NO. 541. APRIL 1971 AGRICULTURAL EXTENSION SERVICE, UNIVERSITY OF MINNESOTA

Minnesota AGRICULTURAL ECONOMIST

Milk Assembly and Processing Costs in the Butter-Dry Milk Industry

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Minnesota is the leading state in the production of butter and nonfat dry milk. In 1970 Minnesota dairy plants produced about 294 million pounds of butter and an estimated 482 million pounds of nonfat dry milk. About 70 percent of the milk production in the state is processed into these two products.

The optimum organization and operation of the butter-dry milk (or butter-powder) industry is an important concern of dairy plant managers and dairy farmers in the state. Selection of an appropriate type of processing plant, equipment, and capacity is important in achieving greater efficiency and lower processing and marketing costs.

The economic effect of recent technological changes in the dairy industry is being studied by the Department. This article summarizes some of the findings.

ECONOMIES TO SIZE

An important general finding in this research in the dairy processing industry is that there are significant economies to size in plant operation. Large processing plants, properly managed, can achieve lower per unit operating costs than smaller plants. We found this to be the case when we analyzed specialized butter plants, specialized milk drying plants, or combined butter-powder plants. It holds true for other types of dairy plants including cheese and milk bottling plants. Larger plants and larger dairy equipment such as separators, churns, evaporators, and driers cost less per unit of capacity and they require little, if any, more labor to operate.

The availability of significant economies to size in dairy processing is a major factor accounting for the continuing trend toward fewer and much larger butter, dry milk, and cheese plants in Minnesota. These trends and the changing organization of the state's dairy industry are discussed on pages 3 and 4.

Technological changes, especially in the form of improved equipment requiring larger operating volume, have been numerous in the butter-powder industry. The last few years have brought such innovations as: (1) high capacity and almost totally automated evaporators and driers; (2) automated powder packaging equipment; (3) large self-cleaning cream separators; (4) high capacity churns, both batch and continuous flow models; (5) high speed soft butter printers; and (6) totally engineered plants where all processes are linked in a continuous flow of product and where the labor requirement is reduced to a few supervisors. As these technologies are more fully adopted by the industry, economies of size will be even more pronounced and the trend toward fewer and larger processing units will continue.

MILK ASSEMBLY COSTS

The trend toward fewer and larger dairy plants in the state is not a result of economies to size in processing alone. Important technological changes also have occurred in the farm assembly of milk which have facilitated gathering of larger volumes of milk in a given plant. The major change has been the gradual shift from farm milk storage and hauling in 10-gallon cans to bulk tanks and bulk tank truck transportation. Bulk assembly has enabled dairy plants to expand their supply areas for at least two reasons: (1) bulk tank trucks can carry larger loads at lower unit costs, and, (2) bulk trucks can pick up milk from longer distances without fear of quality deterioration.

The least cost size of butter-powder plants depends on the nature of plant processing costs and the nature of milk assembly costs. Economies to size in processing can be translated into savings for the milk plant and the producer only if the cost of assembling a larger volume of milk does not offset the cost savings obtained in processing. This is illustrated in figure 1.

It may be noted that the longrun average *processing cost* curve slopes down and to the right, illustrating economies to size. The longrun average milk *assembly cost* slopes upward and to the right. This cost increase results as plants need to haul milk from longer distances to obtain additional quantities. The *combined* processing and assembly cost curve is the total of the individual assembly and processing costs. It may be observed that the least cost point (A) on the combined curve is achieved at a smaller volume of operation than when processing costs alone are considered (point B).

The foregoing model summarizes the basic economic principles important in determining the best size (volume of milk) for a butter-powder plant. In this study it was used to evaluate the cost advantages of (1) two alternative butter-powder *processing systems*, and (2) two alternative *milk assembly systems*.

The processing systems analyzed in this study were: (System I) a butter-powder system of the type now widely used in the state; and (System II) a new system of specialized milk drying plants operating in conjunction with and supplying cream to a lesser number of very large specialized (super) butter manufacturing plants.

