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A Cost Analysis of Encapsulated Spray-Dried Milk Fat[1]

V. H. Holsinger, A. J. McAloon, C. I. Onwulata, and P. W. Smith
Dairy Products Research Unit, Agricultural Research Service,
U.S. Department of Agriculture Eastern Regional Research Center,
600 East Mermaid Lane, Wyndmoor, PA 19038

ABSTRACT

Anhydrous butter oil or cream was encapsulated in all-purpose flour, modified cornstarch, or sucrose and then spray-dried. We estimated the processing cost for a plant designed to produce 57,000 kg/d (125,000 lbs/d) of encapsulated milk fat powder. Powder with a 50% milk fat content could be produced for about $0.23/kg plus the cost of the butter oil or cream, the encapsulant selected, and the other ingredients. Spray-drying of milk fat improved ease of handling and reduced storage costs.
(**Key words:** butter oil, cream, encapsulation, spray-drying, cost)

INTRODUCTION

Milk fat in the form of cream or butter is characterized by seasonal demand and price variation. Shelf life of fluid cream is limited, and spray-dried cream tends to undergo oxidative deterioration, resulting in flavor loss. Reduced fat consumption because of changing dietary habits has resulted in significant worldwide butter surpluses at times, a trend that may repeat in the future (6, 16). Salted butter can be stored frozen for up to 3 yr, but frozen food storage and transportation costs are expensive and add to the total cost of butter. If milk fat is converted to a powder, a storage life of 12 to 24 mo may be achieved (1).

Previous research (4, 13) demonstrated that the production of high fat butter powders is technologically feasible, but widespread use did not follow because of processing difficulties with flowability (4, 13). An alternative is to spray dry butter with functional encapsulants, such as starches, gums, or proteins, which enhance stability of the powder. Stability is attained through the formation of microcapsules that can protect the milk fat from oxidative deterioration during storage. Such powders may be readily utilized as ingredients in many food systems (2, 3).

We have demonstrated (9) that anhydrous butter oil or cream may be successfully encapsulated in all-purpose flour, modified corn starch, or sucrose, although the physical and structural properties varied with the source of milk fat and the type of encapsulating agent. The powders flow, withstand compression, and may be substituted for vegetable shortening in a variety of products (7, 11, 12). This encapsulation technology may offer additional marketing opportunities for milk fat if the powders could be produced at a reasonable cost. In this paper, we estimated the cost to produce encapsulated spray-dried powder containing 50% milk fat.

MATERIALS AND METHODS

A process has been described (10) to encapsulate and spray dry milk fat (in the form of anhydrous butter oil or 40% cream) in various encapsulants. Encapsulated powders contained 40 to 60% milk fat, 5% added emulsifier, and 5% NDM; the remainder was encapsulating agent (all-purpose flour, modified corn starch, or sucrose).

We estimated the capital costs to construct a facility to produce spray-dried encapsulated milk fat. Annual operating costs for plant labor, raw materials, utilities, and other production and overhead expenses were also calculated, based on anticipated operating conditions. Aspen Plus, Release 10.1 (Aspen Technology, Cambridge, MA), a process simulation program with the ability to evaluate cost and economics, was used to calculate the capital and operating costs. The average cost of powder was then determined by prorating the facilities capital costs over a 10 yr, combining these costs with the annual operating costs, and spreading these costs over the amount of encapsulated powder produced.

Operating Criteria

The milk fat encapsulation plant was designed to produce 57,000 kg/d. The facility was assumed to be in operation 24 h/d for 262 d/yr.

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Corresponding author: C. I. Onwulata; e-mail: conwulata@arserrc.gov.
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The milk fat encapsulation process consisted of four operations: ingredient blending and heating, homogenization, spray-drying, and packaging. The processing sequence was as follows: The selected encapsulant was first dry-blended with NDM and dispersed in water at 24°C to form a slurry about 25% TS. The anhydrous butter oil or cream was warmed and combined with the emulsifier. After the two blends were combined to produce a mixture with about 25% TS, the slurry was stirred vigorously for 5 min with a milk stirrer, heated to 63°C with continued stirring, homogenized at 17.2 MPa, and spray dried (inlet air temperature 193 to 196°C and outlet air temperature 82 to 87°C). Details of the powder formation process were given by Onwulata et al. (10). After drying and cooling, we assumed that the powder would be packaged in paper bags for shipping and storage.

Physical Plant Costs

We assumed that a facility for encapsulation would be integrated into a larger dairy processing plant. Costs of the facility included the costs for purchasing and installing the processing equipment, the building to house this equipment, and all necessary materials, labor, and technical support required to ensure proper operation. Not included were additional costs common to the entire plant: raw milk unloading and storing, cream separation, and pasteurization. In addition, land, quality control facilities, administrative offices, and the plant utility system were assumed to be part of the total facility and were not addressed.

Specific equipment would be needed for each of the four unit operations described. Equipment would also be needed for CIP systems for process control, and for monitoring to prove sanitation and conformation to regulations.

