ıricultural Economics Report No. 138

September, 1980

WHEY UTILIZATION IN NORTH DAKOTA

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FOREWORD

The authors wish to acknowledge the contributions of the clerical and professional staff of the Department of Agricultural Economics who have participated in the preparation of this report. Special thanks is due to Ms. Becky Dethlefsen for typing the manuscript. Dr. Delmer Helgeson, Mr. Timothy Petry, Dr. Jerome Johnson, Mr. Donald Thomson, and Mr. John Mittleider have been especially helpful with their comments and suggestions.

Appreciation is extended to the managers and personnel of the cheese plants who assisted by supplying data and information. Gratitude is also expressed to the staff of the Dairy Commissioner for their cooperation.

Financial support for this study came from the North Dakota Agricultural Experiment Station.

Highlights

Whey, the by-product of cheese manufacture, has not found a ready market. Thus, as the amount of cheese manufactured increases, the problem of whey utilization or disposal becomes more complex.

Fifty-five percent of North Dakota's milk production goes into the manufacture of cheese, which is now the state's most important dairy product. North Dakota ranked eighth in the nation in the manufacture of American cheese in 1980, while manufacturing two percent of the nation's cheddar cheese.

Whey has low economic value and is composed of 93 percent water and 7 percent solids; it is rich in minerals. The value of dried whey is about equal to the cost of drying. It is difficult to dispose of in sewers or lagoons due to the mineral and food content.

North Dakota cheese plants utilized several methods to dispose of their whey. Five plants fed all or part of their output to livestock, six plants dried whey, four plants used whey as fertilizer, and six plants dumped all or part of their whey in gravel pits, on land, or in a lagoon.

Whey can be separated into its various components before utilization. Several processes are available for this. Two are applicable to North Dakota: reverse osmosis and spray drying. Spray drying presents an alternative to dumping or other localized disposal methods. Profitable spray drying requires a large volume of whey. No plant in the state produces enough to meet the requirements of a spray drying operation, so whey would need to be collected from several cheese plants. However, drying and transportation costs dictate the maximum distance liquid whey may be economically transported to a central drying facility.

WHEY UTILIZATION IN NORTH DAKOTA

by

Gordon W. Erlandson and Theodore J. Smith*

Little Miss Muffet
Sat on a tuffet
Eating her curds and whey . . .

American consumers have developed tastes for certain dairy foods while ignoring others. Per capita consumption of cheese (curds) has increased from 8.2 pounds in 1960 to 17.1 pounds in 1980 (4:15).** The by-product of cheese manufacture (whey) has not found a ready market. Unlike Miss Muffet, consumers today have discriminated against whey. This creates problems for the dairy industry and especially for cheese plants.

About 11 percent of the domestic milk supply was used to manufacture cheese in 1960, while over 26 percent was used in 1979 to match the increase in cheese consumption (4:20). About 55 percent of the milk produced in North Dakota is utilized in cheese manufacture, now the state's most important dairy product. North Dakota ranked eighth in the nation in the manufacture of American cheese in 1980, manufacturing 2 percent of the nation's cheddar cheese while producing less than 1 percent of the nation's milk supply (6:4).

The increase in cheese manufacture has created a problem of whey utilization or disposal. Ten pounds of milk will produce one pound of cheese and nine pounds of whey. With North Dakota's 1978 cheese production of 49.8 million pounds, the cheese industry faces the problem of utilizing or disposing of 224 thousand tons of whey annually. Whey is bulky, containing 93 percent water and only 7 percent solids. The solids precipitate and harden readily, causing buildup problems in transport and storage tanks as well as in lagoons.

Whey can be used as human food, livestock feed, or fertilizer, but has a low economic value either in liquid or dried form. It is costly and difficult to transport due to its bulk and organic composition. The organic nature gives whey a high biological demand (BOD) so it is difficult to dispose of by conventional sewage disposal means.

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**The first number refers to the item as numbered in the Literature Cited list, followed by the page number.

If dried, returns normally do not cover drying costs. The low density of milk production in North Dakota intensifies the problem by adding to transportation costs.

This report investigates the utilization of whey produced in North Dakota cheese plants. Current disposal and utilization methods are described, as well as costs and benefits associated with the various disposal methods. Data were obtained from interviews with cheese plant managers during the summer of 1977.

NORTH DAKOTA CHEESE INDUSTRY

The North Dakota cheese industry began in 1959 with the building of the first plant at Lefor. The industry expanded to 16 plants in 1972 and 1973, before reducing to ten plants in 1980. The ten plants are located at Beach, Bismarck, Dickinson, Lakota, Medina, Selfridge, Strasburg, Towner, Tuttle, and Wishek (Figure 1).

Cheese production increased from 0.8 million pounds in 1960 to 48.2 million pounds in 1980. During the same period, butter production decreased from 56.9 million pounds to 6.7 million pounds (Table 1).

