ECONOMIES OF SIZE IN PROCESSING MANUFACTURED DAIRY PRODUCTS AND IMPLICATIONS FOR THE SOUTHERN DAIRY INDUSTRY*

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INTRODUCTION

Fluid milk marketing is characterized by daily and seasonally fluctuating raw milk production, variable fluid processing schedules and seasonally fluctuating consumption patterns. These conditions, plus the perishable nature of the product and a relatively low short-run elasticity of demand for fluid milk, are generally considered to be factors requiring volume of Grade A milk available to an area at any given time to exceed the amount actually consumed in the fluid form—if the market is to be characterized by a reasonable degree of price stability. This excess is often referred to as the minimum or "necessary" reserve. The volume of excess milk available may be greater than this minimum, however, as a result of other factors such as classified pricing or producer prices above equilibrium levels.

Milk produced in excess of fluid consumption is processed into a variety of dairy products. Such products as cottage cheese, yogurt and ice cream ("soft" products) are closely associated with the fluid milk processing function. Other major products—butter, powder and cheddar cheese ("hard" products)—constitute a separate segment and are usually identified with the national manufacturing milk industry. Although the hard products sector may be regarded as a residual claimant on Grade A milk under prevailing institutional arrangements, most areas normally carry excess milk for this use. As a general rule, therefore, under the above conditions, a region can be expected to maintain facilities for processing raw milk produced but not consumed in either the fluid form or as "soft products." It is surmised that the number, size and location of such manufacturing facilities is quite critical for minimizing costs of the total marketing function in a given region. The exit of many hard product manufacturing plants in the South in recent years suggests the timeliness of a forward-looking analysis of this number/location problem.

Several studies have been conducted on per-unit costs of processing, packaging and distributing milk for fluid consumption. Work by Babb, Cobia and Babb, Devino, *et al.*, and Webster, *et al.*, are examples. These studies tend to show substantial economies in fluid processing and have provided some evidence of the economic forces which partially explain both reduction in numbers and growth in the average size of such facilities. However, few studies are available on the comparative costs of processing raw milk into either cheddar cheese, butter or powder. A recent study by Nolte and Koller specified, for 1972 conditions, costs of milk assembly and raw product processing in the Minnesota butter/powder industry. Their results indicated substantial economies at plant sizes processing up to about 29 million pounds of milk per month. Specification of these cost relationships becomes relatively more important in a period when the dairy industry is undergoing major adjustments and restructuring. It may well be that the existence of substantial processing economies is at least partially responsible for the changes taking place.

The purpose of this paper is to present results of a recent attempt to specify the volume-cost relationship for processing raw milk into either cheddar cheese or butter/powder. Detailed data for the study

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are contained in an in-house report prepared for Dairymen, Inc. (Pardue and Wright). In this paper we summarize our work and discuss implications of our findings for dairy industry policy, indicating the important role economic forces appear to be playing in ultimately reducing the number and increasing the size of such facilities.-The paper itself is divided into four sections. Following this introduction is a short discussion of data development and the procedure used in the study. In Section 3, results are presented and discussed. Finally, in Section 4, implications of our findings are presented.

PROCEDURES

An engineering cost approach was used to develop hypothetical total and average processing cost curves for the manufacture of raw fluid milk into either cheddar cheese or butter and powdered milk. Processing milk into butter and powder was assumed to take place in the same plant. Estimates developed were for plant costs only. When costs were logically assumed to be a function of location, prevailing costs in the Louisville, Kentucky area were used as the base.

On the basis of a pragmatic assessment of equipment capacities and feasible ranges of operation, equipment and building space requirements were identified for three different sizes of plants for each of the two types of operations. For each size, in turn, operating input requirements were specified at three levels of output per week (minimum, average and maximum production). These output levels, designated in terms of raw milk processed, were established as a function of the number of eight-hour shifts per day and operating days per week. This procedure provided total cost estimates for nine different production levels, for both the cheddar cheese and butter/powder plant operations.

Table 1 summarizes sizes and operating levels considered in this study. Maximum capacity for the largest cheese plant considered was almost six million pounds of raw milk per week, or 25.58 million pounds per month. Plant capacity for butter/powder operations was established at 7.7 million pounds per week or 33 million pounds per month. Given this approach, it was possible to obtain a large degree of overlap in volumes determined for the three plant sizes. Furthermore, since plants were synthesized for both cheese and butter/powder operations processing roughly identical volumes at minimum levels, a basis was established for developing a number of cost estimates at overlapping volumes for the two processes.

