Cost Analysis of Foam-Spray Drying of Whole Milk

A. W. Farrall, R. L. Selman, and F. P. Hanrahan
LIFE FELLOW ASAE

2592

NEW developments in multiple effect evaporation coupled with spraydrying of a highly concentrated liquid are described as making possible important economics of production, as well as improvement in quality of dried whole milk. A cost analysis of operation now theoretically possible, is presented.

One of the important developments in the milk industry has been growth of dry milk production. About two billion pounds of milk powder are produced yearly in the United States. (6) Most of the production is of the nonfat form. There is considerable interest in dried whole milk. It is now possible to produce an excellent flavor. The use of the foam spray drying process (1) has given improved capacity, and improved dispersibility. (2 and 3) Improvements in inert gas packing, better packages, and the use of antioxidants, have been important (4).

Whole milk powder (3) offers many advantages as a source of beverage milk solids as well as for use in industry, particularly in countries and areas where the fresh milk supply is limited or not available. If properly made and stored, it will give an excellent reconstituted product even after a powder storage of 3 to 6 months, at 40 F.

One of the important aspects of the use of whole milk powder is that of cost. This study was made to determine the probable cost of making whole milk powder, using the most modern techniques, which would allow the production of a top quality beverage grade milk at the lowest possible cost as compared to fresh milk.

Experimental Procedures

A theoretical milk concentrating system using the latest type of thermocompression triple-stage unit of all stainless steel construction was decided upon after study of several actual field operations and analysis of laboratory performance of major elements of the theoretical plant. A stainless steel spray-drier system was selected on the same basis.

The powder-handling and packaging equipment which is a major part of the system for preservation of the powder, was also selected from commercially used equipment. All prices of such equipment, as well as minor items, were taken from leading manufacturers quotations as of January 1965. Labor, taxes, and other costs were taken as applied to the installation and operation of the plant in a midwest area of the USA. Milk price was determined as that being paid in Michigan for manufactured grade market milk.

Operating Time

The dryer was calculated to operate 7½ hr per day, 250 days per year. The cleanup and sanitizing time was 8 hr per day for a 3 man shift. One half hr per day was alloted for starting up and shutting down the operation.

Paper No. 66-320 presented at the Annual Meeting of the American Society of Agricultural Engineers at Amherst, Mass., June 1966, on a program arranged by the Electric Power and Processing Division. Approved for publication as journal article 3839 of the Michigan Agricultural Experiment Station.

The author—A. W. FARRALL, R. L. SELMAN and F. P. HANRAHAN—are respectively, professor of agricultural engineering, Michigan State University, East Lansing; and food technologist, and mechanical engineer, USDA, ARS, Eastern Utilization Research Development Division.

* Numbers in parentheses refer to the appended references.

† This degree of concentration has been readily accomplished in the laboratory and in some commercial plants.

Author's Note: This paper represents work done in part by the senior author while serving as a consultant to the dairy products laboratory, EURDD, ARS, USDA.

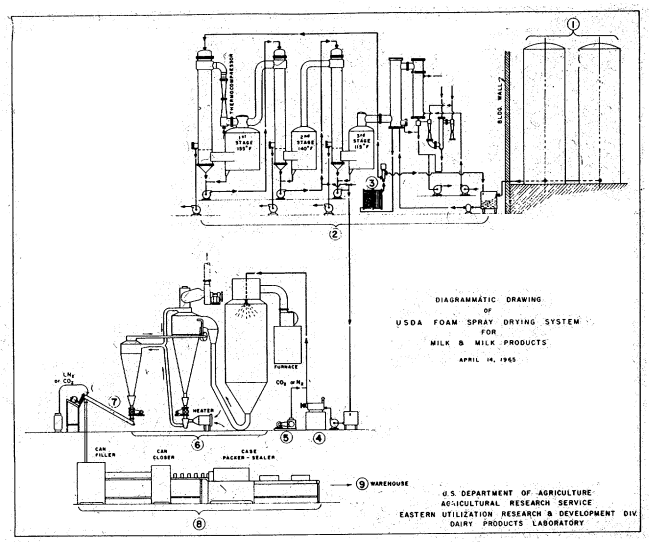

FIG. 1 A diagrammatic drawing of the USDA foam-spray drying system for milk and milk products.

The Process – see Fig. 1

Milk is delivered in bulk at 40 F and stored in refrigerated silo-type tanks, to be used as needed.

