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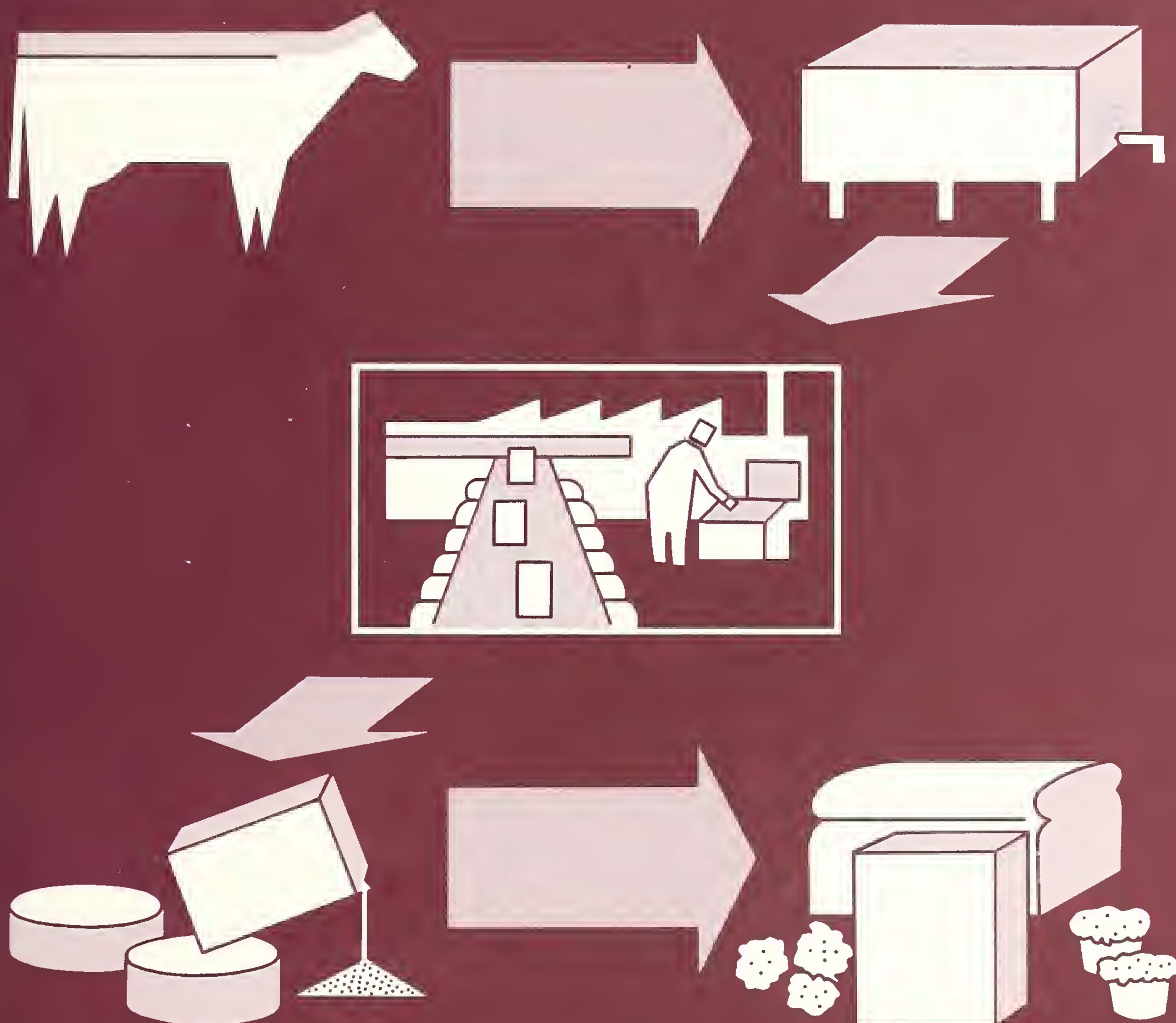
Processing Cottage Cheese Whey

Proposed Commercial Systems for Recovering Edible Protein



Preface

This report describes a fermentation procedure for removing a yeast-whey protein material from cottage cheese whey while reducing the biological oxygen demand (BOD) of the remaining effluent. Commercial systems, based on pilot plant experiments, are described for two different-size plants and include facility and equipment layouts, initial investment and operating costs, and potential benefits.

Special recognition is extended to the late Dr. James B. Mickle, Oklahoma State University, for his dedication and pioneering efforts in the development of the fermentation procedure. Appreciation is also extended to a major public utilities company, and a number of private food and equipment companies for their contribution in developing the equipment cost and product values for the report.

This study was conducted under the general supervision of T. F. Webb, Leader, Animal Products Group, Market Research and Development Division, Agricultural Marketing Service.

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Proposed Commercial Systems for Recovering Edible Protein

By Charles F. Stewart and Stanley E. Gilliland[1]

Summary

Cottage cheese whey, a traditional dairy plant waste product, has presented a serious problem to the industry in recent years due to more rigid environmental controls. The economic impact of these controls has forced the industry to seek new solutions to the whey disposal problem. In an effort to solve this problem, a fermentation procedure has been developed that utilizes the organism *Kluyveromyces fragilis* in conjunction with continuous aeration to remove a yeast-whey protein material from whey, while significantly reducing the biological oxygen demand (BOD) of the remaining effluent. This report includes a detailed description of the fermentation procedure, an evaluation of the recovered yeast-whey protein material, the potential uses and value of the material in various food preparations, and a cost/benefit analysis for two commercial whey-processing plants of different sizes.

A pilot plant was used to conduct the experiments and to evaluate the effectiveness of the fermentaton process and recovery system. The results obtained, based on numerous experiments, showed that the BOD of the whey was reduced by 41.5 to 50.6 percent for an average of 46.4 percent, and the chemical oxygen demand (COD) was reduced by 43.6 to 55.1 percent for an average of 49.0 percent. Additional experiments showed that the reductions in solids were very similar whether whey alone or the whey and first rinse water were included in the treatment process. However, an increase in the aeration rate within reasonable limits was found to contribute to a greater reduction in the COD content of the whey. Approximately 73 pounds of pressed cake or 30 pounds of dried yeast-whey protein material was recovered from each 450-gallon batch of whey processed. Although the volume of recovered material was increased slightly by including the first rinse water in the treatment process, its recovery was considered impractical because of the problems involved and the greater cost of handling the larger volumes of liquid.