The basic cost structure developed for each of the different plant types and sizes is shown in Table 2. Building costs are based on a 20-year depreciation, an 8.5 percent declining balance average annual interest charge and a one percent annual repair and maintenance charge. In arriving at equipment

TABLE 1. PLANT SIZE AND OPERATIONAL SPECIFICATIONS FOR DETERMINING WEEKLY PROCESSING VOLUMES FOR CHEESE AND BUTTER/POWDER OPERATIONS

Cheese Operations: Plant Size & Operational Criteria: Number of Vats [a]	Hours /Day	Days /Week	Weekly Processing Capability (000 lbs.) [c]	Butter/Powder Operations: Plant Size & Operational Criteria: Evaporator Capacity [b]	Hours /Day	Days /Week	Weekly Processing Capability (000 lbs.) [c]
Small Size							
3	8	5	750	15	16	4	792
3	16	6	1,500	15	24	5	1,650
3	24	7	2,975	15	24	7	2,310
Medium Size							
5	8	5	1,000	32	16	4	1,680
5	16	6	1,800	32	24	5	3,500
5	24	7	3,500	32	24	7	4,900
Large Size							
6	8	5	1,500	50	16	4	2,640
6	16	6	3,000	50	24	5	5,500
6	24	7	5,950	50	24	7	7,700

[a]Cheese vats of 25,000 pound capacity.

[b]Rated capacity of evaporator in thousand pounds of skim milk per hour.

[c]Volume of raw milk processed.

TABLE 2. COSTS ELEMENTS ESTABLISHED FOR DEVELOPING OPERATING COSTS FOR CHEESE AND BUTTER/POWDER PLANTS OF THREE SIZES EACH OPERATING AT ITS AVERAGE PRODUCTION LEVEL, 1975

Type of Costs	Cheese Plant Size: Small	Medium	Large	Butter/Powder Plant Size: Small	Medium	Large
Dollars						
Building/yr. [a]	66,486	73,454	89,857	101,139	127,873	167,533
Equipment/yr. [a]	252,620	277,682	339,182	298,502	351,764	441,770
Labor/mo. [b]	30,000	30,000	34,447	19,907	23,054	26,935
Cents [c]						
Packaging/cwt.	8.3	8.3	8.3	7.8	7.8	7.8
Utilities/cwt. [d]	10.0	8.8	7.6	24.9	24.0	23.1
Ingredients/cwt.	10.1	10.1	10.1	.3	.3	.3
Supplies/cwt. [d]	8.8	8.7	7.7	7.1	6.3	5.5

[a]Building and equipment costs for any given size of plant were assumed to remain the same whether operating at minimum, average or maximum production.

[b]Labor requirements were determined to vary with both plant size and level of operation. However, in the case of small and medium size cheese plants, the effect of larger volume on labor requirements was, by coincidence, exactly offset by the effect of greater investment in equipment.

[c]Cents per cwt. of milk processed.

[d]The costs per cwt. of raw milk for utilities and supplies were assumed to vary slightly with both size of plant and level of production.

costs, the same interest, repair and maintenance bases were used but the depreciation period was reduced to 12 years. Labor costs were estimated by assuming 1975 management salaries and union wage contracts for the Louisville, Kentucky area. Other cost estimates were derived from actual 1975 cost data for several operating plants.

Costs shown in Table 2 are for each different plant size operating at average production level. Similar costs were developed for each size and type plant operating at both minimum and maximum capacity levels. A brief explanation of how costs at these levels were determined is given in footnotes to Table 2.

Given these estimates of cost components for operating each synthesized plant, and with weekly plant volumes converted to a monthly basis using 4.3 weeks per month, it was possible to calculate a monthly total processing cost for each plant type and each level of operation. These cost data are summarized in Table 3. For the cheese plant operations, average processing costs per unit ranged from \$1.75 per cwt., when operating the smallest size plant at minimum volume, to \$0.69 per cwt. when operating the large size plant at its maximum capacity. Per-unit costs in the butter/powder plants ranged from \$1.83 per cwt. to a low of \$0.62 per cwt.

