common dogma is that firms make choices between the allocation of variable and fixed requirements for production. A plant that operated seasonally might choose to have fewer full–time employees (lower fixed hours) and more part–time help (higher variable hours).

correlation between seasonally operated plants and plants with a high proportion of variable hours relative to fixed, however that could not be substantiated with this data.

The same type of analyses are run for the major utilities in the plants. Some quantities of No. 6 fuel oil or LP gas are being used at most plants. However, their contribution to the generation of steam is of minor importance in all plants surveyed. Only kilowatt hours (kwh) of electricity and therms of natural gas are reported in Figure 19.

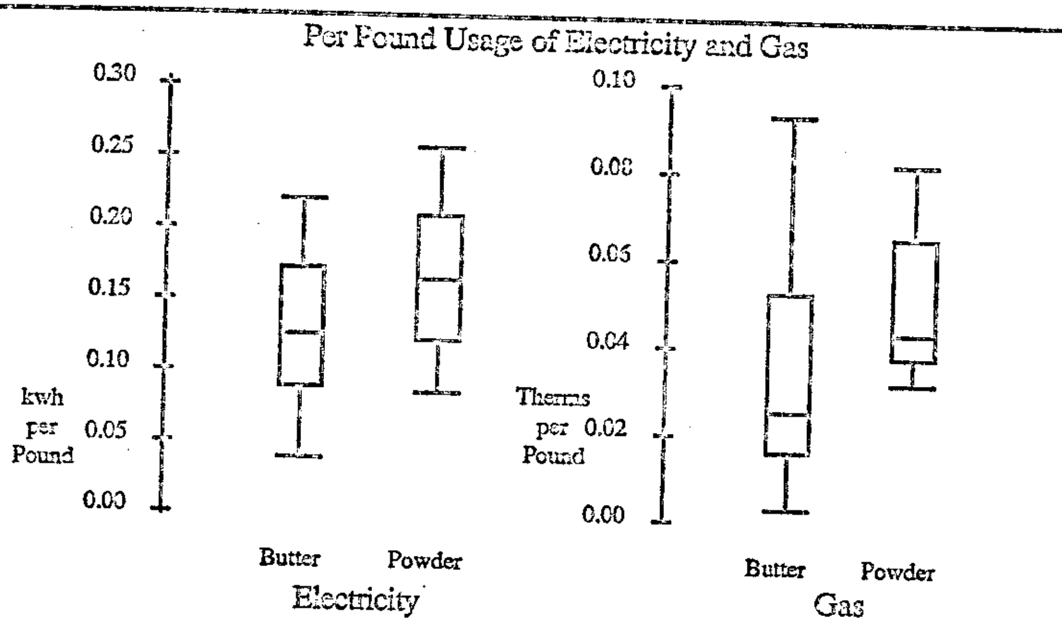

Figure 19. Allocation of Electricity and Gas to Butter and Powder

The statistical results of the regressions on individual plants were not reliable when estimates of both fixed and variable utility usages were calculated[24]. Therefore, it is assumed that the amount of electricity and gas used at a plant would be negligible if no products were being produced. The regression analyses are then constrained to assign only variable quantities of kilowatt hours and therms. No allocation to a fixed amount is made. Figure 19 displays the spread between the plants for electric and gas usage per pound of butter or powder with other plant products having been taken into account. Once again, these allocations of kwh and therms include all pumps and motors, HTST etc. involved in the manufacture of the products.

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24 R^2 values for these regressions were as low as 10% for several plants. This is likely to be a result of little variability from month to month in utility usage and at most 9 degrees of freedom for each regression.

When the data on all plants are combined, good estimates of variable and fixed values are obtained. As with the aggregated labor regressions, the variable values obtained are "average" values over all the plants with unique plant values for fixed utility usage. These results are exhibited in Figure 20. There is a higher proportion of variable to fixed utility usage than with labor hours. Variable kilowatt hours account for 33.1% of total hours and variable therms explain 46.3% of total usage.

Electricity

$R^2 = 97.9\%$ — 99 degrees of freedom

Variable	Coefficient	t-ratio
Butter	0.061746 kwh/lb	4.27
Powder	0.053467 kwh/lb	2.32

Fixed kwh — (averages 16,945 kwh per day)

Gas

$R^2 = 97.7\%$ — 99 degrees of freedom

Variable	Coefficient	t-ratio
Butter	0.009040 therms/lb	2.88
Powder	0.026576 therms/lb	5.30

Fixed therms—(average 2,708 therms per day)

Figure 20. Aggregate Allocations of Electrical and Gas Usage to Fixed, Butter and Powder

Inter–Plant Costs of Production

Per unit rates for labor wages and benefits, electricity and natural gas vary widely between the plants. Figure 21 illustrates the differences between the various plants in remuneration of employees. Plants also differ greatly in their structure of wage rates and employee profiles. Of the ten survey plants, three operate with union labor while the other seven do not. In general, union plants show very small differences in pay scale between employees working in different plant centers and between levels of seniority. On the other hand, non–union plants had a much larger spread in pay scale. No generalizations could be made regarding correlations of union/non-union labor with employee profiles or with wage/benefit levels and employee profiles. It can however be said that some plants have an average seniority of less than three years while for others it is greater than fifteen years. It would appear as though geographical region of the country has an influence on wage and benefit rates although proximity to urban centers does not.