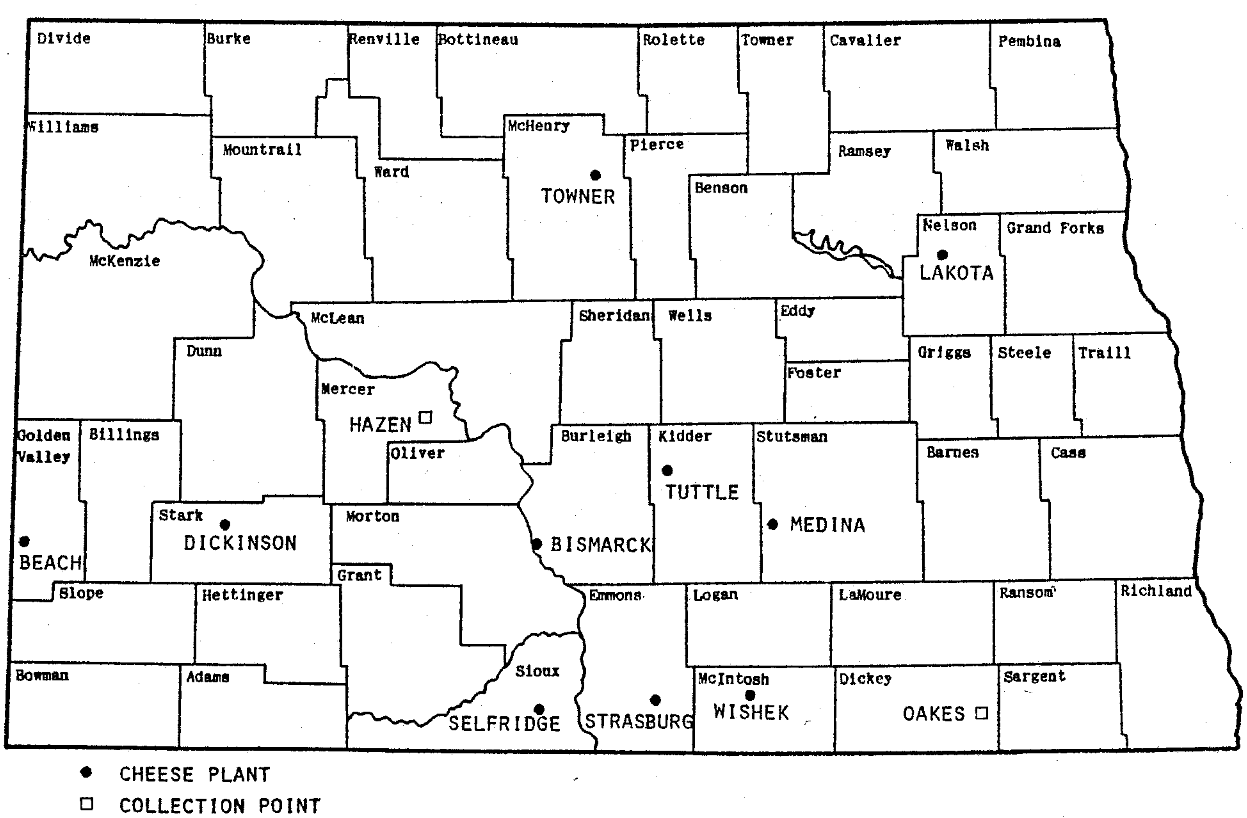


Figure 1. Location of North Dakota Cheese Plants, 1980

TABLE 1. PRODUCTION OF BUTTER AND CHEESE, NUMBER OF PLANTS, NORTH DAKOTA 1960-1980 (PRODUCTION IS IN 000 POUNDS)

Year	Creamery Butter		Cheddar Cheese	
	Plants	Production	Plants	Production
	Number			
1960	79	56,867	a	813
1961	79	56,498	8	6,756
1962	77	52,889	10	10,249
1963	73	49,001	12	13,468
1964	73	49,295	12	16,349
1965	69	42,082	12	15,656
1966	59	34,639	13	20,412
1967	56	31,295	12	27,329
1968	50	29,871	13	32,449
1969	40	25,529	13	34,119
1970	33	22,818	15	34,197
1971	29	20,735	15	37,334
1972	28	17,328	16	38,965
1973	24	11,698	16	50,115
1974	22	8,882	15	51,818
1975	19	9,221	15	47,158
1976	13	7,230	13	51,962
1977	12	6,590	13	53,430
1978	11	6,099	13	49,769
1979	10	6,496	11	44,952
1980	8	6,701	10	48,186

[a]Not available.

SOURCE: USDA, SRS, Dairy Products, Annual Summary, 1960-1980.

North Dakota cheese plants have the capacity to process 2,170,000 pounds of milk per day. Capacity per plant ranges from 30,000 to 300,000 pounds of milk per day; the most common size was 150,000 pounds per day (Table 2). Plant sizes vary greatly as shown by these capacities.

TABLE 2. NORTH DAKOTA CHEESE PLANT CAPACITIES (THOUSANDS OF POUNDS PER DAY) 1977

Capacity	30-99	100-199	200-299	Most common (150)
Number of plants	3	6	4	(4)

Hours of operation per week by the plants ranged from 50 during the slack fall season to 168 during the spring. The average number of hours of operation was 92 hours per week (Table 3).

TABLE 3. HOURS OF OPERATION, NORTH DAKOTA CHEESE PLANTS, 1977

Hours per week	30-60	61-99	100-168
Number of plants			
Spring	4	5	4
Fall	7	4	2

The plants employed from three to 35 workers. The number of employees followed the pattern of plant size and hours of operation.

MILK COLLECTION

Milk is collected from as far as 150 miles from the cheese plants. The average distance was about 80 miles (Table 4).

TABLE 4. DISTANCE MILK IS TRANSPORTED TO NORTH DAKOTA CHEESE PLANTS, 1977

Distance (miles)	Less than 70	70-99	100-145	Over 145
Number of plants	4	6	1	2

Twelve plants received milk from a total of about 1,680 producers. Individual plants collected milk from 20 to 350 producers (Table 5).

TABLE 5. NUMBER OF PRODUCERS SELLING TO NORTH DAKOTA CHEESE PLANTS, 1977

Number of producers	20-80	81-145	146-225	226-350
Number of plants*	4	4	2	2

*Total equals 12; one plant not reporting.