The butter plant is equipped with large continuous churns, coordinated with a high speed soft butter printer and other related equipment. The soft butter printer prepares one-pound and quarter-pound packages of butter. Under the older systems, bulk butter was assembled in 68-pound cartons at central packaging plants for printing. Under both systems in this study, final consumer packaging will be done at the large country butter or butter-powder plants.

A few specialized butter processing plants (or departments) of the type described under the second system above have recently started to operate in the state. So, this study essentially compares a newly developing butter-powder processing system with the conventional system widely used in recent years.

The two alternate milk assembly systems included in the analysis were: (1) direct farm-to-plant bulk milk assembly, and (2) a combination of direct assembly and indirect assembly using milk receiving stations. The receiving stations would serve the outlying producers.

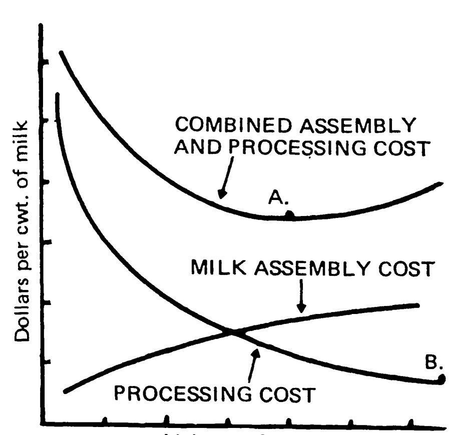

Figure 1. Hypothetical average cost curves for assembly and processing milk.

It should be noted in this analysis that all milk is assembled and handled on a bulk basis. This results in somewhat lower per unit assembly and milk receiving costs. This assumption is realistic since even now about 70 percent of all milk received at Minnesota dairy plants is received in bulk.

METHOD OF ESTIMATING COSTS

The processing and assembly cost functions were all developed by the economic-engineering method, (sometimes called the synthetic or building block method). The processing and assembly systems were divided into their various functional parts and overall costs were built up from the estimated costs of each of these parts. For example, processing was first divided into various size plants, each plant was divided into processing stages, such as receiving, separating-pasteurizing, etc., and finally the stages were divided into factor cost categories such as labor, fuel, electricity, etc.

The same type of building block approach was used with the milk assembly systems. At each stage the appropriate input-output relationships were estimated, based on engineering recommendations and/or estimates obtained in actual milk assembly operations. These input-output relationships were converted into cost-volume relationships by applying the appropriate factor prices.

ESTIMATING PROCESSING COSTS

The butter churning and printing operation and the skim milk drying operation are distinct operations, even in butter-powder plants where both operations are performed in the same plant. In modern, automated plants the flow of product (whole milk equivalent) is coordinated to the capacity of the drying unit. The separators and pasteurizers are adjusted to give a continuous flow of skim milk to the evaporator-drier complex.

The butter department is usually not, and need not be, coordinated with the dryer. The cream must be stored for tempering, so there is no technical or economic reason for synchronizing the flow of the butter department with the skim milk drying department.

Given these facts, it was necessary first to build, in a cost sense, a series of different sized specialized milk drying plants. Secondly and again in a cost sense, a series of butter departments of different size that could be combined with the specialized drying plant in various sizes were set up. If the same whole milk equivalents are processed in both the skim milk plant and the butter department the resulting cost curve represents the costs of a traditional butter-powder plant system. If the butter plant processes larger volumes than the drying plant the resulting cost curve represents the combination of specialized drying plants and super butter plants described earlier in the article.

The estimated longrun average costs for specialized drying plants, specialized butter plants (or departments), and butter-powder plants are shown in table 1. The average cost for drying plants declines from $.494 per hundred pounds of milk at a volume of 50 million pounds annually to $.179 per hundred at a volume of 623 million pounds. The average cost for the butter plants ran from $.103 per hundred pounds of milk to $.032 per hundred pounds, over the same volume range. The average cost of the butter-powder plants, the simple addition of the previous two functions, runs from $.597 per hundred pounds of milk to $.211 per hundred, over the same volume range.