The recovered yeast-whey protein material is composed of 53.4 percent whey protein and 46.6 percent yeast cells. The material in paste form contains an average of 10.13 percent protein, 0.48 percent fat, and 13.10 percent solids. The pressed cake contains approximately 32.01 percent protein, 1.52 percent fat, and 41.40 percent solids. The average content of the dried material is 73.75 percent protein, 2.18 percent ash, and 93.70 percent solids. The material in both pressed cake and

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dried form has been used successfully on an experimental basis as an ingredient in improved recipes for various bakery products and snack foods. The estimated value of the material in human food preparations ranges from 56 to 78 cents a pound for pressed cake and $1.30 to $1.80 a pound for the dried material, depending on the type of product in which they are utilized. The material in dry form also has broad application as a nutritional supplement in animal feeds, but at the estimated value of 41 cents a pound, its use for this purpose cannot be economically justified.

Commercial systems based on the pilot plant operation are provided for a 150,000 and a 300,000-pound-a-week whey-processing plant. The 150,000-pound-a-week plant was designed to handle the whey produced in the production of 16,875 pounds of cottage cheese curd, compared with 33,750 pounds for the 300,000-pound-a-week plant. Facility and equipment layouts are provided for each plant operation, as are initial investment cost, annual operating cost, and potential benefits. The production of the finished products in a 1:1 ratio of pressed cake to dried material, for use as a supplement in human food preparations, can be economically justified at the three different price levels ($0.56, $0.67, and $0.78 per pound for pressed cake and $1.30, $1.55, and $1.80 per pound for dried material) in the 150,000-pound-a-week plant. The total annual sales and reduction in sewage surcharges minus total operating cost provides an annual profit margin of $5,385 at the lowest value, $20,473 at the average, and $35,560 at the highest. The break-even volumes, which represent the production levels where total income equals total annual operating cost, are 137,250 pounds a week at the lowest value, 105,000 at the average, and 73,500 at the highest. In the 300,000-pound-a-week plant, the annual profit margin is $39,189 at the lowest value, $69,364 at the average, and $99,539 at the highest. The operating cost per pound of finished products is $0.77 in the 150,000-pound-a-week plant, compared with $0.62 in the 300,000-pound-a-week plant.

Introduction

The dairy industry is facing a major problem concerning the disposal of cottage cheese whey and its impact on the environment. Cheese whey contains the high percentage of biological oxygen demand (BOD), and is the most concentrated waste product the industry must deal with in meeting the pollution standards established by the Environmental Protection Agency (EPA) (*20*).[2]

During 1970-75, the amount of whey produced increased 7.2 times due to greater cheese production. Approximately 58 percent of the whey solids produced in 1975 was utilized in the processing of other products or as animal food, with the remainder disposed of through municipal sewage systems and other methods (*8*).

The industry has long considered whey too dilute to profitably recover the much needed proteins, and the low cost of lactose from other sources made its recovery impractical except in a few limited cases. Consequently, the whey disposal problem has caused municipalities to apply high surcharges on dairy plants for dumping whey in the sewage systems or to ban such practices completely, forcing the dairies to seek alternative methods. These actions became necessary because of the high BOD content and the difficulties sewage plants have in treating whey. For example, a plant producing 100,000 pounds of whey each day would need a sewage treatment plant for whey disposal equal in size to one required for a city with a population of 21,000 (*2*).

Several methods are available to the industry for utilizing liquid whey. Feeding it to farm animals is a common but inadequate method of disposal, because the amount consumed is only a small portion of the large volumes produced. Using liquid whey as a fertilizer presents a problem in that runoff from the land pollutes the natural streams and other waterways. Drying has not proved satisfactory because of high transportation and equipment costs compared with the low value of the product. Ultrafiltration removes the proteins from the whey and concentrates the liquid permeate, but it is a costly procedure that is feasible only in the larger volume cheese-processing plants. Even with this method, the lactose remains in the liquid permeate and must be removed either by drying or by further treatment to reduce the BOD prior to disposal. Many of the larger plants are reluctant to install the process until a more profitable market has been developed for the recovered products. Other methods of concentrating the whey and removing the BOD have also been developed but have many of the same limitations.

[2]Italicized numbers in parentheses refer to items in the references.

Description of the Fermentaton Process and Recovery System

There are approximately 1,924 dairy processing plants in the United States that process fluid milk products and also produce 96 percent of the total annual volume of cottage cheese (*21*). These operations produce approximately 6 billion pounds of acid whey each year. The disposal of this whey because of its high acid content is a serious problem—not only due to the nature of the material, but also the large number of widely scattered plants involved in processing such small volumes (less than 10,000 pounds a day) of cottage cheese as a secondary part of the total operation. Most of the plants are located in metropolitan areas with limited options available for disposing of the material. Since cottage cheese whey contains highly nutritious food ingredients (lactose and protein) and presents a serious disposal problem, an efficient recovery system should be developed for salvaging the product and controlling pollution.

This report deals exclusively with the utilization and/or disposal of cottage cheese whey. The purpose of the study is to develop a workable and efficient whey-handling system for small- to medium-size plants, utilizing to the fullest extent possible lower cost used equipment commonly available in the industry. Research is directed toward determining the most reliable procedure on a pilot plant scale for treating and recovering the protein material from whey while reducing pollution, establishing the nutritional value of the recovered product, identifying possible market outlets and obtaining a realistic value for the product, and developing commercial plant systems of various sizes for industry applications. Initial investment, annual operating costs, and potential benefits for two different-size plants are provided, as well as facility and equipment layouts and proper operating methods. The feasibility of the commercial systems is determined on the basis of whether the value of the recovered product offsets the cost of the recovery system or to what extent the systems reduce the disposal cost of the whey through municipal systems.