Three managers indicated they obtained milk from plants which could not process the entire volume they received. The former cheese plant at Hazen serves as a collection point for the cheese plant at Towner. Eleven plants owned their own trucks for milk collection. Three plants hired private truckers to transport the milk.

Cheese produced in North Dakota is sold in bulk form as block cheese to firms in Wisconsin, Minnesota, and Missouri. The firms include Kraft and Bordens. None is marketed locally under the brand name of a North Dakota producer.

WHEY DISPOSAL

Whey, the by-product of cheese production, compares to cheese making as buttermilk compares to butter manufacture. Whey is composed of 93 percent water and 7 percent solids, including 5 percent lactose, and is rich in minerals (Table 6).

TABLE 6. COMPOSITION OF WHEY

Composites		Percentage
Water		93.0%
Lactose		4.9%
Nitrogenous matter		0.9%
Fat		0.3%
Lactic acid		0.2%
Ash		0.6%
(Nitrogen	0.3%)	
(Phosphorous	0.075%)	
(Potassium	0.35%)	

Five cheese plants fed all or part of their whey to livestock, six dried their whey, four used whey as a fertilizer, and six disposed of it as sewage. Totals add to more than thirteen because several plants utilized more than one disposal method (Table 7).

TABLE 7. METHODS OF WHEY DISPOSAL, NORTH DAKOTA CHEESE PLANTS, 1977

Disposal Method	Number of plants*
Feed (liquid)	5
Dry	6
Fertilizer	4
Dump	6
Lagoon	1

*Total number of plants exceeds thirteen because some plants use more than one disposal method.

Feeding Whey

Five plants fed from 5 to 100 percent of their whey to livestock. One plant owned a hog operation and utilized all of its whey as hog feed on this farm. Other plants returned the whey free of charge to farmers who fed it to livestock. Whey was being used for 15 to 20 percent of the hog ration. Whey has also been used for feed for mink and dairy cattle, but these practices have been discontinued.

Drying Whey

Six cheese plants dried whey. Two owned roller dryers and produced a dry whey powder for livestock feed. The other four transported whey to a centrally located drying plant that used a spray dryer to produce a whey powder suitable for human consumption.

The roller dryer facilities had a combined capacity of 48,000 pounds of liquid whey per hour, while the spray drying facility had a capacity of 30,000 pounds per hour. (One plant operating a roller dryer has closed down since 1977.)

Roller dried whey was reported by plant managers to be selling for $5.25 to $7.15 per hundredweight in July 1977. Spray dried whey powder was selling for $9.00 per hundredweight at that time.

Fertilizer

Four plants used whey as a fertilizer. One plant owned a farm and spread whey over the land. Whey was applied to pasture, summerfallow, and small grain crops. The other plants returned liquid whey to farmers who applied it to their fields.

During the summer of 1977, it was observed that wheat grown on whey-irrigated land had large, full heads and a nice stand, while other farmers in the area were mowing their wheat for hay, due to drought conditions.

Dumping Whey

One cheese plant built a four-cell lagoon for whey disposal. The whey was allowed to settle and decompose by microbial action. Odor was controlled by using chemicals.

Five plants dumped all or part of their whey. Gravel pits and school lands were mentioned as two dump sites.

FUTURE PLANS

Several plant managers indicated they plan to start whey feeding operations in the next few years. More managers would dry whey but do not have sufficient volume to justify the installation of drying equipment. Since the survey was taken, one cheese plant has ceased operations, primarily due to whey disposal problems.

REGULATORY AGENCIES

Regulatory agencies have had minimal contact with the plant managers regarding whey disposal. Most managers said they have not been contacted by state or federal agencies. The only groups mentioned by any of the managers were the State Health Department, the sheriff's office, and the city commission. In North Dakota, cities are responsible for regulating whey disposal within their boundaries. Plants must obtain a discharge permit from the State Health Department before releasing whey into a stream. There are no restrictions on whey usage on private property, such as for fertilizer.

WHEY USES

The supply of whey has grown proportionately with cheese production. United States cheese production has doubled since 1950 and has increased by 458 percent since 1925. The increases in volume of milk utilized for cheese have resulted in a large increase in the volume of whey. With the increased cheese production has come decreased use of milk in other manufactured dairy products such as butter.

The percentage changes for cheese production and whey volumes have been even greater in North Dakota. The problem of whey utilization or disposal, therefore, is of major importance. Some of the possible uses of whey will now be examined, considering potential benefits and limitations.

Liquid Whey as an Animal Feed

Whey may be fed to animals in liquid or dried form. Traditionally whey has been fed as a liquid -- "slopped to the hogs."

Swine

Feeding liquid whey to hogs dates to ancient Rome. Before World War II, the major use on the farm was as feed for swine.

One hundred pounds of liquid whey will substitute for about one-fourth bushel of corn or six pounds of tankage. Animals, however, cannot live on whey alone. Liquid whey cannot be more than 20 percent of the total digestible nutrients (TDN) in a hog ration. Hogs fed high rates of whey are susceptible to certain digestive problems, particularly scours.

Wisconsin, Illinois, and California research indicates swine weighing over 100 pounds made good gains when fed liquid whey with barley or wheat (9:558). Whey consumption averaged 20 pounds per day and barley consumption averaged 8 pounds per day. Growth rates were usually acceptable for consumption of up to 20 percent dry matter as whey (3:16).

Dairy Cattle

Dairy cows will drink between 17 and 20 gallons of liquid whey per day. Utah, Vermont, and USDA researchers have found milk production is not affected when whey replaced all or part of the water fed to lactating cows (9:558). Cows fed whey as their only liquid received 29 percent of their dry matter as whey. It is estimated that one milking cow can consume the whey from the production of three to five average cows (1:1206).