A surge tank with float control supplies a metering type pump which forces the milk through an economizer condenser and heats the product to 90 F. The milk then passes through a section of a plate heat exchanger, which uses vapor from the first stage evaporator to heat it to 130 F. The milk then passes through a second section of the plate heater, where live steam heats it to 164 F. The milk next passes through a 16 second holding period, then through a flow diversion valve to the first stage of the evaporator. The milk is then sent through the triple effect falling film type evaporator where it is concentrated to 55 to 60† percent t.s. This degree of concentration has been readily accomplished in the laboratory and in a few commercial plants. It then passes to the homogenizer, where it is homogenized and simultaneously forced into the spray feed line. Liquid CO_2 is added in this feed line at the rate to give approximately 1 cu ft of gas at atmospheric pressure to 1 gal of concentrate. The foamed concentrate is sprayed into the conventional dryer and is dessicated to a powder having 3 percent moisture. The powder is drawn off and cooled, to approximately 100 F in the presence of N_2 or CO_2 gas.

Packaging

The powder is packed and sealed in metal cans size 303 x 509, under essentially oxygen free conditions. Each can holds 0.546 lb of powder having 3 percent moisture. This powder when reconstituted with water gives 2 quarts of whole milk having 12.3 percent t.s. (8.8 percent S.N.F. and 3.5 percent fat).

Storage of Powder

The packaged powder will be stored at the plant at 40 F for a maximum of one week and then be shipped. Based on results of the USDA Products Laboratory and industry experience, it is expected that the product will maintain a good flavor for a minimum of 6 months, if kept at a temperature of 40 F.

Calculations

I. **Milk purchased** (includes 2 percent to cover plant losses

	Pounds of milk
Pounds per hour	32.134
Pounds per day (7½ hours)	241,005
Pounds per year (250 days)	60,251,250

II. **Product quantity** (output)

	Pounds of powder	Number of cans	Equivalent reconstituted quarts
Per hour	4,000	7,320	14,640
Per day (7½ hr)	30,000	54,900	109,800
Per year (250 days)	7,500,000	13,725,000	27,450,000

III. **Building and plant**

1 Land site – road and parking	$ 11,000.00
2 Processing plant, storages (cans and product)	136,800.00
3 Boilers	30,000.00
4 Instrumentation	4,250.00
5 Piping and ductwork, insulated (erected)	21,900.00
6 Electric power installation	26,800.00
7 Fork-lift trucks (2)	12,000.00
8 Office furniture and fixtures	4,000.00
9 Contingencies, 10 percent of total	30,274.50
10 Engineering fees, 6 percent of total	18,164.50
11 Contractor fee, 2 percent of total	6,055.00
12 Fire protection and safety	1,500.00
Total	$302,744.00

IV. **Equipment**

All equipment is to be of stainless steel construction. Prices are based upon January 1965 figures.

1 Storage tanks for raw milk, 15,000-gal capacity with 2 in. of cork insulation and 100 sq ft of jacketed cooling surface, with refrigeration system to hold milk at 35 F.	
Two tanks required	$29,000.00
Shipping charges	3,000.00
2 One triple-effect, falling-film-type evaporator with thermal compressor and economizer condenser, with capacity to evaporate 25,000 lb of water per hour and turning out 6,466 lb of whole milk concentrate of 60 percent t.s. per hour. (Evaporator, with pumps and surge tanks, installed price)	136,975.00
3 Plate pasteurizer complete with 16 second holding tube and flow-diversion valve	5,000.00
4 Homogenizer, feed pump and surge tank pump capacity 7,000 lb per hour at 6,000 psig	11,078.00
5 CO_2 pump and metering unit	5,000.00
6 Spray drier, capacity 4,000 lb powder per hour from 60 percent t.s. with direct fired natural gas heater (450 F air) (installed price)	130,120.00
7 Powder cooling conveyor	5,000.00
8 Packaging system for cleaning, filling, sealing, and packing of powder and palletizer for cases Inert gas packing	
Total packaging cost	154,821.00
9 Clean in-place system for entire plant	20,000.00
10 Installation of equipment, 25 percent of (Less drier and evaporator)	54,975.00
11 Freight, 2 percent on all except drier and evaporator	3,818.00
Total	$558,787.00

V. **Utilities**

	Daily cost
1 Steam, 96,705 lb day at 12 hours at 1.00 M	$ 96.70
2 Gas, 39,000 C.t. at $0.33 M	12.87
3 Electricity, 4500 kwh at $0.0142	63.90
4 Water, 252,500 gal at $0.15/M gal	37.95
5 CO_2 or N_2, 945 lb at $.04	37.80
Total	$249.22

VI. **Interest, taxes and insurance**

1 Int. on fixed invest. (861,531) at 6 percent (½ cap.)	$103.76
2 Int. on operating capital (500,000) at 5 percent	100.00
3 Taxes on investment (861,531) at 2 percent	68.92
4 Insurance on investment (861,531) at 2 percent	68.92
5 Maintenance of building (302,744) at 1.5 percent	18.16
6 Maintenance of equipment (558,787) at 4 percent	89.40
Total	$449.16