A fermentation process using the yeast *Kluyveromyces fragilis* to utilize the lactose, coupled with a heating process to precipitate the whey proteins along with the yeast cells, significantly reduces the BOD level of the remaining effluent. This yeast, previously identified as *Saccharomyces fragilis* (*2, 12, 22, 23, 24, 25, 26, 27*), has been used successfully in other studies to remove the lactose from whey. *Tovula cremoris* (*9, 10, 11*) has also been utilized in a similar manner.

In most of the studies using *K. fragilis*, the whey was supplemented with either ammonium sulfate, dipotassium phosphate and yeast extract (*23, 24, 26, 27*), peptone (*22*), or corn steep liquor (*2*) to increase the yield of yeast cells. However, the addition of these materials complicated the disposal of the remaining effluent after the yeast cells had been removed. The whey in most cases was heated to precipitate the protein prior to inoculation on the assumption that it would improve yeast cell growth. But Wasserman (*27*) found that *K. fragilis* grew equally well in unheated whey and therefore, eliminated the preheating procedure in his experiments. Knight et al. (*12*) reported that fermenting unsupplemented cottage cheese whey with *K. fragilis* followed by heating and removal of the yeast-whey protein material resulted in a reduction of the COD of the effluent by as much as 70 to 80 percent. Based on these findings and the additional research conducted in this study, the fermentation process was selected for use in developing an acceptable recovery system for commercial application.

Culture Preparation

The preparation and handling of the starter culture used in fermenting whey is a key element of the recovery process, and one in which extensive research has been conducted. Redel (*17*) and Redel et al. (*18*) found that frozen storage (−16°C) of suspensions of *K. fragilis* containing 25 percent sucrose resulted in a gradual loss of culture viability, while similar suspensions stored at 3°C resulted in even greater losses. These preparations and storage conditions failed to provide a suitable means of maintaining highly active cultures during long-term storage. Biweekly subculturing appears to be the most promising method of maintaining culture viability. Experiments in this study comparing frozen storage (−14°C) and subculturing procedures showed that the number of yeast surviving at −14°C decreased as storage time increased up to 10 weeks (table 1). In most cases, the biweekly subculture procedure produced higher populations. However, the centrifugation and aseptic methods required to prepare the cultures in either form would prohibit their use in most dairy processing plants. The handling methods

Table 1.—Storage stability of *K. fragilis* in frozen culture compared with biweekly subculture

Weeks of storage	Frozen culture[1]	Biweekly[2] subculture
0	6.3 × 10^9	6.3 × 10^9
2	5.1 × 10^9	7.6 × 10^9
4	---	5.7 × 10^9
6	3.3 × 10^9	3.9 × 10^9
8	3.1 × 10^9	5.7 × 10^9
10	2.3 × 10^9	6.8 × 10^9
12	3.0 × 10^9	8.3 × 10^9

[1]Stored at – 14°C.
[2]Stored at 8°C.

are also costly in terms of the time and labor involved, and impractical for the smaller plants which would normally not have the required specialized equipment.

The following procedure was developed for preparing the initial or fresh culture for fermenting whey in the pilot plant. A schematic presentation of the culture preparation procedure is shown in figure 1. One loop of cells from a fresh lactose agar slant (4 percent lactose, 2 percent peptone, 0.1 percent yeast extract, and 1.5 percent agar; autoclaved 15 minutes at 121°C) of *K. fragilis* Y-1156 is inoculated into 10 milliliters (ml) of lactose broth (same formulation with agar deleted) and