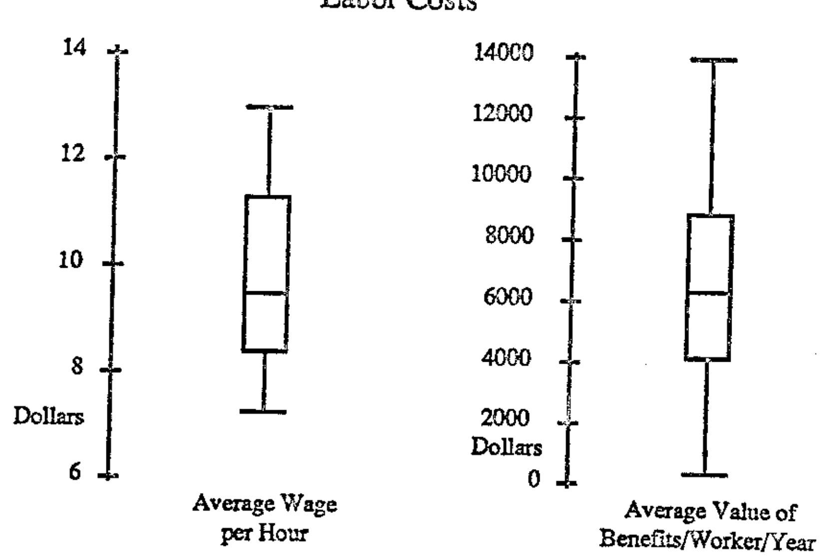

Figure 21. Average Wage and Benefits Paid

Utility rates, shown in Figure 22, display large differences between plants. Neither the electric rates nor the rates for natural gas have strong correlation with regions of the country. One explanation for the spread in natural gas rates comes from plants that have negotiated with utility companies for interruptible service rates. These plants have propane tanks as a backup system; however they report that service has typically been interrupted for only a few days per year. The rates for the interruptible service are about half of the non-interruptible commercial rates.

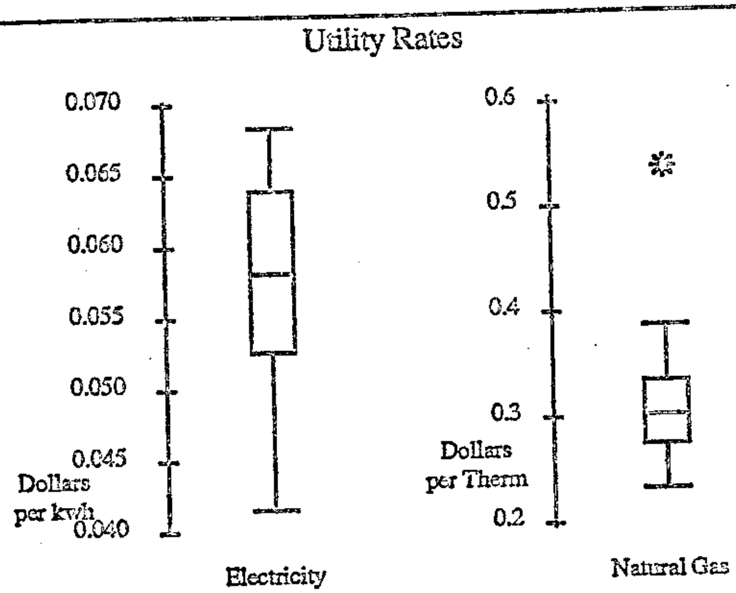

Figure 22. Average Electrical and Gas Rates

Regression analyses is again used as a statistical means of allocating total costs in each plant. Here, the attempt is to be able to predict the total costs of processing in a plant if the pounds of butter and powder to be produced are known[25]. In the regression, costs are distributed between fixed costs and the variable costs associated with production of butter, powder, condensed skim milk, etc. In general, these individual plant regressions have better statistical results than the individual regressions on labor hours. This provides some confidence for inter-plant comparisons. Poor results are not reported or used in the analysis in an attempt to reduce biasing the remaining results. Figure 23 shows these results, reporting only the fixed costs and the variable costs for butter and powder production.

[25] In the vernacular of statisticians, total costs are the dependant variable and the independent variables are pounds of butter, powder, condensed sales etc. From the results, suppose daily fixed costs are $8,000 and per pound costs for butter and powder are $0.03 and $0.0325 respectively. Further, daily production of butter and NDM is 175,000 and 150,000 pounds respectively. Then predicted costs would be $8,000 + ($0.03 x 175,000) + ($0.0325 x 150,000) = $18,125 per day.

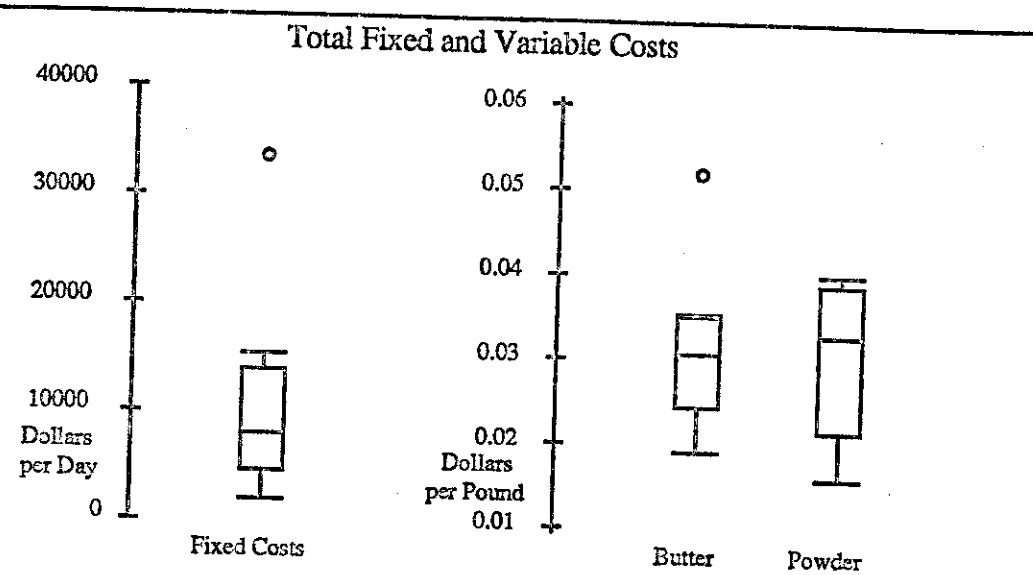

Figure 23. Allocation of Total Costs to Fixed, Butter and Powder

Total costs for processing are calculated from plant data and do not include the cost of raw product[26]. The "non–cash" cost of depreciation is included in the total cost to reflect investment levels in plant facilities. The rationale for this is that investment patterns would show up in fixed costs for the plants with the balancing cost center of repairs and maintenance being revealed in variable costs. Thus it is hypothesized that higher fixed costs in facilities would be offset by lower variable costs and vice versa. Although high fixed costs are indeed highly correlated with depreciation (89%), variable costs are not necessarily even negatively correlated with fixed costs.