TABLE 3. ESTIMATED TOTAL MONTHLY PLANT OPERATING COSTS AND UNIT COSTS PER HUNDREDWEIGHT OF MILK PROCESSED FOR CHEESE AND BUTTER/POWDER OPERATIONS OF DIFFERENT SIZE AND OPERATING LEVELS

Operating Level	Cheese Operations			Butter/Powder Operations		
	Volume Monthly (1,000 lbs.)[a]	Total Costs Monthly	Cost /Cwt.	Volume Monthly (1,000 lbs.)[a]	Total Costs Monthly	Cost /Cwt.
			Small Size			
Minimum	3,225	\$ 56,573	\$ 1.75	3,406	\$ 62,347	\$ 1.83
Average	6,450	80,589	1.25	7,095	81,660	1.15
Maximum	12,793	121,002	.95	9,933	99,520	1.00
			Medium Size			
Minimum	4,300	\$ 68,897	\$ 1.60	7,224	\$ 84,679	\$ 1.17
Average	7,740	87,047	1.13	15,050	120,817	.80
Maximum	15,050	130,390	.87	21,070	152,965	.73
			Large Size			
Minimum	6,450	\$ 78,005	1.21	11,352	110,841	\$ .97
Average	12,900	113,673	.88	23,650	164,506	.69
Maximum	25,585	175,591	.69	33,110	204,375	.62

[a]Monthly volume is the weekly processing capability given in Table 1 x 4.3, the average number of weeks per month.

RESULTS

Given total operating costs at nine discrete volumes for each plant type, it was possible to generate a scatter diagram representing the relationship between volume and total costs for each plant type. Employing the traditional assumption that profit maximizing firms tend to choose plant size and level of operation capable of processing a specified volume at lowest per-unit costs, only those points lying on the interior of the scatter diagram were used to develop continuous cost/volume relationships. That is, those points from the scatter diagram which would lie on the theoretical long-run total cost curve provided "observations" needed to estimate, via ordinary least squares regression, coefficients of the two total cost functions.

Parameter estimates for the cost functions were obtained using the linear, double logarithmic and semi logarithmic functional forms. While the data points were slightly curvilinear, neither log form provided estimates which improved the explanatory power substantially when compared to a simple linear function. In fact, the standard error of the estimate was smallest for the linear form.

The estimated total linear cost functions are:[1]

$$TCC = \$42{,}466 + \$0.52922\,(q) \underset{(.00807)}{} \qquad \bar{R}^2 = .997 \quad (1)$$

(.00807)

$$TCP = \$49{,}730 + \$0.47882\,(q) \qquad \bar{R}^2 = .998 \quad (2)$$

(.00667)

where

TCC = total cheese processing costs (\$/month)

TCP = total butter/powder processing costs (\$/month)

q = quantity of raw milk processed (cwt./month)

Coefficient standard errors in parentheses.

While these cost functions approximate the envelope points quite well, they are not expected to yield valid cost estimates for volumes outside the ranges used in developing the estimates; that is, below 3.5 million pounds of raw milk per month or above

[1]For ease in comparing these results with other published work, the estimated double-log average cost functions are:

$$\text{Cheese: } AC = 5.3134Q^{-.4600} \qquad \bar{R}^2 = .995$$

$$\text{Butter/powder: } AC = 5.2999Q^{-.4587} \qquad \bar{R}^2 = .984$$

25.5 million pounds for cheese operations, or 33 million pounds for butter/powder operations. Furthermore, since these estimated total cost functions are best thought of in terms of long run planning relationships, they will not duplicate exactly the total costs for a specific plant and volume initially obtained from the industrial engineering procedure specified earlier.

To illustrate potential economies of size available in cheese and butter/powder processing, the estimated total processing costs obtained above were converted to average processing costs per unit. These average cost curves are, of course, rectangular hyperbolas. Their general shape is shown in Figure 1. Substantial reduction in per-unit costs with increases in monthly volume processed are clearly evident, particularly in the lower volume range. An increase in volume processed from 3.5 million to 10 million pounds per month is estimated to reduce costs $0.80 per cwt. for milk in cheese operations and $0.90 in butter/powder. Additional reductions of $0.25 and $0.35, respectively, are accomplished in the largest plants considered here—when they operate at maximum production levels. These volume-cost relationships indicate that at least 10 million pounds per month should be available if a processing facility is to be reasonably efficient in terms of processing costs.