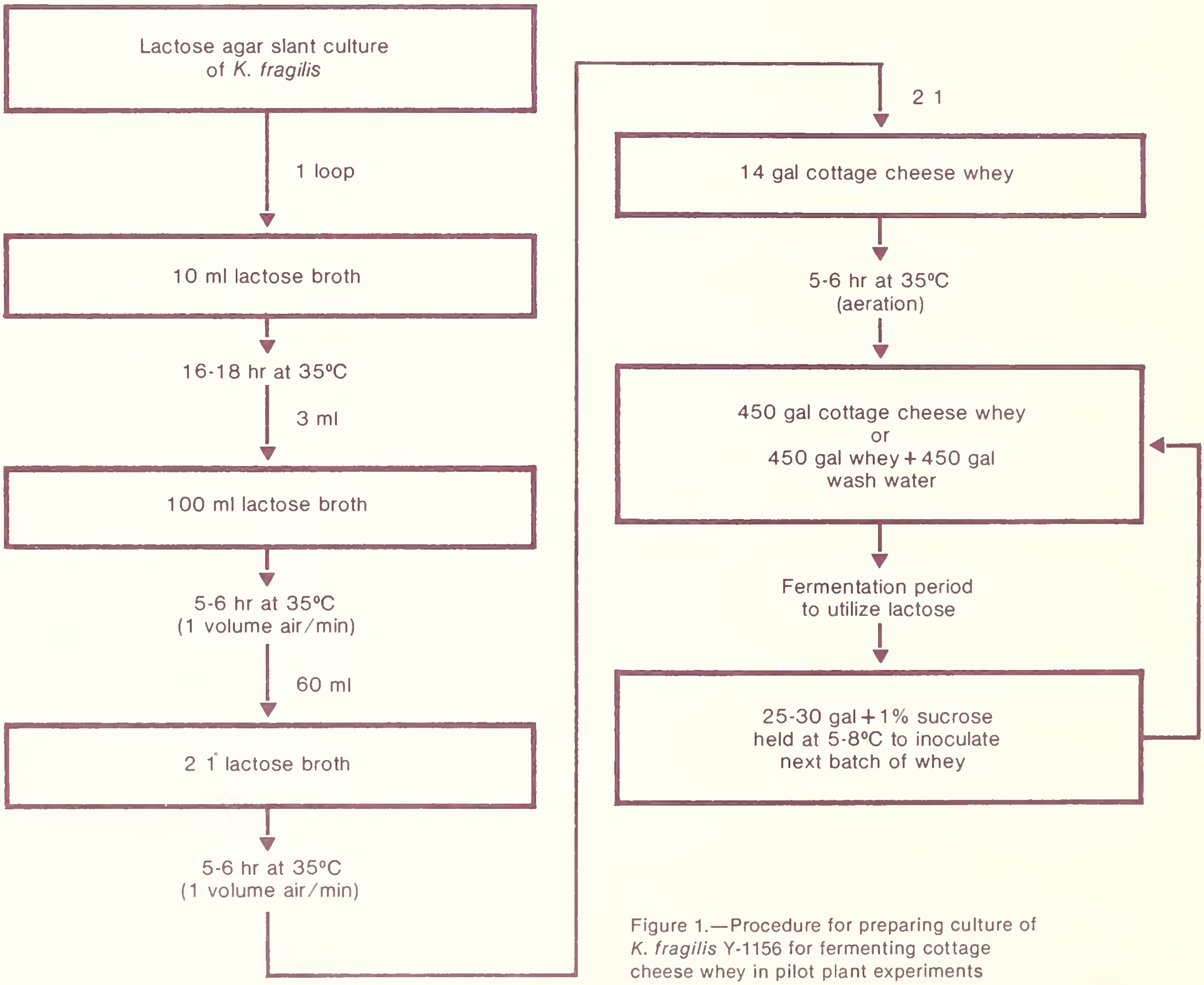

Figure 1.—Procedure for preparing culture of *K. fragilis* Y-1156 for fermenting cottage cheese whey in pilot plant experiments

incubated 16 to 18 hours at 35°C. A 3 ml portion of this culture is inoculated into 100 ml of lactose broth and incubated 5 to 6 hours at 35°C with continuous aeration (1 volume of air per volume culture per minute). From this culture, 60 ml is inoculated into 2 liters (l) of lactose broth and incubated 5 to 6 hours at 35°C using the same rate of aeration. The 2 l of lactose broth culture, which is then incubated 5 to 6 hours at 35°C with continuous aeration, is used to inoculate 14 gallons of fresh cottage cheese whey. The 14 gallons of whey culture is used to inoculate either 450 gallons of cottage cheese whey or 450 gallons of whey plus 450 gallons of the first wash water. In order to ferment successive batches of whey, 25 to 30 gallons of each batch is collected after complete fermentation of the lactose, supplemented with 1 percent sucrose, and held under refrigeration (5° to 8°C) for inoculating the next batch. Sucrose is added to provide an energy source for the yeast during refrigeration.

This culturing procedure provides a reliable means of producing adequate amounts of active *K. fragilis* for fermenting cottage cheese whey in commercial dairy plants. However, future developments may provide suitable frozen concentrated cultures of this organism for direct inoculation of the whey. The availability of concentrated cultures would make the fermentation process even more attractive because handling of the culture would be greatly simplified (*3, 4*).

Pilot Plant Experiments

Equipment Utilized The pilot plant equipment used to evaluate the cottage cheese whey fermentation process and the recovery of the yeast-whey protein material is shown in table 2. The 1,000-gallon tank used to ferment the whey was aerated by piping air from the air compressor at maximum output (346 liters or 12.2 cubic feet per minute) through a stainless steel sparging line positioned along the inside bottom of the tank. The hot water and steam needed to precipitate the solids was supplied by a small boiler. A wire rack lined with duck cloth was used to drain the spent whey from the recovered solids. Plastic containers (30-gallon capacity), some of which have perforated bottoms, and duck cloth were used for pressing the recovered yeast-whey protein paste material to further remove the liquid effluent. A small cheese press was used to further concentrate the yeast-whey protein material. A wire sieve with 1/4-inch openings was used to cut the pressed yeast-whey cakes for ambient drying on a table covered with unbleached muslin. Laboratory equipment was used to determine the effectiveness of the whey treatment procedure and the compositional value of the recovered product.

Table 2.—Equipment utilization and total time required in pilot plant trials to ferment cottage cheese whey and recover yeast-whey protein

Equipment	Primary function	Time[1]
		Hours
Stainless steel insulated, water jacketed, horizontal tank (1,000-gallon capacity)	Holding vessel	44
Stainless steel sparging line (5/8-inch diameter, 6 feet long, with 1/8-inch holes at 2-inch intervals over entire length)	Distributes air	24
Boiler (25 hp with steam-water mixing station and hoses)	Steam injection	5
Air compressor (two cylinder, 22 cubic feet per minute at 100 psi, 1800-rpm motor)	Sparging	24
Draining rack (5 feet long, 2-1/2 feet wide. and 4 inches deep with wire bottom)	Initial drainage	4
Plastic containers—6 (30-gallon capacity)	First pressing	12-16
Cheese press (small conventional type)	Second pressing	4
Wire sieve (16 by 16-inch with 1/4-inch opening)	Cutting and dicing	1
Drying table (2 by 3 ft)	Ambient drying	24-30
Miscellaneous (stainless steel fittings, tygon hoses, adapters, valves, etc.)	---	---

[1]Includes cleaning.

Operating Procedures Approximately 450 gallons of cottage cheese whey and 450 gallons of first rinse water were pumped directly from the plant cheese vat into the 1,000-gallon fermenting tank. The temperature of the whey and rinse water was adjusted to 35°C by circulating either cold or warm tap water through the jacket of the tank. Antifoam (50 ml of Sigma Antifoam A emulsion, containing 30 percent silicone, manufactured by the Sigma Chemical Company) was added to control excessive foaming. Thirty gallons of *K. fragilis* starter (withdrawn from the previous batch) or 14 gallons of freshly prepared culture were added to the mixture and allowed to incubate for 24 hours with continuous aeration (0.1 volume of air per volume of whey per minute). After 16 hours of incubation, 30 gallons of culture were withdrawn for inoculating the next batch, 1 percent sucrose was added, and the mixture was stored at 5°C. The aeration was discontinued at the end of the 24-hour period, and "live" steam was injected by submerging a steam hose into the cultured whey until the temperature reached 88°C. After steaming, the precipitated solids (yeast cells and whey protein) were allowed to settle for a minimum of 14 hours.