VII. **Labor**

	Daily Cost
1 Operating labor	
14 men 1 shift at $2.53 per hour	283.36
3 men 1 shift at $2.53 per hour	60.72
2 Indirect labor	
Supervision 1 at $30.00 per day	30.00
Mechanic 1 at $3.00 per hour	24.00
Office help 2 at $2.00 per hour	32.00
Bacteriologist and quality control	28.00
Total	$458.08

VIII. **Supplies**

	Daily cost
Milk, at 3.56 per cwt. 3.5 percent butterfat and 12.3 percent t.s.	$8,579.77
2 Packaging materials	
(a) Cans, size 303 × 509 at $46.00 per M delivered at plant	2,520.00
(b) Corrugated cartons, 95.75 per M, 24 cans per carton	218.50
(c) Labels at 2.00 per M	110.00
(d) Glue and misc. sup. est.	15.70
Total	$11,443.97

IX. **Depreciation**

	Daily cost
1 Building, st. line, 30 years 302,700 = 10,091.40 year =	per day $40.36
2 Equipment – st. line, 10 years 558,787 = 55,878.70 years =	per day 223.51
Total	$263.87

X. **Other direct operating costs**

1 Soc. Sec. 4.2 percent of first 6600 per year 22 persons	24.39
2 Workmen's compensation, 1.5 percent total payroll	6.87
3 Unemployment insurance, 2 percent of total payroll	9.16
4 Vacation time, 2 wks per year paid	18.32
5 Laboratory supplies (est.)	10.00
6 Misc. factory expenses (supplies, est.)	20.00
Total	$88.74

XI. **Other indirect operating expenses**

Research and development (1 percent of sales, 4,117,500)	159.2
Administration and general sup. and maint.	51.00
Selling cost (2 percent sales)	318.40
Total	528.60

XII. **Summary of daily operating costs (not including indirect)**

Item	Cost per day
Utilities	249.22
Interest – taxes, insurance, and maintenance	449.16
Labor	458.08
Supplies	11,443.97
Depreciation building and equipment	263.87
Other direct operating costs	88.74
Total	12,953.04

XIII. **Financial summary**

1	Gross annual sales, 27,450,000 qt. eq. at $0.145	3,980,250
2	Returns, allowances, discounts at ½ percent sales	19,901
3	Net annual sales	3,960,349
4	Production cost (daily × 250)	3,238,260
5	Gross annual profit	722,089
6	Indirect operating expense	132,150
7	Profit before taxes	589,939
8	Taxes – income, 48 percent federal and 2 percent state	294,969
9	Net annual earnings	294,969
10	Percent earned on fixed investment	34.2%
11	Selling price quart milk eq. FOB plant	$ 0.145

Summary

A cost analysis is presented covering a process for the manufacture of beverage-quality, whole milk powder utilizing the most modern system and equipment. The availability and ease of reconstituting the product make it particularly attractive for use in areas where fresh milk is not readily available or where costs are high and quality a problem. The selling price of the powdered whole milk FOB plant is calculated to be $0.145 per quart equivalent of reconstituted whole milk. At this price the profit after taxes would be 34.2 percent on the fixed investment if the raw milk was obtained at a price of $3.56 per cwt. and the other cost items were at the normal prices indicated.

Alternate evaporating systems could be devised which would utilize a triple effect evaporator to reach 45 percent solids and either a double tube chest pan to reach the 60 percent total solids level. This would avoid the danger of gelation of high solids concentrate in the pan. Either of these systems would add approximately $15,000 to the cost of the initially equipment.

In the case of the double tube chest system, there would be no added heating cost while the separate finishing pan would require about 1,000 lb more steam per hour due to lower operating efficiency.

These changes would increase the production costs by about .06 and .12 cents per quart equivalent respectively.

References

1 Bell, R. W., Hanrahan, F. P., and Webb, B. H. Foam spray drying methods of making readily dispersible non-fat dry milk. Jour. of Dairy Science, 46:(12)1352-1356, 1963.

2 Hanrahan, F. P., and Webb, B. H. USDA develops foam-spray drying. Food Engineering 33:(8)37-38, August 1961.

3 Hanrahan, R. P., Tamsma, A., Fox, K. K., and Pallansch, M. J. Production and properties of spray-dried whole milk foam. Jour. of Dairy Science 45:(1)27-31, 1962.

4 Howlet, N., and Tamsma, A. Effect of residual oxygen on flavor stability of dry milk foams. Jour. of Dairy Science 45:(12)658, 1962.

5 Tamsma, A. Flavor stability of of dry milk prepared by vacuum shelf drying procedures. Jour. of Dairy Science 45:(12)658, 1962.

6 United States Department of Agriculture., Agr. Statistics, 1966, U.S. Govt. Printing Office, Washington, D.C., 1966.