When whey is fed as the only source of protein, cows drank about 100 pounds per day and about 150 pounds per day when water was available Cows will drink two-day-old whey but not three-day-old whey (1:1206). Concentrated whey will not be eaten by cows unless it is mixed with equal amounts of molasses (11:634). Steers also show acceptable weight gains when fed whey as part of their ration (12:681).

Problems Feeding Liquid Whey

Animals will reject whey in favor of water if they are not started on it when young or if it is not gradually introduced into the ration.

Flies and sanitary problems during warm weather may be a problem in feeding liquid whey. Transporting liquid whey also may present a problem, because of its bulk, mineral content, and perishability.

Feeding Dried Whey

Dried whey has been fed to nonruminants for many years with good results. Adding dried whey to the ration increases weight gains and feed efficiencies for poultry, swine, and horses. Protein digestibility, nitrogen retention, and fat digestibility are increased and mineral absorption and retention are improved when dried whey or lactose is fed to nonruminants (9:559).

Poultry show the best response to whey when rations contain 3 to 4 percent dry whey. Mature hens are less tolerant of whey than younger birds.

Swine are more tolerant to lactose than poultry and can consume 20 percent dried whey rations. Younger swine seem able to digest diets containing more dried whey. The whey content in the ration should decrease as the animal's age increases (9:560). The amount of whey which can be fed to nonruminants is limited because they cannot digest it properly.

Ruminants

Whey has been used as an additive to high-concentrate rations to prevent the milk fat depression often caused by such high-energy rations. It has been found to be more palatable than most of the other feed additives used for this purpose (9:560).

Calf starter consumption was increased when rations contained up to 10 percent dried whey, but decreased when rations contained 30 percent dried whey (5:430). It is not known how much whey can be fed to growing ruminants before performance is impaired.

Adding dried whey to grass and legume silages improved quality of the silages, probably because of the fermentable carbohydrates available in the whey. The best result usually is obtained feeding 1 to 2 percent dried whey. Up to 10 percent dried whey, however, has been added successfully (9:554).

Non-Ruminants

Research indicates dried whey is an excellent substitute for 40 percent or more of the corn normally used in hog and poultry feed. Dried whey has a protein content of 12-13 percent, compared to corn with about 8 percent. With these percentages it becomes profitable to substitute dried whey for corn when the price of corn is within 25 percent of the price of whey. The price at which whey and corn can be profitably substituted for each other is shown in Table 8. If dried whey costs seven cents per pound, it is profitable to substitute dried whey for corn when corn costs $2.94 or more a bushel.

TABLE 8. WHEY-CORN SUBSTITUTIONS

Price of Corn	Price of Dry Whey
$/bushel	*$/pound*
1.68	.04
2.10	.05
2.52	.06
2.94	.07
3.36	.08
3.78	.09
4.20	.10
4.62	.11
5.04	.12

Whey as Human Food

Human prejudices limit the use of whey in human food. Many people think of whey as pig feed, despite its nutritional value. Federal Food and Drug Administration standards reflect this view and limit whey use in certain foods. But each year more food products contain whey; about one-fourth of the whey produced is used in human foods.

Whey is used in margarine, canned corn, canned grapefruit and applesauce, frozen vegetables, fruit butters, jellies and other preserves, ice cream, yogurt, pickles, salad dressings, candy, caramels, beverages, cheeses, soups, gravies, cake mixes, pharmaceuticals, infant foods and formulas, and many other products. Research continues into new uses.

One promising new product is a whey-soy drink (7:48-55). This was developed in 1973 by the United States Department of Agriculture (USDA) and the United States Agency for International Development (AID) for use in the U.S. Food for Peace Program. The drink mix contains:

Sweet whey solids	41.7%
Full fat soy flour	36.9%
Soybean oil	12.3%
Corn syrup solids	9.1%

Protein content of the drink is 20 percent, it provides 160 calories per eight ounce serving, and it dissolves completely in water. Before whey can be used as a human food, it must be pasteurized at 160°F for 15 seconds (8:94).

The U.S. Army Natick Laboratories tested the drink mix in Chile, India, Pakistan, Sierra Leone, Vietnam, and Dominican Republic. The children who tasted it liked it, and the beverage mix is now being used by AID in its programs.

Use of dried whey in frozen desserts has been permitted by federal regulations since 1962. Dried whey is allowed to replace 25 percent of the milk-solids-not-fat in most frozen dessert mixes. Recent attempts to increase the percentage were unsuccessful. Whey has passed taste tests when used in ice cream, ice milk, sherbet, soft-serve ice cream, and shake mixes.

Beverages containing whey are divided into three categories: alcoholic, nonalcoholic, and high protein (10:91). Alcoholic beverages are prepared from deproteinized whey and are mainly consumed in Europe. Nonalcoholic beverages are normally mixed with fruit juices and provide an alternative to carbonated drinks. Protein beverages were developed to help fight the malnutrition problem in the world and have been used with limited success. Whey-based beverages have not been accepted by the U.S. consumer.

Whey is being used as a starter medium for yogurt, sour cream, cheeses, and buttermilk. A whey medium costs one-third as much and supports a microbial population 19 times greater than a skim milk medium (10:91).

Whey as a Fertilizer

Whey contains about 0.3 percent nitrogen, 0.075 percent phosphorous, and 0.35 percent potassium. An acre-inch (about 28,000 gallons) of whey contains about 320 pounds of nitrogen, 100 pounds of phosphorus, and 400 pounds of potassium. If these nutrients were purchased as commercial fertilizer, they would cost $150 to $175. This makes whey worth about

7 cents per hundredweight to farmers, providing these nutrients are needed. Three tons of whey contain as much plant food as one ton of manure.