After the yeast and whey proteins settled, the effluent was siphoned from the tank and allowed to flow directly into the drainage system. The solids (yeast-whey protein material) remaining in the bottom of the tank were recovered by draining the highly viscous material on racks covered with duck cloth. After the material had drained for 4 hours on the racks, the solids (approximately 200 pounds) were placed into 30-gallon plastic containers with sloping walls and perforated bottoms and lined with duck cloth. Each container was filled to approximately one-third capacity and contained about 70 pounds of solids. A nonperforated plastic container of the same size and shape was placed on top of the solids material in the perforated container and filled with water to serve as a press. The material was pressed for 12 to 16 hours and then placed in gauze-lined cheese hoops and pressed for 4 hours with the cheese press by gradually applying increased pressure to further expel the residual effluent. In those instances where the material was dried, the resulting yeast-whey pressed cakes were forced through coarse wire sieves with ¼-inch openings and spread on clean muslin cloth for ambient drying using electric fans for blowing air over the material. This operation presented a problem because of the length of time required to dry the material sufficiently. There is also a question of whether slow drying at room temperature has an undesirable effect upon the chemical structure or bacteriological composition of the material. The research data did not show this to be a problem; however, a faster drying method is needed to reduce processing time.

Approximately 73 pounds of pressed cake or 30 pounds of dried yeast-whey protein material was recovered from each of the 450-gallon batches of whey processed in the pilot plant. An additional 3 pounds of dried material was obtained by including the first rinse water in the fermentation process. The recovered material could be utilized either in pressed cake or dry form. The pressed cake is somewhat more difficult to handle, but can be easily incorporated into recipes where other ingredients having a texture such as shortening are used. The dry form, which is much simpler to handle, is highly versatile and can be easily blended with other dry ingredients in preparing various food recipes or products for nonhuman consumption.

The yeast-whey protein material in cake form can be stored in polyethelene-lined barrels or corrugated boxes and held until used at 40°F (4.4°C) in refrigerated storage. The material stored in this manner must be utilized within a reasonable length of time because of eventual quality deterioration. The impact of extended storage time was not determined, although it could be an important factor for processors or potential users to consider in selecting the form best suited to their individual needs. The material in dry form requires no refrigeration and can be stored for longer periods in paper containers (sacks) or heavy gage plastic bags. The packaged products can be handled individually or in palletized form, and shipped in the appropriate environment.

Analytical Monitoring of Fermentation Process Samples for analyses were taken from the fermentaton tank immediately after inoculation (0 time), at the end of the incubation period (24 hours), after steam injection when the solids had settled (effluent), after draining (yeast-whey protein cake), and after drying (dried-yeast-whey protein material). The whey was analyzed for lactose content at 0 and 24 hours using the picric acid method (*16*). Protein measurements were made using the Kjeldahl procedure. The biological oxygen demand (BOD) and the chemical oxygen demand (COD) of the unfermented whey and the effluent from the heated and precipitated cultured whey were determined using procedures outlined by the Environmental Protection Agency (*19*). The numbers of *K. fragilis* per ml in that portion removed at the end of the fermentation period for culturing successive batches were determined by plating samples on Sabauraud dextrose agar and incubating the plates 48 hours at 35°C.

The results obtained from analyzing samples collected during five trials in which cottage cheese whey plus the first wash water were fermented are shown in table 3. No lactose remained in the whey at the end of the 24-hour fermentation period in any of the trials. The amount of total protein decreased slightly during the same time period, while the pH increased from a range of 4.6 to 4.7 up to 4.8 to 5.1. The reduction in BOD values ranged from 41.5 to 50.6 percent for an average of 46.4 percent, while the reduction in COD values ranged from 43.6 to 55.1 percent for an average of 49.0 percent. These reductions are considerably lower than the 70- to 80-percent reduction of COD obtained in laboratory experiments reported by Knight et al. (*12*). These experiments included the fermentation of undiluted whey rather than the combination of whey and first rinse water as was done in the initial pilot plant trials. Since this difference could account for variations in the fermentation and resulting reduction of COD, additional pilot plant trials were conducted to study the fermentation of undiluted whey.

The results obtained from analyzing the samples collected in these trials are presented in table 4. Only an average of 0.03 percent lactose remained in the whey at the end of the 24-hour fermentation period. The amount of total protein also exhibited little or no change. The BOD values were not determined on these samples. However, the COD values were determined showing that the reductions ranged from 39.7 to 49.6 percent for an average of 44.2 percent. These reductions in COD were very similar to those obtained in the earlier pilot plant trials involving the fermentation of the whey and the first wash water. Because of the large volume of liquid involved in treating the whey and the first rinse water compared with whey alone and the small differences in the analysis, the first rinse water should be eliminated in the treatment procedure. Larger capacity equipment is required to handle the greater volumes resulting in unnecessarily higher costs that cannot be justified economically on the basis of the small amount of additional solids recovered (approximately 3 pounds per batch) and the slight increase in COD reduction.

Table 3.—Analyses of whey and effluent samples from cottage cheese whey and first wash water fermented with *K. fragilis*

Sample/time	Analysis	Trial I	II	III	IV	V	Avg.
Whey-0 hr	Lactose (%)	2.15	2.85	2.95	2.88	2.31	2.63
	Protein (%)	0.42	0.46	0.45	—	0.53	0.47
	BOD (ppm)	18,640	26,480	24,960	22,420	28,360	24,172
	COD (ppm)	62,120	46,886	45,300	44,680	51,613	50,120
	pH	4.60	4.70	4.70	4.70	4.70	4.68
	K. fragilis/ml	2.4×10^6	5.0×10^6	3.1×10^6	2.0×10^6	1.7×10^6	2.8×10^6
Whey-24 hr	Lactose (%)	0	0	0	0	0	0
	Protein (%)	0.33	0.37	0.35	0.39	—	0.36
	pH	4.90	4.80	5.10	5.10	5.10	5.00
	K. fragilis/ml	1.2×10^8	6.8×10^8	1.2×10^8	1.3×10^8	1.3×10^8	1.1×10^8
Effluent-24 hr	Protein (%)	0.12	0.13	0.13	0.16	0.16	0.14
	BOD (ppm)	10,360	15,480	13,080	11,074	14,720	12,943
	BOD (% reduction)[1]	44.40	41.50	47.60	50.60	48.10	46.40
	COD (ppm)	28,490	26,293	20,353	23,040	29,110	25,457
	COD (% reduction)[1]	54.10	43.90	55.10	48.40	43.60	49.00
	pH	4.90	4.80	5.10	5.20	5.10	5.02