Once again, the data from all plants are combined to provide a strong basis for determining "average" variable costs over all the plants. Figure 24 exhibits the results from this regression. As with labor hours, plants have a very small proportion of total costs that are variable. The average ratio of the group was 19.4% variable to 80.6% fixed.

$R^2 = 99.7\%$ — 97 degrees of freedom

Variable	Coefficient	t–ratio
Butter	0.029129 $/lb	3.94
Powder	0.023918 $/lb	3.60

Fixed costs—(varies from $3,197 to $37,074 per day and averages $11,003 per day)

Figure 24. Aggregate Allocations of Total Costs to Fixed, Butter and Powder

[26] Total costs were determined from survey answers: 16, 17, and 22 through 32.

The results from these regressions are used to generate the total processing costs per pound of butter and powder and for a theoretical hundredweight of raw milk in the ten plants[27]. To generate a cost of processing per cwt of milk, a theoretical yield of 4.34 pounds of butter, 8.69 pounds of NDM and 0.44 pounds of buttermilk powder for every cwt of raw milk is assumed. These values are displayed in Figure 25.

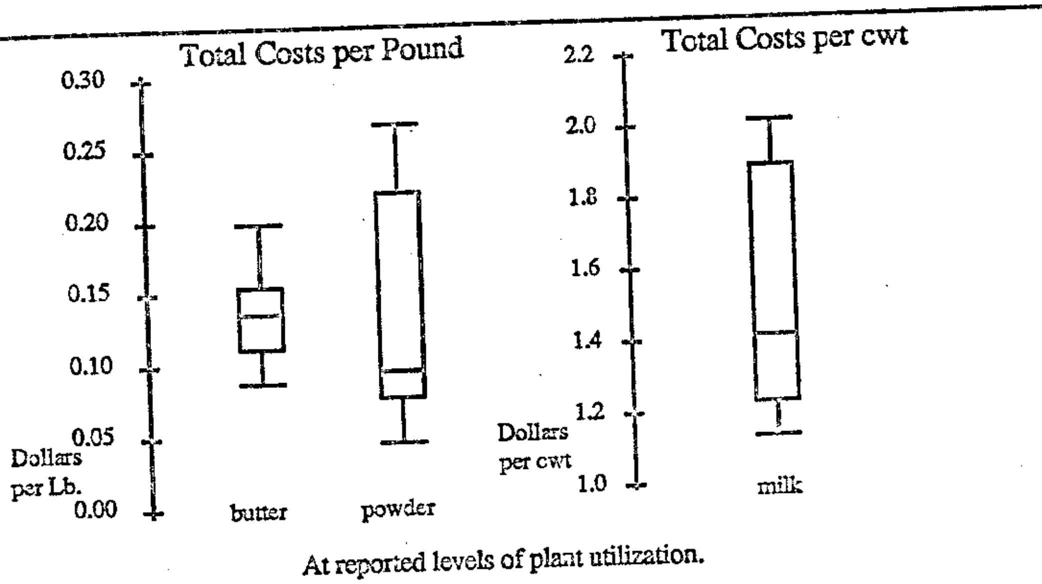

Figure 25. Manufacturing Costs of Butter, Powder and cwt of Milk

A few of the plants surveyed had offered their in–house calculated values for processing costs per cwt. The values determined in this report are consistently higher than the plants' determinations. It is believed that this is because the calculations used here assume that a plant incurs the highest expense and processes all of the milk equivalent into the end products of butter and powder. In reality, all plants had significant volumes of transfers or bulk shipments of skim milk, cream, condensed skim milk, and blends which imply lower production costs for plants in total.

It is interesting to note that there is an 80% correlation between plant ownership and the costs of production. Privately owned plants were consistently lower cost producers of butter than their cooperatively owned counterparts. One possible explanation for this observation is that cooperatives typically have made the investment in facilities to guarantee a market for member milk, whereas the proprietary firms are operating under a different set of priorities.

27 The calculations that were used to generate these values may be found in Appendix B.

As shown in Figure 10, utilization of actual plant capacity is quite low for butter processing and less than capacity for most plants' powdering capability. The same fixed and variable costs per pound that are calculated for individual plants are projected on the operations as though they were operating at 100% of capacity[28]. These results can be seen in Figure 26. Under this scenario, the average costs of production over all plants is reduced from 13.68¢ to 5.71¢ per pound of butter and from 13.29¢ to 7.89¢ per pound of powder. This up-scaling of plant utilization also alters the ranking of high to low cost producers of both products. If these plants had been able to process milk uniformly over the year (non-seasonally) and had been built such that their output during the twelve months of the survey was 100% of their capacity (no over capacitization), there would be a $18,249,934 savings projected over all the plants in butter production alone. The savings in processing costs for powder would be $11,071,960. Obviously these assumptions are extreme, but they provide a measure of the costs resulting from seasonal flows of milk and cream to these plants and under-utilization of existing capacity.