Liquid whey performs best on cereal crops and grasses and less well on legumes. It should not be applied on oats because it causes oats to grow too rank, increasing lodging. Whey improves the water holding ability of the soil and improves soil structure, making soil easier to work.

For every 100 pounds of whey used, 93 pounds of water are added to the soil. The additional water may be helpful in dry times but creates problems when the soil is wet. Whey cannot be applied when the soil is saturated, after a rain or in the winter when the ground is frozen. During winter months, whey has to be stored until it can be applied in the spring. One-half of North Dakota's moisture typically falls in June, July, and August -- the same months that crops require the most moisture and whey production is greatest.

Whey as a Pollutant

The high organic content of whey causes it to be a serious pollutant when discharged untreated into a stream or body of water. Microorganisms in the water decompose the organic material but use up oxygen in the process. If enough oxygen is used, aquatic plants and animals will be harmed and may be destroyed. The measurement of pollutants which use oxygen in this manner is called "biochemical oxygen demand" or BOD (2:8).

Another pollutant in whey is the suspended solids which may discolor and cloud the water.

Federal regulations state that by 1985 no untreated wastes may be discharged into streams. Whey can be treated, but problems exist here also. Many municipal sewage plants do not have the capacity to handle all the whey which cheese plants produce, and some are not equipped to handle the whey's high organic content. The minerals in whey cause lagoons to develop a hard floor; this build-up is difficult if not impossible to remove.

Odor is also a problem. The smell from whey as it ripens is very strong and offensive. People living near places where whey is dumped or stored or near lagoons object to the smell, making measures to control the odor necessary.

A number of processes are available for the concentration and fractionation of whey. These processes include lactose crystallization, protein recovery, reverse osmosis, ultrafiltration, gel filtration, roller and spray drying, evaporation, electrodialysis, transport depletion, and ion exchange.

Processes practical for North Dakota cheese manufacturers are reverse osmosis and spray drying. Reverse osmosis can be used for concentrating the whey before hauling it to a central point for drying. A spray dryer then can be used to produce a powder suitable for human consumption. However, the whey volumes and markets required may not be available in this state, and costs of the process may exceed returns for the product.

WHEY TRANSPORTATION IN NORTH DAKOTA

Efficient operation of whey spray-drying facilities requires a large volume of whey; roughly one million pounds per day. None of the cheese plants in North Dakota individually produce this volume. The largest plant has about one-fourth this volume during the flush or spring period while during the fall, the smallest plant produces about 24,000 pounds of whey daily. If cheese plant operators wish to dry their whey, it will be necessary to combine production from several plants. This requires transportation of whey to a central point.

The 12 cheese plants produced an annual volume of about 323 million pounds of whey (January, 1979). Daily production was about 1.6 million pounds during the flush spring season and 940 thousand pounds during the fall months.

For the purposes of this study, Bismarck was selected as the location for a centralized spray drying facility. It is the same distance from the two largest cheese plants in the state, and much of the cheese production centers around it. Bismarck also has the transportation facilities to allow the dried whey to conveniently reach eastern markets. Bismarck is located on Burlington Northern Railroad's main line and on Interstate Highway 94.

One cheese plant is located in Bismarck, while the farthest plants are located at Powers Lake and Lakota, at a distance of 190 and 200 miles respectively. Average distance from all twelve plants is 104 miles from Bismarck.

SEASONALITY OF PRODUCTION

Data in Table 9 show the seasonality of cheese production in North Dakota. Seasonality must be considered since production ranges from 3 million to nearly 6 million pounds of cheese per month. Nearly 22 percent of the cheese manufacture occurs during the months of June and July.

Whey handling facilities need to cope with this range in volume. Capacity adequate to handle the peak volumes will be idle during much of the year: excess capacity would result in higher drying costs. If the plant is to operate at full capacity all year it need be adequate to handle only the fall whey production. For the rest of the year, some additional disposal method will have to be used.

Volume and cost estimates were calculated on an individual basis for all 12 plants. Summaries of these estimates follow.

COMPUTATIONAL PROCEDURE

Annual and peak milk volume data were obtained from a survey of cheese plant managers. Low volume figures were estimates obtained by finding the percentage of cheese produced each month in 1975-1976, relative to total cheese production. The ratio between the peak month (July) and the low month (October) was computed as 1.7:1 (Table 9). This means 70 percent more cheese was produced in July than in October. The low volume figure was found by dividing each plant's peak whey volume by 1.7.

Estimated annual, peak, and low whey volumes were obtained by multiplying the respective plant milk volumes by 0.9 (100 pounds of milk yields 90 pounds of unconcentrated whey). The corresponding volumes of concentrated whey were obtained by multiplying the volume of whey by 0.248 (Figure 2). The pounds of whey solids were estimated by multiplying the whey volume by 0.06 or the concentrated whey volume by 0.242 (100 pounds of milk yields 5.4 pounds of whey solids).