It can also be seen that the major cost economies occur in the smaller volume ranges. An average cost saving of $.294 per hundred pounds of milk occurs as volume is increased from 50 million pounds to 350 million pounds annually in the drying plants. However, in the volume range 350 million pounds to 623 million pounds annually only a $.021 per hundred pound saving occurs. The same basic pattern holds for the butter departments in these plants. In the volume range 50 million pounds of milk annually to 350 million pounds, there is an average cost savings of $.066 per hundred pounds of milk. On the other hand, in the range from 350 to 623 million pounds of milk annually there is a cost savings of only $.005 per cwt. of milk.

FARM-TO-PLANT ASSEMBLY COSTS

Farm-to-plant milk assembly costs were estimated on the assumption that the processing plant would be located at the center of a diamond shaped milk assembly area. A diamond shaped assembly area tipped 45 degrees to a square road grid gives equal road distances to all road points on the periphery of the area. The area was assumed to have a constant and uniform milk production density.

Because milk production density varies from area to area in the state, assembly costs were estimated for four different densities. The densities selected were 260,000; 130,000; 65,000; and 32,500 pounds of annual milk production per square mile. It was further assumed that the average annual production per farm was 260,000 pounds of milk, the approximate production per dairy farm in the state. This translates production densities into a farm for each 1, 2, 3, and 4 square miles, respectively.

In estimating milk assembly costs or a function of volume, the foregoing assumptions allowed for the estimation of average milk route costs and for a relationship between volume of the milk assembled and average distance between plant and assembly routes. As the volume of milk needed in a processing plant increases the average distance to the routes at the periphery of the supply area increases, which in turn results in an average cost of assembly that increases.

The basic data for estimating the assembly cost functions were divided into two parts, truck costs and labor costs.

Table 1—Estimated long run average costs for specialized drying plants, specialized butter plants, and butter-powder plants of varying size

Annual whole milk volume	Specialized drying plants	Specialized butter plants	Combined butter-powder plants
million lbs.	.....dollars per cwt. of milk.....		
50	.494	.103	.597
100	.318	.064	.382
150	.264	.052	.316
200	.236	.045	.281
250	.219	.041	.260
300	.208	.039	.247
350	.200	.037	.237
400	.194	.036	.230
450	.189	.034	.223
550	.183	.033	.216
623	.179	.032	.211

The costs for the two parts were estimated from data obtained in a field survey which included a number of detailed time studies of each operation involved in assembling bulk milk. From the data an "average" farm milk route was estimated. The costs associated with the farm-to-farm milk pick-up routes were treated as an average fixed cost. Only the cost of going to and coming from the routes were treated as a variable cost. As volume increased, more routes were required which caused the average distance to the routes to increase which, in turn, meant the average cost of assembling milk increased with volume. See table 2.

INDIRECT MILK ASSEMBLY COSTS

Large semi-trailer tank trucks can haul milk at a lower average cost than small straight trucks used to assemble milk from farms. If milk routes are located far enough away from the processing plant it may pay to first assemble the milk in local milk receiving stations and then transfer it to the processing plant in large semi-tankers. The indirect assembly cost functions were estimated by the economic engineering method similarly to the method used in estimating other cost functions in this study.