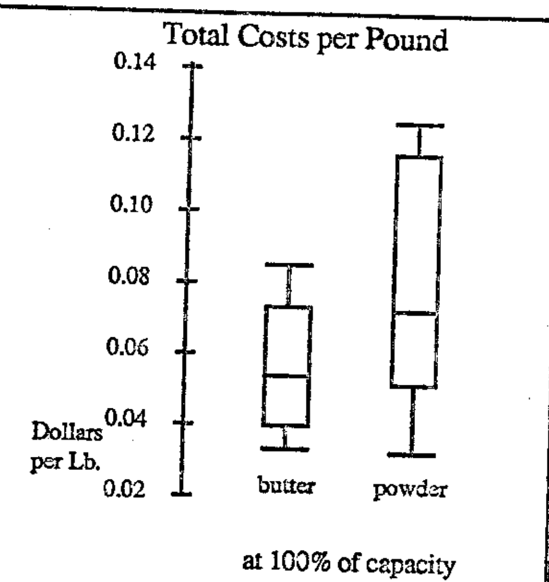

Figure 26. Manufacturing Costs at 100% Plant Capacity

It appears as though plant ownership and utilization are important determinants of average cost of production. To determine more rigorously if this is the case and to explore other possible elements of variation, an analysis of variance (ANOVA) was run on the processing costs of both butter and powder in the plants. In the introduction of this report, it was noted that selection of the survey plants was made on the basis of ownership, location, size and seasonality, and it is these factors that are tested for influence on processing costs. Ownership is only a factor for plants producing butter in this study and is excluded as a category in the ANOVA on powder. Location was divided into three regions: the Northeast, the upper Midwest and everywhere else. The size of the plants

[28] The calculations that were used to generate these values may be found in Appendix B.

were also given three factor levels: small, medium and large based on their 24 hour capacity to produce (see Figure 8). These levels were representative of 0—100,000 pounds, 100,001—200,000 pounds, and greater than 200,000 pounds respectively for butter and powder. Seasonality as a factor is proxied by plant usage and is given a level for every ten percentage points of plant capacity used.

Source	df	Sum of Squares	Mean Square	F-ratio	Prob
Ownership	1	0.087933	0.087933	12.8	0.0006
Region	2	0.340872	0.170436	24.8	0.0000
Size	2	0.320650	0.160325	23.3	0.0000
Seasonality	7	1.55855	0.222650	32.3	0.0000
Error	80	0.550854	0.006886		
Total	92	2.38058			

Figure 27. Analysis of Variance for Cost of Butter Processing

Figure 27 demonstrates that cost of processing butter is highly influenced in this survey sample by each of the factors of selection. The "Prob" or probability column is the key to interpretation of the results. Technically speaking, if the F-ratio is large enough we can reject the null hypothesis that the variation between the categories is the same as the variation within the categories. The probability column indicates the likelihood of the categories being non–important. For example, results here indicate that we might expect 6 plants out of a sample of 10,000 where ownership does not contribute to a measurable variation in the cost of processing. Thus, the plant ownership category had a demonstrable effect on differences in cost with proprietary firms being lower cost processors than cooperatives. Location is also an influential factor with the Northeast firms being high cost processors, the upper Midwest observed to be low cost processors, and everyone else in between. Size appears to be a factor with low cost associated with large capacity processors and the higher costs with the smaller processors. Seasonal variation, by its definition, implies differential usage of plant capacity throughout the year. The proxy of plant usage as a measure of seasonality provides a clear partition for variation in processing costs.

Source	df	Sum of Squares	Mean Square	F-ratio	Prob
Region	2	0.099595	0.049798	6.91	0.0021
Size	2	0.005798	0.002899	0.402	0.6708
Usage	9	1.76728	0.196365	27.2	0.0000
Error	54	0.389165	0.007207		
Total	67	3.53526			

Figure 28. Analysis of Variance for Cost of Powder Processing

Figure 28, shows the ANOVA results for powder processing to be similar to those of butter. The one exception is the size category. Results here suggest that with this data, there is a 67% probability of being incorrect in assuming that the size of a processor has any affect on the processing costs of powder. To some extent, large capacity processors who face highly seasonal variation provide the mixed results. Evaporators and dryers used to powder milk are strategically different to operate than are the churns for butter. Churns can profitably be operated for an eight hour run, but evaporators and dryers would not be started until a 16–24 hour run can be assured. During a seasonally slack period, product at these plants must be held until a run of that length can be made. This requires more silos for holding the raw product and more cost for refrigeration. Labor at these plants is found to be highly fixed and is an additional cost incurred during periods of slight activity. This may account for the inconclusive effects of size on powder processing costs.

It can be seen from Figures 25 and 26 that average cost of processing a pound of product is a function of both fixed and variable costs. For any given plant, plotting the average cost for every achievable level of production will yield a short–run average cost curve unique to that plant's fixed and variable costs at a particular point in time. Over the long run, a plant could choose different equipment capacities, or fixed factors, and operate on different short–run average cost curves. Taking all of these short–run average cost curves together, the minimum achievable costs of production can be found for any level of output. The collection of these points forms a curve known as the long–run average cost curve.