[1]Percent reduction $= \frac{(\text{“0” time value}) - (\text{effluent value})}{(\text{“0” time value})} \times 100.$

The air flow rate used in sparging the tank of whey and/or whey and first rinse water during the fermentation period was 12.2 cubic feet per minute when applied at the maximum output of the compressor. This is equivalent to 0.2 volumes of air per volume of whey per minute for the tank containing 450 gallons of whey, and 0.1 for the tank containing 450 gallons each of whey and first rinse water. In the laboratory scale experiments reported by Knight et al. (*12*), air was sparged through the whey during fermentation at a rate of one equal volume per minute, resulting in the higher percentage reduction in COD. The lesser amount of aeration in the pilot plant trials might have accounted for the poorer performance in reducing the COD of the whey. It may also be attributed to the differences in the laboratory procedures used by Knight and those used in these experiments, which appear to be more suitable for measuring the COD content of cultured whey (*6*).

Three additional trials were conducted in the pilot plant to determine and evaluate the effects of increased aeration during the fermentation period on the reduction of COD. In these trials, 225 gallons of whey were placed in the tank with one-half of the previous amount of inoculum added. The whey was aerated at the maximum output (12.2 cubic feet per minute) of the compressor which, in effect, doubled the rate of aeration to 0.4 volume of air per volume of whey per minute. The results obtained from analyzing the samples collected in these trials are shown in table 5. The reduction in COD values ranged from 51.9 to 58.2 percent for an average of 55.9 percent. This average reduction is somewhat greater than the 44.2 percent obtained in the previous trials using an aeration rate of 0.2 volume per minute (table 4). However, from a practical and economical standpoint, there is a limitation on the amount of air that can be effectively sparged into a tank containing whey without experiencing serious operational problems. The maximum aeration rate for a tank of a given size and volume of whey was not determined because of equipment limitations in the pilot plant, although a greater rate than that used in these experiments would be feasible.

A centrifuge could be expected to improve the removal of fine precipitated protein particles from the cultured whey, further reducing the organic matter in the effluent. It would also reduce the operations time required for removing the solids from the effluent by approximately 35 hours per batch and eliminate the draining racks and possibly the plastic containers used in the pilot plant experiments. Further research is needed prior to incorporating a centrifuge into the recovery system to determine if an existing model can be modified and used or if one designed specifically for this operation will be required. Since this equipment is not normally found in a cottage cheese plant, the cost in relationship to the benefits obtained may be prohibitive, particularly for a small-volume operation.

The cheese press was evaluated to determine its effectiveness in removing the residual effluent remaining in the yeast-whey protein cake, after it had been pressed for 12 to 16 hours using the plastic drainage containers. The results obtained from six experiments showed that the pressed material contained approximately 41.4 percent solids, compared with 25.0 percent prior to using the press. The cheese press was unsatisfactory when attempts were made to press the yeast-whey protein material prior to using the plastic drainage containers. Therefore, the plastic drainage containers are necessary and should be used in conjunction with the cheese press for removing the residual effluent.

A forced-air oven would significantly reduce the drying time of the yeast-whey protein material. The present method of ambient drying which requires 24 to 30 hours does not lend itself well to a continuous operation and requires excessive time, equipment, and floor space for drying the material. A commercial-type oven such as is found in the baking industry could be used; however, one designed specifically for the operation would probably be more effective. Before incorporating the use of an oven, determinations should be made concerning the appropriate temperature, air velocity, and exposure time required to achieve the desired drying level. Although an oven is not standard equipment in cottage cheese plants and was not evaluated in the pilot plant experiments, its application would be highly beneficial when considering the substantial reductions in drying time and associated costs.

Table 4.—Analyses of whey and effluent samples from undiluted cottage cheese whey fermented with *K. fragilis*

Sample/time	Analysis	Trial I	Trial II	Trial III	Avg.
Whey-0 hr	Lactose (%)	4.30	4.35	3.54	4.06
	Protein (%)	0.78	0.90	0.86	0.85
	COD (ppm)	72,060	75,726	75,780	74,522
	pH	4.50	4.70	4.70	4.63
	K. fragilis/ml	2.4×10^5	2.4×10^5	1.7×10^5	2.2×10^5
Whey-24 hr	Lactose (%)	0.01	0.04	0.05	0.03
	Protein (%)	0.80	0.96	0.87	0.88
	pH	4.70	4.80	4.80	4.77
	K. fragilis/ml	1.5×10^8	1.6×10^8	1.6×10^8	1.6×10^8
Effluent-24 hr	COD (ppm)	40,910	38,160	45,710	41,593
	COD (% reduction)[1]	43.20	49.60	39.70	44.20

[1]Calculated by formula shown in table 3 footnote.

Table 5.—Effect of increased aeration on the reduction of chemical oxygen demand (COD) in whey and effluent samples from undiluted cottage cheese whey fermented with *K. fragilis*[1]

Sample/time	Analysis	Trial I	Trial II	Trial III	Avg.
Whey-0 hr	Lactose (%)	4.80	4.82	4.44	4.69
	Protein (%)	0.89	0.90	0.91	0.90
	COD (ppm)	72,478	69,330	74,041	71,950
Whey-24 hr	Lactose (%)	0.07	0.10	0.03	0.07
	Protein (%)	0.96	0.99	1.03	0.99
Effluent-24 hr	COD (ppm)	30,285	33,333	31,576	31,731
	COD (% reduction)[2]	58.20	51.90	57.40	55.90

[1]Aeration rate doubled from 0.2 to 0.4 volume per minute.
[2]Calculated by formula shown in table 3 footnote.