It was assumed that a milk processing plant would expand its direct farm-to-plant assembly of milk so long as the per unit cost of assembling milk from the outer edge of the supply area was less

Table 2—Average cost of farm-to-plant (direct) assembly of milk for four densities of production and selected volumes

Annual milk volume	Milk production density (pounds per sq. mile)			
	32,500	65,000	130,000	260,000
million lbs.	.... dollars per cwt.			
50	.171	.144	.127	.114
100	.196	.163	.142	.124
150	.212	.175	.151	.130
200	.225	.184	.157	.134
250	.235	.192	.163	.138
300	.244	.198	.168	.141
350	.252	.203	.171	.143
400	.259	.208	.175	.145
450	.265	.213	.178	.147
550	.276	.220	.184	.151
650	.285	.227	.188	.154

Table 3—Long run average costs of assembling and processing milk for two systems of butter and dry milk production

Annual whole milk volume	Milk production density (pounds per sq. mile) 32,500		65,000		130,000		260,000	
	I[1]	II[1]	I	II	I	II	I	II
million lbs.	dollars per cwt.							
50	.76	.70	.73	.67	.72	.65	.71	.64
100	.58	.56	.55	.52	.53	.50	.51	.48
150	.53	.52	.49	.48	.47	.45	.46	.43
200	.51	.51	.47	.46	.44	.43	.42	.41
250	.50	.50	.46	.45	.42	.42	.40	.40
300	.49	.50	.45	.45	.41	.42	.39	.39
350	.49	.50	.44	.45	.41	.41	.38	.38
400	.49	.50	.44	.45	.41	.41	.38	.38
450	.49	.50	.44	.45	.40	.41	.37	.38
550	.49	.51	.44	.45	.40	.41	.37	.37
623	.49	.51	.44	.45	.40	.41	.36	.37

[1] Numerals I and II refer to Systems I and II.

than the unit cost of adding a milk receiving station at the outer edge. Comparison of the unit costs of a system of indirect assembly of milk through receiving stations with a system of direct farm-to-plant assembly indicated that the former method was always the higher cost alternative up to 623 million pounds of milk annually for a given dairy plant. At the maximum volume of 623 million pounds considered in this study the per hundred pound cost of assembling milk from the outer edge of the supply area using receiving stations (indirect assembly) was \$.225, \$.260, \$.303, and \$.365 for the four milk production densities considered. In contrast the direct assembly costs under the same conditions were \$.175, \$.214, \$.262, and \$.328 per hundred, respectively.

COMPARISON OF PROCESSING AND ASSEMBLY SYSTEMS

Once the least cost milk assembly system was determined, it was possible to combine it with the processing cost functions assuming two alternative processing systems. For System I, the traditional butter-powder plant system, this was a simple procedure. Average processing costs for the butter-powder plants were added to the direct assembly costs for each of the four milk production densities. The average costs of milk processing and assembly for butter-powder plants for four milk densities and selected annual milk volumes are shown in table 3.

Estimation of the average combined cost of assembling and processing milk under System II in which specialized milk drying plants operate in conjunction with and supply cream to a lesser number of very large specialized (super) butter manufacturing plants involved combining costs in several production steps. First, the same direct milk assembly cost functions, assuming the same four densities of milk as used in System I, were determined. To these were added the cost of receiving and processing milk in a specialized drying plant. To this was added the cost of shipping cream by semi-trailer tank trucks to the specialized (super) butter plants. The final step was that of adding processing costs in the large specialized butter plants. The combined cost was then estimated for selected annual volumes of milk receipts as shown in table 3.

Comparison of the combined costs for the two alternative butter-powder processing systems reveals that the lowest costs for all four densities of milk are achieved at the higher annual milk volumes with the traditional butter-powder plant system—System I. It appears that the savings achieved in drying milk in an optimum sized drying plant and a specialized butter plant were not large enough to offset the cost of hauling cream between the plants.

However, the difference in the combined costs of the two systems in the larger volume range, where least costs are achieved, is small. For example, average cost at the least cost volume of 500 million pounds a year for the butter-powder plant (System I) at a milk density of 65,000 pounds per square mile is \$.436 per cwt. The average cost of the specialized drying plant and specialized butter plant system (System II) is \$.447 per cwt. or just a little over one cent per cwt. higher.