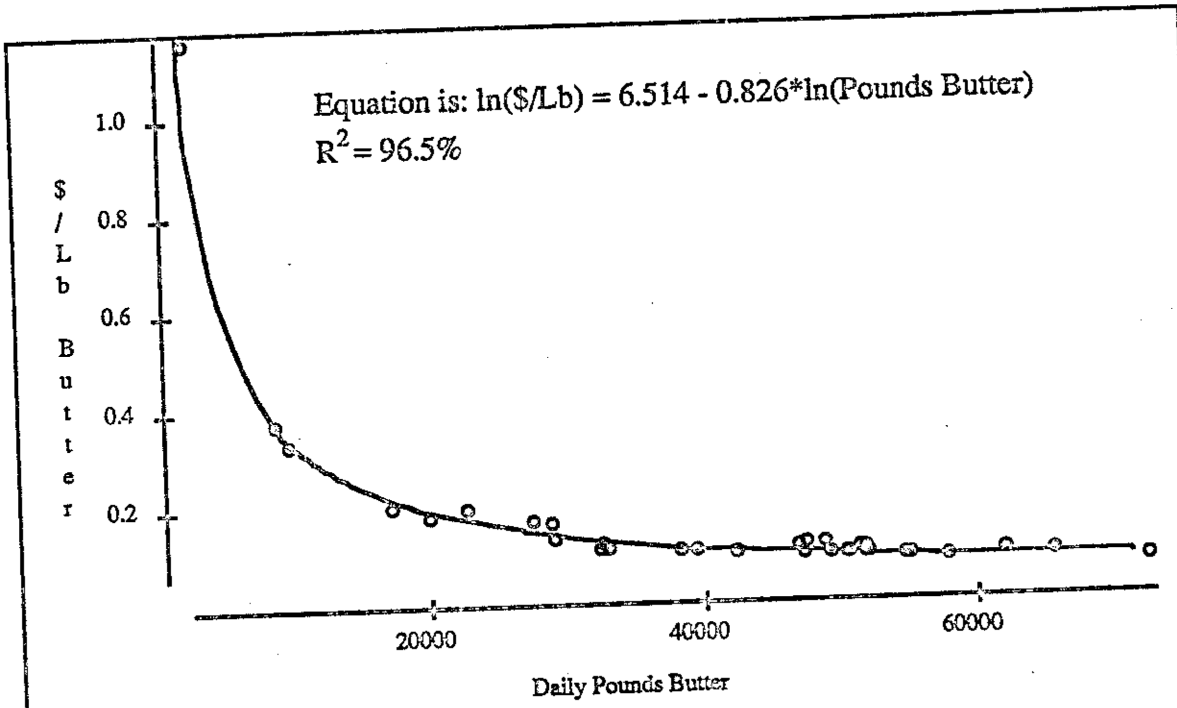

Figure 29. Long–Run Average Cost of Processing Butter

Each of the plants in the survey provides data for a short–run average cost curve. Taken together, they provide data which enables the estimation of long–run average cost curves for butter and NDM processing. The "envelope" or minimum cost of production over different levels of output is surprisingly regular for the combined firm data. Figure 29 shows the long–run average cost curve for butter processing which is estimated for the ten plants in the survey. The points that were chosen for the estimation are shown as small circles and the curve that is fitted by regression analysis is described by the equation and line through the points above[29]. Figure 30 provides a similar estimation for the long–run average cost of processing NDM.

29 The use of the equation for determining average processing cost per pound is related in Appendix B.

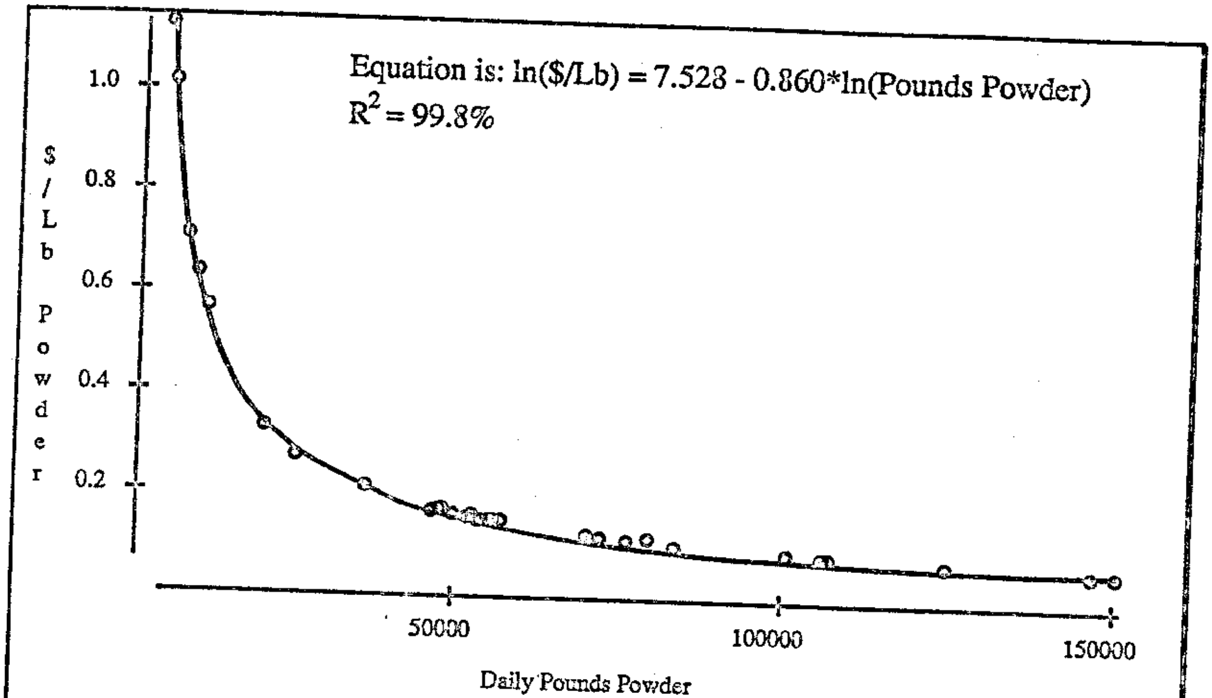

Figure 30. Long–Run Average Cost of Processing Powder

These cost functions summarize all economically relevant information regarding the technology of these firms. The processors in this study ranged from about 2,000 to about 80,000 pounds of butter manufactured per day. At these levels of output, the long–run average cost function indicates a processing cost spread of $1.27 to $0.06 per pound. The slope of the average cost curve is indicative of the fact that the added cost of processing additional pounds of butter declines rapidly from 2,000 pounds per day to, say, 25,000 pounds per day. For example, the average cost of each pound of butter processed at the rate of 2,000 pounds per day is $1.27; however the marginal cost of processing one more pound is only 22¢. The marginal cost of processing at the 80,000 pound level is an even smaller 1¢ per pound. More than 90% of the cost economies are achieved when production is at the 25,000 pound per day level. In the case of nonfat dry milk, production ranged from about 5,000 to 150,000 pounds of powder per day. These output levels are characterized by average costs ranging from $1.23 to $0.07 and marginal costs dropping from 17¢ to 1¢ respectively. More than 90% of the cost economies are obtained when NDM production reaches 50,000 pounds per day.