Labor Requirements in the Pilot Plant Approximately 6.75 hours of labor is required of one employee to carry out the necessary procedures for processing each of the 450-gallon batches of whey or the whey and first rinse water. This represents the actual working time to conduct the entire process from preparing the starter through the various stages including cleaning and maintenance of equipment and facility. Of the 6.75 hours, 4.25 are required to conduct the process through the stages where the yeast-whey protein material is pressed into cake form, while the remaining 2.50 hours are needed for the drying and packaging operations. Most of the estimated total elapsed time of 100 hours per batch involves those processing periods requiring no labor such as the fermentation, pressing, and drying operation, some of which could be substantially reduced by incorporating a centrifuge and drying oven.

The following is a breakdown by functions of the actual labor hours required to process and handle each batch.

Functions	*Hours*
Preparing starter	.33
Transferring whey	.17
Fermenting whey	.25
Removing solids and draining	1.50
Pressing solids	.75
Cubing solids for drying	1.25
Drying	.75
Packaging and storing	.50
Cleaning equipment	.75
Cleaning facility	.33
Maintenance	.17
Total	6.75

Evaluation of Recovered Yeast-Whey Protein Material

Compositional Analysis The amount of yeast cells and whey protein contained in the recovered yeast-whey protein material has been reported (*7*). A summary of the results showed that 53.4 percent of the recovered material was whey protein and 46.6 percent was yeast cells (table 6). However, the actual amount of yeast cells in the material is probably somewhat less than 46.6 percent since any fine curd particles remaining in the whey from the cheese processing operation would have been included with the yeast cells in these measurements.

The yeast-whey protein material in both paste and dry form was analyzed for protein content using the Kjeldahl digestion method. Fat content determinations were made using ether extraction, while conventional procedures described by the Association of Analytical Chemists were used to determine ash content (*1*). Total solids were determined by drying analytically weighed 2-gram portions of the material in a forced air oven for a minimum of 15 hours at 100°C.

The results obtained from analyzing five batches of the yeast-whey protein paste material and resulting dried product are presented in table 7. The paste material contained an average of 10.13 percent protein, 0.48 percent fat, and 13.10 percent solids. The average content of the dried material was 73.75 percent protein, 2.18 percent ash, and 93.70 percent solids. The low ash content shows that only a small amount of the salts in the original whey were collected with the yeast-whey protein material. Fat content was not determined on the dried material, however; the 0.48 percent in the paste material is equivalent to 3.67 percent on a dry weight basis. Based on the protein/solids relationship of the material in paste form, the composition of the pressed cake is approximately 32.01 percent protein, 1.52 percent fat, and 41.40 percent solids.

Table 6.—Concentration of yeast cells and whey protein in product recovered from cottage cheese whey fermented with *K. fragilis*

Sample	Weight			Percentage	
	1st set	2nd set	Average	Yeast cells[1]	Whey protein[2]
	Grams	*Grams*	*Grams*	*Percent*	*Percent*
Yeast + whey protein	0.2961	0.3034	0.2998	—	—
Yeast cells	.1347	.1447	.1397	46.6	—
Whey protein	.1614	.1587	.1601	—	53.4

[1] $\frac{\text{Yeast cells weight}}{\text{Yeast + whey protein weight}} \times 100 = \%$ yeast cells.

[2] $\frac{\text{Whey cell weight}}{\text{Yeast + whey protein weight}} \times 100 = \%$ whey protein.

The yeast-whey protein material in dry form was analyzed for mineral and amino acid composition. Mineral content was determined using an atomic absorption spectrophotometer with the results presented in table 8. Amino acid determinations were reported by Mickle, et al. (*14*). These data are summarized in table 9. The information contained in these tables provides an excellent profile of the nutritional value of the recovered product, which is necessary in developing improved formulations of animal or human food products.

Table 7.—Analyses of yeast-whey protein material recovered from cottage cheese whey fermented with *K. fragilis*

Sample	Analysis	Batch					Average
		I	II	III	IV	V	
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Paste material[1]	Protein	11.58	11.13	11.84	7.81	8.29	10.13
	Fat	.54	.64	.46	.45	.31	.48
	Solids	15.40	13.40	15.50	10.40	10.80	13.10
Dried material	Protein	72.95	71.76	73.46	73.56	77.00	73.75
	Solids	91.60	92.90	95.80	92.00	96.40	93.70
	Ash	1.43	2.50	2.50	1.99	2.48	2.18

[1]Composition before pressing.

Table 8.—Mineral composition of yeast-whey protein material recovered from cottage cheese whey fermented with *K. fragilis*

Mineral	Ppm[1]
Sodium	1,437
Potassium	11,168
Magnesium	794
Calcium	3,636
Phosphorus	9,405

[1]Parts per million on dry weight basis.

Table 9.—Amino acid composition of yeast-whey protein material recovered from cottage cheese whey fermented with *K. fragilis*

Amino acid	m moles/100 g protein	g/100 g sample[1]
Valine	38.4	3.2
Leucine	64.1	6.0
Isoleucine	31.2	3.1
Phenylalanine	17.8	2.1
Methionine	10.2	1.1
Cystine	22.8	2.0
Lysine	47.6	5.0
Threonine	32.6	2.8
Alanine	43.7	2.8
Proline	29.8	2.4
Glycine	24.5	1.3
Serine	36.0	2.7
Tyrosine	16.4	2.1
Aspartic acid	58.9	5.5
Glutamic acid	79.0	8.2
Arginine	13.6	1.7
Histidine	9.2	1.0
Nonprotein nitrogen	93.6	1.3

[1]Dried material containing 73.75 percent protein.

Economic Analysis. The economic value of the yeast-whey protein material is based on both the market value of the product as an animal or human food supplement and the reduction in high surcharges for disposing of untreated whey in municipal sewage systems. Therefore, the analysis must include an evaluation of the production cost/selling price relationship of the material, as well as the difference in disposal cost of untreated whey compared with the effluent remaining after the fermentation process.

The estimated cost of producing the yeast-whey protein material is based on the operating capital and total annual ownership and operating cost required in establishing a processing system. It includes such items as facilities, equipment, supplies, utilities, and labor, which have the greatest influence on operating cost. Since many of these costs vary significantly in relation to the volume processed, they are presented in detail only in that section of the report dealing with specific-size commercial systems.