Unconcentrated Whey

The range in daily whey volume during the flush period was from about 40,500 pounds to 270,000 pounds in 1977. During the fall months, daily whey production ranged from about 23,700 pounds to 158,100 pounds per plant. Total whey production per day for North Dakota ranged from

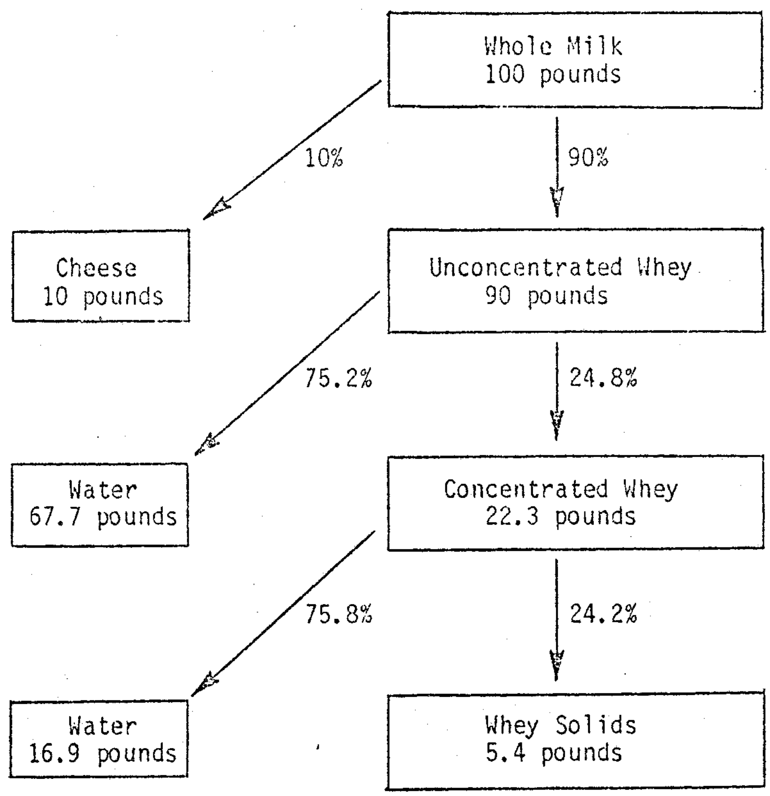


Figure 2. Relationships Between Whole Milk, Unconcentrated Whey, Concentrated Whey, and Whey Solids

TABLE 9. MONTHLY CHEESE PRODUCTION AS PERCENT OF TOTAL, NORTH DAKOTA, 1975-1976 (PRODUCTION IS IN 000 POUNDS)

Month	1975[a]	1976[a]	Total	Percent
	- - - - - - -	- - - - - - - *Number*	- - - - - - -	- - - - - - -
January	3,718	4,107	7,735	7.8
February	3,461	3,610	7,071	7.1
March	3,938	4,331	8,269	8.3
April	4,098	4,706	8,804	8.9
May	4,543	5,244	9,787	9.9
June	5,298	5,512	10,810	10.9
July	5,623	5,211	10,834	11.0
August	4,188	4,335	8,523	8.6
September	3,135	3,538	6,673	6.7
October	2,882	3,503	6,385	6.4
November	2,836	3,682	6,518	6.6
December	3,468	4,273	7,741	7.8
Total	47,188	51,962	99,150	100.0

[a]From 1978 N.D. Crop and Livestock Reporting Service, Agricultural Statistics, No. 42.

938,000 pounds to 1,602,000 pounds. Annual statewide production was about 322,938,000 pounds, with 9,828,000 pounds being produced by the smallest plant and 53,280,000 pounds by the largest.

Concentrated Whey

Concentrated whey volume during the flush season ranged from 10,044 pounds to 66,960 pounds daily. During the fall, concentrated volumes ranged from 5,878 pounds to 39,209 pounds per plant. Daily concentrated volumes totaled 232,624 pounds during the fall and 397,296 pounds during the flush season. Annual concentrated whey volumes ranged from about 2,437,344 pounds to 13,213,440 pounds per plant. Total annual statewide production was 80,088,624 pounds.

Whey Solids

Whey solids production ranged from 9,486 pounds to 16,200 pounds daily for the largest cheese plant in North Dakota. Daily solids production for the smallest plant ranged from 1,422 pounds to 2,430 pounds.

Annual whey solids production ranged from 589,680 pounds for the smallest plant to 3,196,800 pounds for the largest. Annual statewide solids production was about 19,376,280 pounds (Table 10).

TABLE 10. WHEY VOLUME SUMMARY, NORTH DAKOTA, 1977

Item	Range of plant volume	Totals (all plants)
	pounds	*pounds*
Whey Volume		
Per day, peak season	40,500 - 270,000	1,602,000
Per day, fall season	23,700 - 158,100	938,000
Per year	9,828,000 - 53,280,000	322,938,000
Concentrated Volume		
Per day, peak season	10,044 - 66,960	397,296
Per day, fall season	5,878 - 39,209	232,624
Per year	2,437,344 - 13,213,440	80,088,624
Solids Volume		
Per day, peak season	2,430 - 16,200	96,120
Per day, fall season	1,422 - 9,486	56,280
Per year	589,680 - 3,196,800	19,376,280

COST SUMMARY

Transportation costs were determined by multiplying the whey volume by distance transported and by cost per unit. Transportation cost per pound of whey solids was found by dividing the transportation cost by the pounds of solids. Average solids transportation cost was found by dividing total transportation cost by total whey solids (Figure 3). Inter-plant transportation (trucking) was based on a rate of $0.25 per hundredweight per hundred miles.

Transportation Cost
= unconcentrated whey weight X distance X $.25/cwt./100 miles
or = concentrated whey weight X distance X $.25/cwt./100 miles

$$\text{transport cost/lb. of solids} = \frac{\text{transportation cost/plant}}{\text{lbs. of solids/plant}}$$

$$\text{average transport cost} = \frac{\text{total transportation cost}}{\text{total lbs. of solids}}$$

average distance whey is transported (weighted for different plant distances and volumes)

$$= \frac{\text{pounds of solids/plant}}{\text{total lbs. of solids}} \times \text{distance}$$

Figure 3. Transportation Cost Computations

Transporting unconcentrated whey to a centralized drying plant in Bismarck would cost $752,643 annually. Concentrating the whey to 30 percent solids content would reduce transportation costs to $186,655 annually (Table 11).