This punctuates what is instinctively understood by manufactures—the cost of producing additional product at a plant typically is far less than the return (selling price) of the product. Stated another way, this simply means that net returns increase substantially as output increases in a plant. Obviously there is a limit to this defined by, at least, the physical capacity of a plant. In practice, these limits are seldom reached in butter/powder plants.

Comparison of Estimated Costs To CCC Make–Allowance

Under the Dairy Price Support Program, the USDA supports farm milk prices by offering to purchase butter, NDM and cheddar cheese at wholesale prices consistent with farm price goals as reflected in the support price for (manufacturing grade) milk. Calculating these wholesale prices requires USDA to estimate how much they must pay manufacturers for these storable dairy products in order that they can recover their manufacturing costs and be able to pay a price to farmers that is near the support goal. USDA uses a simple formula that involves product yield factors and a so–called make–allowance to calculate their purchase prices, i.e. the prices they will pay for supported products. In the case of butter and NDM, USDA assumes these are jointly produced and have a combined manufacturing cost of $1.22 per cwt of farm milk. In other words, the make–allowance for butter/powder is $1.22. They further assume that this one hundred pounds of milk will yield 4.48 pounds of butter and 8.13 pounds of NDM.

USDA last revised its make–allowances on October 1, 1979. From time to time, it has been suggested that the make–allowance should be increased to reflect higher manufacturing costs since that date. The Producer Price Index for firms processing dairy products has moved from 84.9 to 101.5 from 1979 to 1987, the year of the survey. If the make–allowance had been adjusted by this measure of price inflation, it should have been $1.46 per cwt in 1987.

How does the present $1.22 make–allowance compare to the costs estimated here? This comparison cannot be made without making several assumptions inasmuch as average costs shown above are for butter and NDM separately. The USDA product yield factors may not be what a plant or a set of plants really attain. For example, the theoretical yield from one hundred pounds of milk testing 3.7% butterfat and 8.71% solids–not–fat would be 4.34 pounds of butter and 8.69 pounds of NDM[30]. Moreover, these theoretical values are somewhat higher than would actually be expected as plants in this survey typically experienced a 1–2% loss (shrinkage) of butterfat and less than 0.5% loss of SNF during processing. Nevertheless, if we assume that a butter/powder plant receives only raw milk and produces butter and NDM in the proportions implied by USDA's yield factors, we can estimate long–run average costs for processing a cwt of milk into butter and NDM. Figure 31 displays a long–run average cost curve using these assumptions.

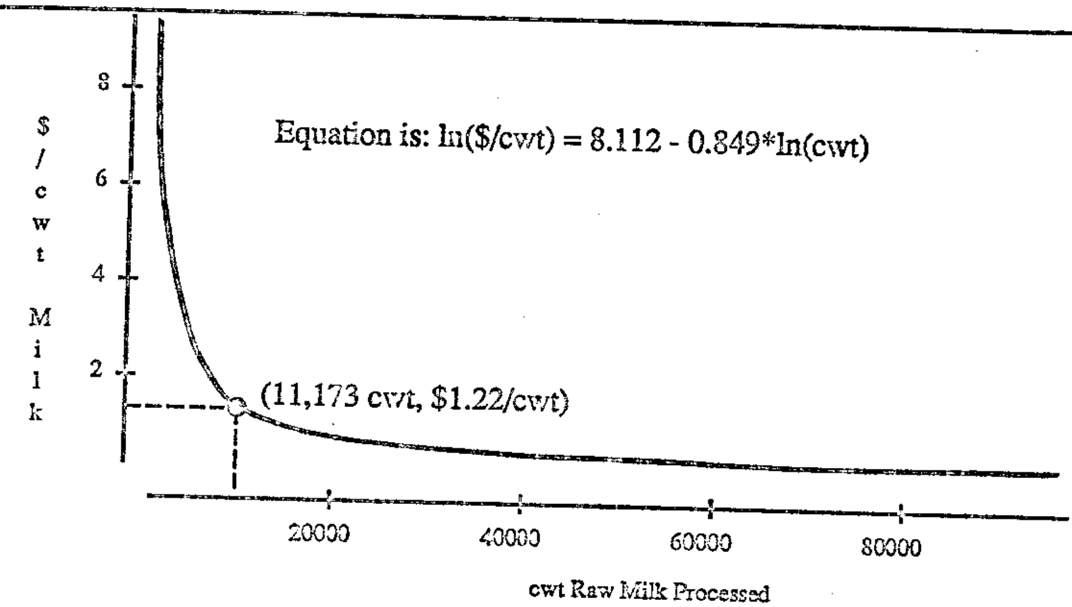

Figure 31. Long–Run Average Cost of Processing Raw Milk Into Butter and Powder

USDA's make–allowance of $1.22 per cwt is consistent with the manufacture of 11,173 cwt of milk into butter and NDM daily. At this level of production, average costs are well toward the flat portion of the curve and most of the cost economies have been achieved. If USDA's yield factors are altered to reflect the theoretical yields above, then their $1.22 per cwt corresponds to 11,229 cwt of daily processing. Had the make–allowance kept pace with inflation as measured by the Producer Price Index, the $1.46 per cwt would have supported a daily processing level of 9,043 cwt. This does not take into account the distinct possibility that higher cost facilities go out of business over time and

30 The 3.7% butterfat and 8.71% SNF are the weighted average component levels for the Upper Midwest in 1985 according to USDA staff paper 86–01 entitled "Upper Midwest Marketing Area—Analysis of Component Levels in Individual Herd Milk at the Farm Level, 1984 and 1985".

that the ongoing adoption of modern or new processing technologies can reduce inflation adjusted (real) processing costs.