The ingredient blending and heating area consisted of storage bins, jacketed mixing tanks, solids feeders, mixing devices, and material handling systems. Stainless steel holding tanks were required for the temporary storage of the encapsulant, NDM, butter oil or cream, and emulsifier. Jacketed, stainless steel tanks equipped with agitators of food-grade construction were needed to blend and heat the ingredients. The first mixing tank was used to blend the encapsulant and NDM; the dry blend was fed into a second tank where ambient temperature water was added to form the slurry. The third mixing tank blended the slurry with the previously warmed source of milk fat blended with emulsifier. The process stream was heated to about 63°C in this tank.

Materials handling systems were also needed to transport solids and liquids to and from the processing equipment. The heated slurry was homogenized with standard double-stage unit 10 and 17.2 MPa, depending on the encapsulant selected.

Spray-drying was a multistep operation. A three-stage air spray dryer equipped with an internal sweep in the drying chamber and a fluidized bed was required. The homogenized slurry was sprayed into a stream of hot air where moisture is reduced to <10%; powder particles drop to a fluidized-bed below the drying chamber for additional drying to <5% moisture; the powder is discharged into a fluidized-bed/cooler, where the product was cooled to 30°C and the final moisture content of <4% was attained. The cooled powder was collected into holding tanks, and then fed onto the packaging line, and packaged into standard 22.7-kg poly-lined brown paper bags for storage. The air from the drying chamber was exhausted into a bag filter for recovery of fines and into a heat exchanger for heat recovery. Recovered heat can be used to preheat air blown into the spray dryer or a fluidized bed.

Because a building was needed to house the equipment and personnel, building costs were included at $645/m^2$ for a 36.6- × 18.3-m processing facility and a 18.3- × 18.3-m packaging and storage facility.

A contingency allowance of 15% of all the other capital costs is included to cover any additional equipment costs or process refinements that may be required.

Labor

Labor costs for three plant operators per shift, maintenance personnel, and one supervisor per day were included. The maintenance force was included at 3% of the capital cost for the plant, which averaged about two per shift. Plant operator wages were estimated to be $10/h plus 35% fringe benefits.

Utilities and Other Costs

Natural gas, electricity, steam, and water were the utilities required. Electric requirements were estimated at 408 kW at an annual cost of $121,000, while 7.4 MM BTU/h of natural gas were needed at an annual cost of $121,300. Steam and water costs were small by comparison and, combined, were less than $50,000/yr.

Cost for maintenance materials and operating supplies was calculated at $267,000/yr as a percentage of plant capital cost and operating labor cost; $431,000 was included for general and administrative production overhead, property taxes, and insurance.

The capital cost of the physical plant was spread over 10 yr and prorated over the plant output.

Table 1. Milk fat encapsulation inputs and outputs.

Ingredients	Butteroil with all-purpose flour	Butteroil with modified cornstarch	Butteroil with sucrose	Cream with all-purpose flour	Cream with modified cornstarch	Cream with sucrose
Encapsulant						
Material	All-purpose flour	Modified cornstarch	Sugar	All-purpose flour	Modified cornstarch	Sugar
Quantity required, kg/d	25,300	25,300	24,100	22,000	22,000	21,000
Unit price, $/kg	$0.28	$2.50	$0.64	$0.28	$2.50	$0.64
Milk fat						
Material	Butteroil	Butteroil	Butteroil	Dairy cream	Dairy cream	Dairy cream
Quantity required, kg/d	29,400	29,400	29,400	67,300	67,300	67,300
Unit price, $/kg	$2.06	$2.06	$2.06	$1.07	$1.07	$1.07
Nonfat dry milk						
Material	Nonfat dry milk	Nonfat dry milk	Nonfat dry milk	Nonfat dry milk	Nonfat dry milk	Nonfat dry milk
Quantity required, kg/d	2800	2800	2800	1700	1700	1700
Unit price, $/kg	$2.24	$2.24	$2.24	$2.24	$2.24	$2.24
Emulsifier material	Mono & di-glycerides	Mono & di-glycerides	Mono & di-glycerides	Mono & di-glycerides	Mono & di-glycerides	Mono & di-glycerides
Quantity required, kg/d	1400	1400	1400	1400	1400	1400
Unit price, $/kg	$1.84	$1.84	$1.84	$1.84	$1.84	$1.84
Process water						
Material	Potable water	Potable water	Potable water	Potable water	Potable water	Potable water
Quantity required, kg/d	82,200	82,000	82,100	51,100	51,100	50,500
Unit price, $/kg	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Plant outputs						
Encapsulated butterfat-qty kg/d	57,000	57,000	57,000	57,000	57,000	57,000
Expelled water-qty kg/d	85,000	84,000	83,000	87,000	85,000	85,000

RESULTS AND DISCUSSION

Cost studies were performed with six different combinations of ingredients. Butter oil and cream were alternate sources of milk fat. All-purpose flour, modified cornstarch, sucrose was the encapsulating agent. The processing facilities and the process remained the same for the six cases. Input variations among the six cases are listed in Table 1, and the cost variations are shown in Table 2.