These cost estimates indicate that, at monthly milk volumes of less than 14 million pounds, the per-cwt. cost of processing milk is less for cheese than for butter/powder. Above this volume, however, butter/powder plants have lower per-unit costs. At capacities of the largest plants considered, per-unit cost of processing raw milk into cheddar cheese is $0.6952, while that of processing milk into butter/powder is $0.6290. Comparison of processing costs among products are relevant, of course, only as one step in the process of determining net returns, which involves relative prices of the finished products as well.[2]

For the most part, conventional equipment and production processes were specified for both operations as a basis for arriving at costs. The technical production processes for cheese are in a transition period—toward more continuous processing. This will likely have some effect on composition and level of costs. It might be hypothesized that these changes will cause the cost function for cheese processing to more closely approach that for butter/powder processing.

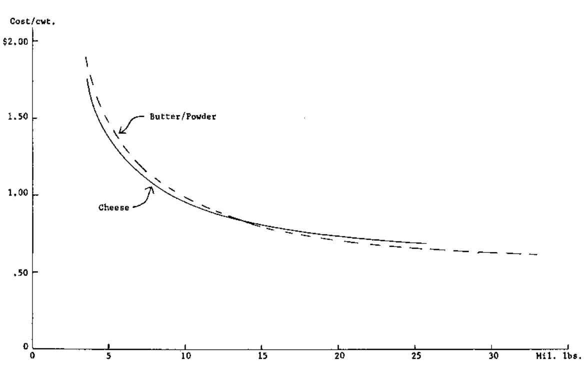

FIGURE 1. ESTIMATED COST PER HUNDRED-WEIGHT OF RAW MILK PROCESSED IN CHEDDAR CHEESE AND BUTTER /POWDER PLANTS AT VARYING VOLUMES HANDLED MONTHLY

IMPLICATIONS

The magnitude of the economies of plant size exhibited by these data point to the critical role of substantial volume for technically efficient conversion of raw milk into hard manufactured products. These results help specify economic forces which are contributing to gradual disappearance of relatively small manufacturing plants throughout the South.

The magnitude of these economies also leads one to suspect that additional technical efficiencies are available through further reduction in plant numbers. It is admitted, of course, that technically efficient plant size may be constrained somewhat by diseconomies arising from both the relatively low density of milk available in some areas of the South as well as from the seasonal nature of milk production.

As conversion of Grade B to Grade A continues and erodes the basic milk source for many manufacturing plants, economies of size in raw milk manufacturing become an increasingly important consideration for the Grade A producing sector. If such facilities are to be retained for the primary purpose of processing raw Grade A milk produced but not sold in the fluid form into a less perishable one, the coordination of number, size and location of such plants with the total milk utilization and

[2] For example, at the March 1976 support prices for dairy products and the following product conversion factors—butter 4.2#, powder 8.0# and cheddar cheese 10#, the gross revenue per cwt. of milk would be 45 to 50 cents greater in cheese than in butter/powder. Under these stipulations, cheese provides greater net returns at all volume levels since cheese processing costs per cwt. of milk are below butter/powder costs at low volumes and only 1 to 2 cents above at large volumes.

movement should contribute to minimizing the combined total industry costs.[3] This appears to be the case particularly for areas like the South, where total milk production does not greatly exceed total fluid consumption, and manufacturing facilities operate mainly on a seasonal basis. Fluctuations in daily production would be balanced with fluctuations in daily fluid bottling.

It is certainly correct that the most appropriate type and size of milk processing plant at any given location, in terms of technical efficiency, must be determined by considering both seasonality of milk production (or amount available for manufacturing) and costs of raw milk assembly. However, even with increased costs for transportation, cost economies for processing raw milk into hard manufactured dairy products must be expected to contribute significantly to the ultimate determination of optimum number, size, type and location of such facilities. In terms of net returns, of course, the appropriate type plant must take into account expected long-run relationship of the product prices, as well as relative costs of processing.

From a public policy viewpoint, it is not obvious that attempts to atomize the raw milk assembly and manufactured product processing function, in an effort to increase price competition for milk at the farm level, will necessarily lead to lower retail prices for either milk or manufactured products. The specification of these processing functions for converting raw milk into hard manufactured products leads us to believe that increased concentration may be explained, at least in part, by technical efficiencies which are available to firms operating plants with volumes of from 10-30 million pounds of raw milk per month. Operating plants that large, particularly in the South, appears to require the milk assembly function be highly coordinated.

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[3] Research on this issue has been initiated by the authors.