The ten plants surveyed in this study processed a median milk equivalent of about 11,000 cwt per day. Looking at USDA's data on national production and numbers of plants, suggests a different picture. The 1987 data imply that the average plant producing butter or nonfat dry milk handled 4,000 to 5000 cwt of milk per day (assuming 365 days per year). At that level of throughput even the inflation adjusted make allowance is inadequate for the average plant. Given the way the national data are collected, it is quite possible that there are relatively large numbers of plants (many of which may be multi-purpose) which report small amounts of butter and/or NDM production, bringing the national plant average down. Further study of the distribution of production by plant size is needed before one could make definitive statements about the adequacy of the make–allowance. The authors opine that USDA's current make–allowance is appropriate for the contemporary processing environment of representative, modern plants.

Appendix A

The Survey Questions

1) Do you own, or are you associated with a small seasonal balancing plant which operates only during a peak season? yes/no.

2) Did the plant have any significant interruptions in the operation or changes in equipment and capacity of the plant during the June '87–May '88 year? yes/no. If yes, explain...

3) List the equipment used and the capacities:

   a) Receiving /Shipping Bays for bulk trucks:
   How many______
   Total unload capacity in lbs/hr.______
   Clean–in–place? yes/no.

   b) Raw milk:
   Number of storage tanks_____
   Silo storage capacity (total gal.)_____
   Separator capacity_____
   Pasteurizer capacity_____
   Other (e.g. Vacreator, Clarifier)

   c) Cream: fresh tank capacity_____

   d) Cream: aging tank capacity_____

   e) Skim Milk: storage capacity_____

   f) Condensed Milk: storage capacity_____

   g) Buttermilk: storage capacity_____

   h) Other tanks:_____

   i) Butter:
   Churns: Type_____ Capacity_____
   Butter Silo: storage capacity_____
   Bulk Packing: manual/automatic
   Butter Printers: Package size_____ Capacity_____

   j) Evaporators: Type_____ Capacity_____

k) Laboratory Equipment:

Infrared milk tester	yes/no
Microwave oven	yes/no
analytical balance	yes/no
milko tester	yes/no
electronic somatic cell counter	yes/no
bacteriology testing	yes/no
other_____	

l) Dryers: describe capacities, type, number of stages, heating system, powder collection, bagging etc. _____

m) Describe the packaging and handling of other products such as skim milk, cream, condensed milk etc. sold from the plant. _____

n) What are the warehouse capacities. Be specific about refrigerated, frozen and dry product._____

4) Does the plant have its own water supply? yes/no.

5) Does the plant have its own waste handling unit? yes/no.
If Yes, then describe the type of waste and system. _____

6) Does the plant have a waste heat reclaim system? yes/no.

7) Describe the most recent <u>planned</u> investment made at the plant and the reason for it:

8) Describe the most recent major investment considered but not yet made at the plant:

9) What steps have been taken at the plant during the past three years to reduce the production costs? _____

10) What were the pounds of Butter, NDM, Buttermilk Powder produced during each of the 12 months?

11) The average number of hours in a normal full–time employee work week is_____hours/person/week (include hours of overtime if it is a regular practice).

12) Does the plant hire part–time labor? yes/no
If Yes, the average number of hours in a normal part–time employee work week__.

13) Describe the availability of part–time employee labor and a typical wage paid. _____

14) Report the average number of days per year that a full-time plant employee receives.

Vacation allowance	_____days
Paid holiday allowance	_____days
Sick pay allowance	_____days
Personal days	_____days

15) Does the plant pay any of the following benefits for a typical plant employee?
Life insurance yes/no
Medical expenses yes/no
Dental expenses yes/no
Pension (beyond Soc. Sec.) yes/no
Other_____

16) What is the annual value of the benefits package for a typical plant employee? ____

17) What were the payroll dollars and payroll hours in the various production centers for the twelve months of the survey. Indicate whether or not the labor is unionized.
—Receiving Room
—Warehouse & Shipping
—Pasteurization/Separator Room
—Condensery Room
—Drying Room
—Bagging Room
—Churning Room
—Package & Printing Room
—Laboratory
—Refrigeration, Maintenance and Boiler Room
—Plant Management/Supervision
—Clerical Staff & Support Personal
—Other_____

18) A "plant operating day" is one on which butter and/or powder is manufactured at the plant. A "plant receiving day" is one on which the plant receives skim, cream or whole milk. Report the frequency of these "days" and the hours per day spent (include clean–up time) for the twelve months of the survey.

19) What would you estimate is your maximum capacity in a 24 hour period to produce butter_____, NDM_____.

20) What was your biggest production day in the June '87–May '88 year? _____
How many pounds of butter_____, and NDM_____ were processed?

21) What percentage of the butter production is typically processed directly in the following forms:
—68 lb commercial
—1/4 lb prints
—1 lb prints
—continentals
—other_____

22) What were the costs of Packaging Containers, Lab Supplies and Cleaning Materials at the plant during the twelve months covered in the survey?

23) What was spent at the plant for Rent and Lease payments, and how much was taken as depreciation during the twelve months covered in the survey?

24) What were the costs of Repairs and Maintenance and how much was paid for outside laboratory testing (do not include testing of individual producers) during the twelve months covered in the survey?

25) What was the consumption and cost of electricity for each of the twelve months?

26) What was the consumption and cost of water/sewer for each of the twelve months?

27) What was the consumption and cost of fuel oil for each of the twelve months?

28) What was the consumption and cost of gas for each of the twelve months?

29) What was the consumption and cost of other fuel for each of the twelve months?

30) Approximately what is the total cost per year for required government certificates or license fees at the plant?

31) Approximately what is the total cost per year for required state and local taxes at the plant?

32) Approximately what is the total cost per year for all insurances at the plant?

33) Describe the type of coverages under question 32 above.

Appendix B

Calculations of Costs Per Pound and cwt

—Assumptions:

—cwt of raw milk yields 4.35 pounds of butter, 8.69 pounds of NDM and 0.44 pounds of buttermilk powder.

—it costs the same to produce a pound of buttermilk powder from buttermilk as it does to produce a pound of NDM from skim milk. Therefore cwt of raw milk yields 4.35 pounds of butter and 9.13 pounds of powder (8.69+0.44).