TABLE 11. WHEY TRANSPORTATION COSTS, NORTH DAKOTA, 1977

Item	Range of Whey Transportation Costs/Plant	Totals (All Plants)
Whole Whey		
Per day, Peak season	$118.13 - $818.10	$3,813.98
Per day, Fall season	69.15 - 478.74	2,231.91
Per year	22,275.00 - 127,260.00	752,643.00
Concentrated Whey		
Per day, Peak season	29.30 - 202.89	945.87
Per day, Fall season	17.15 - 118.73	553.51
Per year	5,524.00 - 31,560.00	186,655.00
Whey Solids		
Per pound, Whole whey	2.54 - 8.42	3.97
Per pound, Concentrated whey	.63 - 2.09	.96
Average Distance of Plants from Bismarck	104.2 miles	
Weighted Average Distance Whey is Transported	91.7 miles	

Transportation costs per plant vary according to volume of whey produced and plant distance from Bismarck. The highest transport cost any one plant would have is $127,260 and the lowest is $22,275, if the whey were transported unconcentrated. Concentrated whey would cost each plant from $5,524 to $31,560 to ship per year (Table 11). Daily trucking costs range from $69 to $818 for shipping unconcentrated whey and from $17 to $203 for concentrated whey, per plant. Transportation cost per pound of solids ranges from 2.5 cents to 8.4 cents for unconcentrated whey and from 0.63 cents to 2.09 cents for concentrated whey. The weighted average distance whey must be transported to reach the centralized drying plant is 91.7 miles.

Transportation economies are substantial if whey is concentrated prior to shipment. If all 12 plants shipped their whey to a central drying plant, the cost of transportation would total $752,643 (Table 12). If the whey was concentrated at the local plant, the total transportation cost could be reduced by about 75 percent, or to $186,655.

TABLE 12. WHEY VOLUME AND TRANSPORTATION COSTS BY DISTANCE, NORTH DAKOTA, 1977

Distance in Miles	Number of Plants	Pounds Concentrated	Transportation Costs	Pounds Unconcentrated	Transportation Costs
0 - 80	5	42,676,040	$ 65,581	172,080,000	$264,447
80 - 140	4	25,154,640	63,738	101,430,000	257,013
over 140	3	12,258,144	57,333	49,428,000	231,183
Total	12	80,088,824	$186,652	322,938,000	$752,643

Operators can reduce transportation's share of whey solids cost by two to six cents per pound of solids by concentrating whey before it leaves the cheese plant. Savings of this magnitude are substantial when drying whey is normally a break-even proposition at best. The savings in transportation may be somewhat offset by higher concentrating costs at individual plants as opposed to a centralized plant. The higher costs could result from the smaller volume of whey to be concentrated at each plant. Plants can find it profitable, however, to pay from two to six cents more to concentrate whey at the cheese plant rather than ship unconcentrated whey to the central drying location for concentration. Whey should be concentrated at the individual plant if the benefit exceeds the additional cost of transporting the unconcentrated whey.

Break-Even Analysis

Break-even analysis was used to determine the maximum distance whey can be transported to a central point. Break-even analysis depends on three variables:

1. Transportation costs
2. Drying costs
3. Selling price of dried whey

The selling price less drying costs determines the net return. The distance whey can be profitably transported increases as the net return increases, and/or the transportation rate decreases.

Data in Table 13 present the equivalent transportation rates for whey and whey solids. If the transportation rate is 20 cents for an hundredweight of fluid whey per hundred miles, for example, the equivalent rate per pound of whey solids would be $0.0333 if whey is unconcentrated and $0.0083 if concentrated.

TABLE 13. EQUIVALENT TRANSPORTATION RATES FOR WHEY AND WHEY SOLIDS

Transportation Rate* (Fluid Basis)	Transportation Rate** (Solids Basis)	
Liquid Whey	Unconcentrated	Concentrated
$0.20	$0.0333	$0.0083
0.25	0.0417	0.0103
0.30	0.0500	0.0124
0.35	0.0583	0.0145
0.40	0.0667	0.0165
0.45	0.0750	0.0186
0.50	0.0833	0.0207

*Transportation rate on fluid basis equals dollars per cwt per 100 miles.
**Transportation rate on solids basis equals dollars per pound solids per 100 miles.

These figures can be utilized to determine the maximum distances unconcentrated (Table 14) or concentrated whey (Table 15) can be transported, given the net return of the selling price of whey over drying costs.

TABLE 14. MAXIMUM TRANSPORT DISTANCES FOR UNCONCENTRATED WHEY AT BREAK-EVEN POINT

Net Return (¢/lb. Solids)	Unconcentrated Whey Transport Charges (¢/lb. Solids/100 miles)*						
	3.33	4.17	5.00	5.83	6.67	7.50	8.33
	Miles						
0	0	0	0	0	0	0	0
1	30	24	20	17	15	13	12
2	60	48	40	34	30	27	24
3	90	72	60	51	45	40	36
4	120	96	80	67	60	53	48
5	150	120	100	86	75	67	60
6	180	144	120	103	90	80	72
7	210	168	140	120	105	93	84
8	240	192	160	137	120	107	96
9	270	216	180	154	135	120	108
10	300	240	200	172	150	133	120

*See Table 13.