Study of table 3 shows that the volume of milk processed in a given plant is much more important in reducing cost than the processing system used. For example, the average cost for a butter-powder plant system (System I) at a milk density of 65,000 pounds drops from \$.73 per cwt. at a volume of 50 million pounds a year to \$.44 at a volume of 350 million pounds, or a saving of about \$.30 a cwt. Yet, at that volume there is only about a one cent difference per cwt. in the two systems.

In this analysis of butter-powder processing systems in which the newest technologies such as continuous churns, high speed soft butter printing, more automation, and other improvements were used the lowest costs per unit were achieved at much larger volumes of milk handled than under older technologies used in recent years. This has important implications in the changing organization of the industry toward fewer and larger plants.

It is of interest that over the years with the gradual introduction of new technologies and production at larger volumes per plant per unit costs of manufacturing butter and powder have slowly declined or held about even in given plants. This has occurred even though cost rates for labor, fuel, supplies, and other inputs have increased sharply. Productivity in the state's butter-powder industry has shown substantial improvement with significant benefit to producers.

CONCLUSIONS

This study has shown that there are significant economies to size in butter-powder processing. New technologies being introduced into the industry are resulting in even more of these economies and the need for even fewer and larger plants to achieve them. This has important implications for the way the dairy processing industry is reorganized in this area in the years just ahead. The analysis shows that changing processing systems from the traditional butter-powder plants to specialized drying and large butter plants operating in coordination is not likely to bring large overall savings when all milk assembly, interplant hauling, and processing costs are considered. Larger volume combined butter-powder plants using the newer technologies when properly managed appear to have a least cost advantage. Direct farm-to-plant milk assembly in bulk has cost advantages over an assembly system involving use of milk receiving stations in the plant size range considered in this study.

Marketing Changes in the Minnesota Dairy Industry

E. Fred Koller

Minnesota's dairy industry has been undergoing major market changes in recent years. One of the most significant changes is an organizational one toward many fewer but larger processing plants. These changes result from new developments in processing technology, changes in milk assembly, merger activities, and other causes.

For instance, the state's creamery industry has been almost completely restructured with only 123 plants remaining in butter production at present compared with 865 in 1940 (see table 1). By 1975 there may be fewer than 60 butter plants in the state. Annual butter output per plant is averaging a little over 2 million pounds at present compared with only 350,000 pounds in 1940. The lead article discusses the economic considerations behind this change.

Most of the creameries which discontinued butter manufacture since 1940 have ceased all dairy operations. About 224 of the plants that have discontinued

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Roland H. Abraham, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55101.

Minnesota AGRICULTURAL ECONOMIST

Prepared by the Agricultural Extension Service and the Department of Agricultural and Applied Economics.

Views expressed herein are those of the authors, but not necessarily those of the sponsoring institutions.

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Table 1—Number and type of dairy plants in Minnesota, 1940-1971

Year	Butter	Milk receiving	Dry milk (human use)	Cheese	Fluid milk
	number of plants				
1940	865	...	11	64	236
1950	669	57[1]	78	54	266
1960	429	110	72	26	227
1965	324	152	71	20	135
1970	158	219	56	16	76
1971	123	224	49	17	63

[1] 1955 data.

butter operations are serving as milk receiving stations for larger butter-powder or cheese plants (table 1). Operation of the creamery as a receiving station often is temporary since this method of milk assembly usually involves relatively high costs per cwt. of milk.

PRODUCT MIX IS CHANGING

The mix of products processed in the state's dairy plants is changing. Minnesota is still the nation's leading butter producer, but since World War II it also became the leader among the states in dry milk output. In 1964 the state's dry milk production of all types reached 670 million pounds, about one third of the nation's total. Here, too, the number of plants engaged in powder production has declined from about 78 in 1950 to 49 in 1971. Major changes occurred in the size of these plants with output of dry milk per plant averaging about 2 million pounds a year in 1950 and about 10 million in 1970. Several plants now process over 20 million pounds a year. This has been a major factor in greatly improving efficiency and reducing per unit costs.