—Definitions:

AB = annual pounds of butter (production during the June '87–May '88 year)
AP = annual pounds of powder (production during the June '87–May '88 year) where powder refers to NDM and buttermilk powder.
VB = variable costs of producing a pound of butter.
VP = variable costs of producing a pound of powder.
FC = annual fixed costs (daily fixed cost multiplied by 365).
BR = the proportion of milk equivalent processed as butter[31].
PR = the proportion of milk equivalent processed as powder (equal to 1-BR).
CWT = the number of cwt raw milk processed at a plant during the twelve months of the survey[32].
BU = the average percent usage of butter processing capacity (see Figure 4)

$$\text{\$/lb of Butter} = \frac{(AB \times VB) + (FC \times BR)}{AB}$$

$$\text{\$/lb of Powder} = \frac{(AP \times VP) + (FC \times PR)}{AP}$$

$$\text{\$/cwt of Milk} = \left(\frac{FC}{CWT}\right) + (VB \times 4.35) + (VP \times 9.13)$$

$$\text{\$/lb of Butter at 100\% Capacity}^{33} = \frac{\left(\frac{AB}{BU} \times VB\right) + (FC \times BR)}{\left(\frac{AB}{BU}\right)}$$

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31 This value is used to determine how much of the fixed cost should be charged to butter. It is calculated by first determining the ME for a plant on a butterfat basis (MEb) and the ME on a solids–not–fat basis (MEs). BR is then equal to MEb divided by (MEb+MEs).

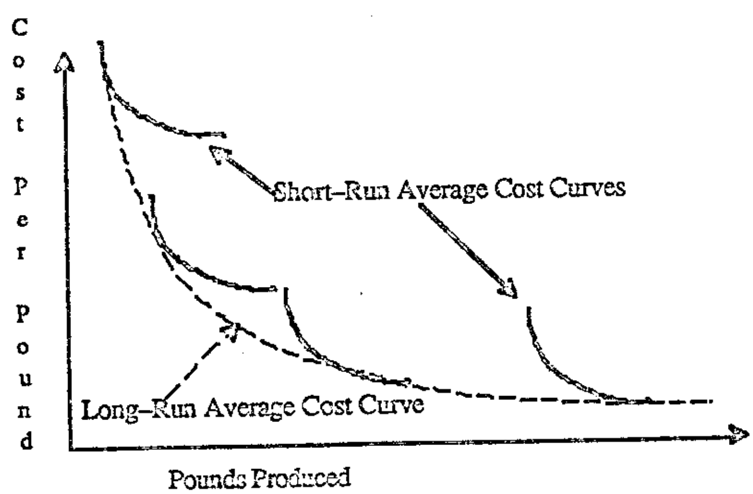
32 This was a judgement call for any particular plant. It was based on the average milk equivalent processed at the plant during the twelve months of the study. The result does not appear to be overly sensitive to an incorrect judgement within the bounds of MEb and MEs.

33 The $/lb of powder at 100% capacity can be calculated by making the appropriate substitutions.

Calculations of Long–Run Average Cost Curves

The long–run average cost curve conceptualized in most economic text books is a U–shaped curve with a distinct minimum point. The declining segment of the curve represents increasing returns to scale which is said to be caused by more efficient combinations of factors and the technological efficiencies of larger pieces of equipment. Theorists are less explicit about the cause of the rising segment of the average cost curve, often ascribing its cause to the increasing difficulty of managing larger operations thus surpassing the point of peak efficiency. In this study, we are only privy to information on performance at less than stated capacity. It is doubtful whether one would ever see the U–shaped curve when considering processing costs alone.

If transportation costs were considered to be part of the cost of processing, then it would be reasonable to observe a minimum cost and quite possibly an increasing segment. Larger capacity processors would need to reach farther into the countryside to assemble raw milk and at some point, a minimum cost would be reached. In this survey, short–run average cost curves and the long–run average cost curve derived from them are strictly declining as in the illustration below.



The long–run average cost curves that were estimated for butter and powder are:

ln($/Lb Butter) = 6.514 – 0.826*ln(Pounds Butter)
ln($/Lb Powder) = 7.528 – 0.860*ln(Pounds Powder)
ln($/cwt) = 8.112 – 0.849*ln(cwt)

where ln stands for the natural logarithm of the value in parenthesis. To evaluate the expected cost per pound of one of the products, the **ln()** must be factored out of the equation by taking the natural exponential function of both sides of the equation[34]. The transformed equations for long–run average processing costs then become:

$/Lb Butter = $e^{(6.514\ -\ 0.826*\ln(\text{Pounds Butter}))}$
$/Lb Powder = $e^{(7.528\ -\ 0.860*\ln(\text{Pounds Powder}))}$
$/cwt = $e^{(8.112\ -\ 0.849*\ln(\text{cwt}))}$

The long–run marginal costs of processing butter, NDM and cwt of raw milk can be determined by taking the mathematical derivative of the total cost function. The total cost function is simply the average cost multiplied by the pounds processed. The marginal cost equations calculated from the three equations above are:

MC/Lb Butter = 0.174*$e^{(6.514\ -\ 0.826*\ln(\text{Pounds Butter}))}$
MC/Lb Powder = 0.140*$e^{(7.528\ -\ 0.860*\ln(\text{Pounds Powder}))}$
MC/cwt = 0.151*$e^{(8.112\ -\ 0.849*\ln(\text{cwt}))}$

For example if we wanted to determine what the average processing cost per pound of butter would be when we processed 40,000 pounds per day we would proceed as follows:

$\ln(40{,}000) = 10.59;$

$0.862 \times 10.59 = 9.13;$

$6.514 - 9.13 = -2.62;$

$e^{(-2.62)} = 0.0728;$

Therefore, the average processing cost per pound when processing 40,000 pounds of butter would be $0.0728 or 7.28¢ per pound and the total cost of processing 40,000 pounds per day would be 40,000*0.0728 = $2,912 per day. Similar calculations can be performed for powder processing or cwt of raw milk.

[34] The two functions, ln and e^x, are found on most calculators.

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