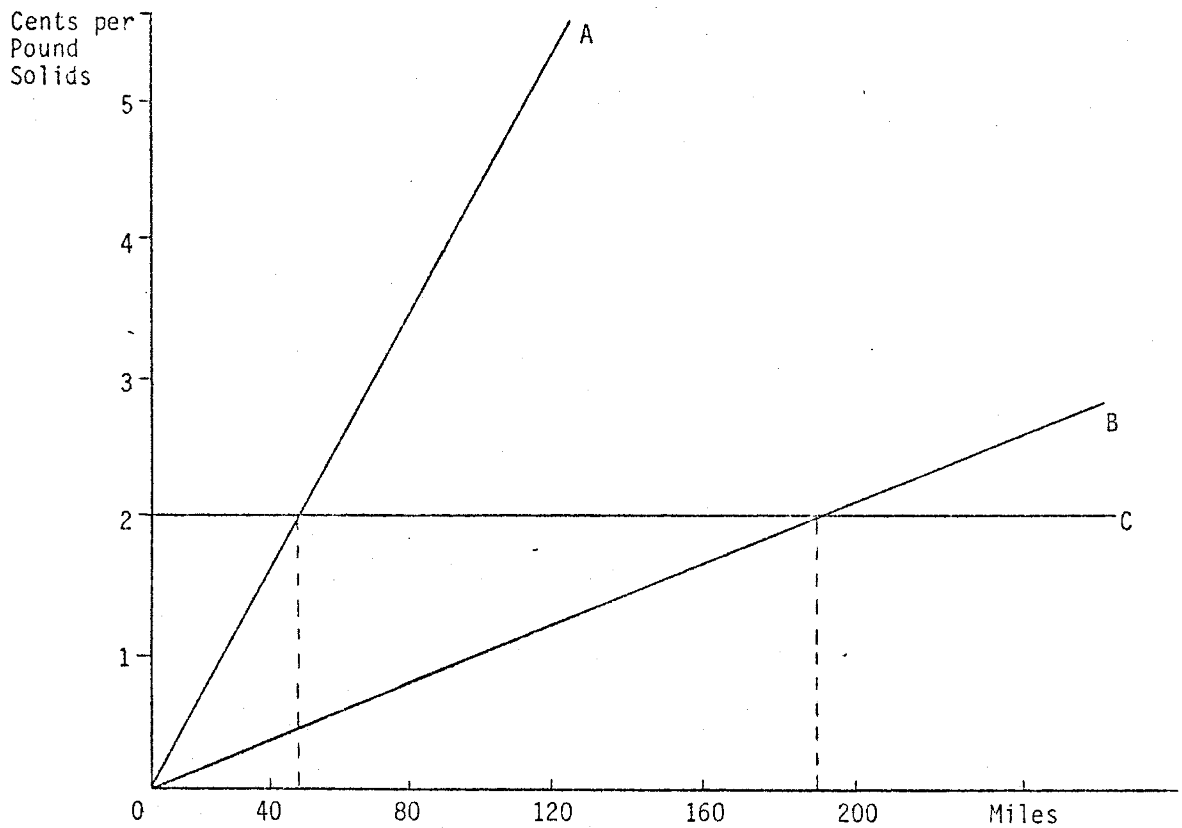
TABLE 15. MAXIMUM TRANSPORT DISTANCES FOR CONCENTRATED WHEY AT BREAK-EVEN POINT

Net Return Per Lb. Solids	Transportation Rates*						
	.83	1.03	1.24	1.45	1.65	1.86	2.07
Cents	*Miles*						
0	0	0	0	0	0	0	0
1	120	97	81	69	61	54	48
2	241	194	161	138	121	108	97
3	361	291	242	207	182	161	145
4	482	388	323	276	242	215	193
5	602	485	403	345	303	269	242
6	723	583	484	414	364	323	290
7	843	680	565	483	424	376	338
8	964	777	645	552	485	430	386
9	1,084	874	726	621	545	484	435
10	1,205	971	806	690	606	538	483

*Transportation rates equal cents per pound solids per 100 miles, see Table 13.

The break-even analysis may be shown graphically (Figure 4). The slopes of lines A and B represent the transportation costs per pound of solids of unconcentrated and concentrated whey, respectively. The higher the transportation rate, the steeper the slope and the lower the break-even distance. Line C depicts the selling price of whey solids less drying cost. For purposes of illustration, the net return per pound of solids was assumed to be two cents, which means the break-even distances are about 45 miles for transporting unconcentrated whey and about 190 miles for hauling concentrated whey. Beyond these distances, whey cannot be economically shipped, given these rates and prices. Shipments may still be made, but the additional costs must be borne by the plant and justified on the basis that it is still less expensive than other disposal methods.

The break-even distances may be altered by a change in one or more of the following conditions:



A = Transport Cost of Unconcentrated Whey
B = Transport Cost of Concentrated Whey
C = Selling Price of Whey Less Drying Cost

Figure 4. Break-Even Distance From Drying Plant, North Dakota, 1977

a. A decrease in transportation costs. Such a decrease would be reflected in the slope of lines A and B becoming less steep, and the break-even distances increasing.

b. A decrease in drying costs. This would be reflected in line C becoming higher on the graph, and again the break-even distances would become greater.

c. A higher price for the product. If the value of whey solids increased, line C would become higher, and the break-even distances would increase.

Energy costs are involved with both drying costs and transportation costs. Therefore, the possibility of either (a) or (b) above happening is remote, given the current energy outlook. The likelihood of the market price of whey solids increasing is tied to increased demand for the product through increases in existing uses and expanded uses through new product development.

This report has addressed some aspects of whey disposal in North Dakota. It has presented data on the volume of cheese produced in the state and the consequent volume of whey that must be utilized or disposed of in some manner. Whey disposal is often costly, since alternative disposal methods require hauling, drying, or dumping into a disposal system, or unto land, or fed to livestock. All methods present some drawbacks. Break-even analysis enables cheese plant operators to determine the maximum distance whey can be economically hauled, given drying costs and transportation rates. Plants located beyond the break-even distance must use other disposal methods, or subsidize hauling to some degree.

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