Because milk fat costs fluctuate significantly, depending on geographical location and season of the year, unit costs are expressed in terms of processing costs and do not reflect the cost of the milk components or the encapsulants. All unit prices in Table 1 are estimated prices for the third quarter of 1999.

The process ingredients required for encapsulation of milk fat were the largest contributors to the cost of the product. The combined cost of the ingredients was approximately 90% of the total production cost (processing cost plus ingredients costs). When cream and all-purpose flour were used as the milk fat source and the encapsulant, respectively, the milk fat cost was about 70% and the encapsulant 8% of the total production cost.

Based on the assumptions and costs described, we estimated that spray-dried encapsulated powder containing 50% milk fat could be produced at a cost of $0.23/kg plus the cost of the dairy ingredients and the encapsulant. Butter, containing 80% milk fat, is reported to have average processing costs between $0.198/kg (14) and $0.301/kg (5).

Total costs of the spray-dried encapsulated powder will vary depending on milk fat source and encapsulant chosen. Use of cream as the milk fat source resulted in a lower product cost than powder made with anhydrous butter oil (Table 2). Modified cornstarch was the most expensive encapsulant; sucrose and all-purpose flour were less expensive. Modified cornstarch increased the cost by $0.86 to $0.99/kg over the cost of the powder made with all-purpose flour. Powders with sucrose as the encapsulant were about $0.12 to $0.14/kg more expensive than powders with all-purpose flour.

Additional factors must be considered to qualify these costs properly. Storage costs of frozen butter are about $0.04/kg greater than for unrefrigerated dry powder; this estimate is based on USDA costs of frozen butter versus NDM (Indulus Kancitis, Agricultural Stabilization and Conservation Service, USDA, 1994, personal communication). Transportation costs for a refrigerated product are also greater than costs for an unrefrigerated product.

Table 2. Milk fat encapsulation unit costs per kilogram of product

	Butteroil with all-purpose flour	Butteroil with modified cornstarch	Butteroil with sucrose	Cream with all-purpose flour	Cream with modified cornstarch	Cream with sucrose
Investment cost						
Equipment & facilities cost	$7,235,000	$7,235,000	$7,235,000	$7,235,000	$7,235,000	$7,235,000
Economic life-years	10	10	10	10	10	10
Unit capital cost	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05
Depreciated over 10 years						
Operating cost						
Raw materials						
Encapsulant	$0.13	$1.12	$0.27	$0.11	$0.98	$0.24
Dry skim milk	$0.11	$0.11	$0.11	$0.07	$0.07	$0.07
Butter oil/cream	$1.08	$1.08	$1.08	$1.28	$1.28	$1.28
Emulsifier	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05
Water	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Packaging Material	$0.03	$0.03	$0.03	$0.03	$0.03	$0.03
Total raw materials	$1.39	$2.39	$1.54	$1.54	$2.40	$1.67
Utilities						
Water-w/raw materials						
Natural gas	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Steam	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Electric power	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Total utilities	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Labor						
Direct operating labor						
(3 Operators per shift)	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Maintenance	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Supervision	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fringe benefits	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Total annual labor	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04
Other costs						
Operating supplies	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Maintenance supplies	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
General & administrative costs	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Property taxes	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Insurance	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total other costs	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05
Return on investment	Not included	Not included	Not included	Not included	Not included	Not included
Total unit cost	$1.55	$2.54	$1.69	$1.70	$2.56	$1.82
Unit cost excl. cost of milk products						
(milkfat & dry milk) and encapsulant	$0.23	$0.23	$0.24	$0.23	$0.23	$0.23
Annual production-kilograms	14,934,000	14,934,000	14,934,000	14,934,000	14,934,000	14,934,000
File	BOST	DRUSL	BOSU	CRFM	CRST	CRSU

Butter and NDM are produced in the same facilities in many locations. Underutilization of capacity tends to be a common problem. It is estimated that the average processing costs of butter and NDM could be decreased significantly by increasing capacity utilization (15). Integration of the milk fat encapsulation facilities described in this paper and NDM production lines would reduce processing costs through a combination of greater utilization of production capabilities and the use of larger, more efficient equipment.

The use of fluid skim milk or milk concentrate in place of NDM would also reduce processing and ingredient costs because the encapsulant could readily be dispersed in the fluid product without the necessity for the dry blending step in the process.

CONCLUSIONS

On the basis of this cost analysis, we concluded that a desirable dry product containing milk fat may be produced at a reasonable cost. Because processing cost was 25% or less of the product cost, the preferred product composition could be determined by planned use and component costs. The convenience of storage and the ease with which the powder could be blended with other dry ingredients in a food processing operation were obvious benefits. Such powders could be substituted for shortening in baked goods with considerable success (11). If the powders are to be incorporated as ingredients in dry bakery mixes intended for consumer use, special packaging would be required to prevent exposure to the flour and other mix ingredients, because the powders readily imbibe water under conditions of high relative humidity (11). The encapsulation technology described offers new market opportunities for milk fat utilization to the dairy industry.

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