Further indication of the changing dairy product mix of Minnesota plants is the rapid increase in cheese production. Output more than doubled from 1965 to 1970 (table 2). Output in 1971 is likely to be considerably larger as new cheese plants and expanded capacity come into production. Most of the state's cheese plants are large, modernly equipped, and operate very efficiently. The average annual output per plant in 1970 was about 10 million pounds of cheese compared with an average of 1,700,000 pounds in 507 Wisconsin plants (1969 data). The expansion of cheese production in the state is a desirable change in view of the expanding demand for cheese, relatively favorable prices, and resulting improved returns to processors and milk producers.

FLUID MILK INDUSTRY CHANGES

The state's fluid milk industry (packaged milk, cream, etc.), like the manufactured dairy products sector, is undergoing major organizational changes. Plant numbers declined from 236 in 1940 to only 63 in 1971. Many of the remaining plants are very large, serving large market areas in the state and in some cases adjacent state markets. There are significant economies to size in the larger fluid plant operations. This fact may lead to further concentration in the number of fluid plants in the 1970's.

Another especially significant market change at this time is rapidly increasing volume of Grade A milk (fluid eligible) in Minnesota. In 1970 about 2.5 billion pounds of milk, or 25 percent of the state's output, was of Grade A quality. This compares with about 1.5 billion pounds of Grade A in 1962, or 14 percent. An estimated 1.5 billion pounds of the 1970 Grade A production was sold in packaged form, some was sold out-of-state in bulk form, and the remainder was manufactured into butter, powder, ice cream, and other products.

Grade A milk prices received by farmers average approximately 50 cents per cwt. over manufacturing grade milk prices, so dairy farm returns are increasing gradually as the shift to Grade A is made. The shift to Grade A milk is expected to continue and there is some expectation that by 1980 nearly all milk in the state may be of this quality. This would be a major benefit to dairy marketing in the state.

LARGE SCALE MERGERS IN 1970

In 1969 and 1970 dairy market organization in the state was revamped in a major way as more than 100 of the state's local and smaller regional dairy cooperatives were merged into three very large regional cooperatives serving this

Table 2—Production of milk and selected manufactured dairy products in Minnesota, 1940-1970

Year	Creamery butter	Cheese[1]	Nonfat dry milk (human use)	Milk production
	million lbs.			
1940	311.2	16.3	18.5	8,405
1950	251.4	52.3	160.4	8,067
1955	281.2	73.3	303.4	8,833
1960	324.6	72.6	500.8	10,272
1965	357.2	74.7	594.9	10,221
1969	313.5	130.7	512.1	9,727
1970[2]	294.1	156.8	482.0	9,772

[1] Hard cheeses only, excluding cottage cheese, etc.
[2] Preliminary

area, namely, Associated Milk Producers, Inc., Land O'Lakes, Inc., and Mid-America Dairymen, Inc.

As these many mergers were effected many of the local plants were closed and some shifted to milk receiving station status as milk processing was concentrated into fewer, larger plants. These organizational changes may be expected to continue in the 1970's.

It is expected that the merged and greatly revised dairy market organization in the state will bring milk producers the advantages of further milk handling economies, improved market outlets, and increased market power in the sale of their products. Concentration of milk processing into fewer and larger plants should bring economies to size (as described in our lead article). Further reduction in the overlapping of farm milk assembly routes should be effected and bring some savings. The merged organizations have varied processing facilities and market outlets which should allow them to shift more milk from lower value to higher value uses as price relationships change. The large regional cooperatives are in a position to gradually open up Grade A opportunities for their patrons. An important source of improved returns for milk results from their superior bargaining position in some fluid markets, making it possible to charge milk dealers higher than federal order prices for milk (over-order payments). Some problems may occur in the programs of these organizations, but in general, changed market structure should bring significant net gains to producers.

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Cooperative Agricultural Extension Work
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