According to a 1980 quotation from the research department of a major animal feeds company, the dried yeast-whey protein material should command a price of at least 41 cents a pound because of its high protein content (73.75 percent). This is a much better return than the 23 to 25 cents a pound received for most feed grade yeast products, which contain only 40 to 48 percent protein. However, the use of the material in animal feed formulations is secondary in that it does not provide the potential returns obtainable in human food preparations.

The estimated value (based on 1980 prices) of the yeast-whey protein material as a food supplement for human consumption ranges from 56 to 78 cents a pound for the pressed cake and $1.30 to $1.80 a pound for the dried material, depending on the type of product in which they are utilized. The price range was provided by a major chemical company involved in the manufacture of food supplements. These estimates are based on the price of comparable commercial products having somewhat similar nutritional values. The material has been evaluated by several different types of food processors as an ingredient in their product formulations, with impressive results. However, most firms are reluctant even to consider establishing a value since the material is not commercially available. The potential for successfully developing new, high-value uses for the material is excellent but will depend to a large extent on the ability of industry to provide a dependable and adequate supply.

The disposal cost of dairy processing waste through municipal treatment systems was provided by the public works water and sewage departments of several cities, both large and small throughout the United States. Most of them based the charges on volume, BOD, and suspended solids, although some included such items as phosphorus and chlorine demand. The cost per pound (based on 1980 quotations) for treating the solids material in the untreated whey and in the effluent was the same in all cases, and ranged from $0.010 to $0.039 per pound for BOD. The fermentation procedure reduced the BOD from 181.4 pounds in the untreated whey to 96.7 pounds in the effluent of each 450-gallon batch. This reduction of 46.6 percent was achieved by eliminating the first rinse water and increasing the sparging rate to 0.4 volume of air per minute. Based on the average quoted rate of $0.0258 a pound, a disposal cost (surcharge) of $4.68 is required for treating the BOD in the untreated whey as compared to $2.49 in the effluent. Therefore, by culturing the whey and recovering the yeast-whey protein material, a savings of $2.19 is obtained for each of the 450-gallon batches of whey processed.

The fermentation procedure does not reduce the BOD of the effluent enough to provide an acceptable sewage without surcharge (less than 250 ppm), therefore, additional treatment is required. In those instances where the municipalities refuse to accept the effluent because its high BOD content overloads their treatment systems, the only alternatives are to discontinue processing or find another method of disposal. However, by culturing the whey and reducing the BOD prior to disposal, less demand is placed on municipal systems, thereby improving the probability of receiving continued service.

Potential Market Outlets

Human Foods

The yeast-whey protein material has been used successfully on an experimental basis as an ingredient in the development of improved recipes for various bakery products and snack foods. It has also been blended with several different types of meat products, such as pork sausage, to increase the nutritional value. These products represent only a small fraction of the potential opportunities that exist for using the material in human food preparations. Therefore, additional uses must be developed in order for the material to reach its fullest potential.

Bakery Products. Bakery products include the general categories of breads and pastries. The material which is either substituted in whole or used in conjunction with the flour in the various recipes improves body texture and increases the protein levels of the finished products. Mayer and Trickel (*13*) developed a yeast-whey protein material using a laboratory procedure similar to the one used in this study. Their product was used as a bakery additive to yeast-ferment bread dough to strengthen the sidewalls, increase baked volume, and produce a finer cell structure.

Snack Foods. Snack foods, which include cookies and wafers, crackers, chips, and other similar products, are natural targets for supplementation with the yeast-whey protein material. They are composed essentially of wheat flour and other sources of carbohydrates, but are generally lacking in protein. The addition of the material in these products does not appear to affect their acceptability and would be beneficial in supplying the much needed protein requirements in a form perhaps more acceptable than the conventional protein sources. A number of food companies have expressed an interest in using the material, due primarily to the current emphasis on improving the nutritional value of these types of products.

Cookies and crackers—The yeast-whey protein material was used experimentally in various forms in developing four different high-protein cookie and cracker formulas (*5*). The ingredients in a basic vanilla wafer were altered to create a recipe for cookies containing approximately 15 percent yeast-whey protein material (table 10). The same recipe was further altered by incorporating cocoa to produce a chocolate wafer. A recipe for oatmeal cookies was also developed using the yeast-whey protein material instead of flour (table 11). All cookie recipes were supplemented with dried, finely ground, yeast-whey protein material containing approximately 90 to 95 percent solids. A cheese-flavored, cracker-type product was also developed using the yeast-whey protein material in a partially dry pressed form containing approximately 40 percent solids (table 12). Incorporation of the material into these products resulted in a 2.3- to 3.9-fold increase in the protein content (table 13). The organoleptic qualities of the products were not adversely affected.

Chips—A "chip type" product similar to many of the commercial types presently on the market has been developed that utilizes the yeast-whey protein material. Detailed information concerning the procedure for manufacturing the product is contained in a recent patent (*15*).

Animal Feeds

The yeast-whey protein material has broad application as a nutritional supplement in animal feeds. Livestock nutritionists have indicated that the material may be useful as a partial replacement for the soybean protein commonly used in feed formulations. The addition of the material would be of particular value for young animals that require a high-quality protein in their diets.

The pet food industry has expressed an interest in the material as a partial replacement for the meat protein in many of the different types of pet foods presently available on the market. There is also a possibility that the material can be used to enhance the flavor of the various blends, making them more palatable and acceptable.

Table 10.—Experimental recipe for vanilla wafers using yeast-whey protein material

Ingredient	Original recipe	Experimental recipe
Shortening	5.25 g	7.75 g
Sugar	25.00 g	27.00 g
Egg	6.00 g	12.00 g
Milk	7.50 ml	3.00 ml
Vanilla	1.88 ml	3.00 ml
Baking powder	.90 g	.90 g
Salt	.38 g	.38 g
Flour	28.00 g	26.50 g
Yeast-whey protein (dry)	—	15.00 g

Table 11.—Experimental recipe for oatmeal cookies using yeast-whey protein material

Ingredient	Original recipe	Experimental recipe
Shortening	21.25 g	21.25 g
Sugar	21.75 g	40.00 g
Brown sugar	25.00 g	—
Egg	12.50 g	12.50 g
Vanilla	.75 ml	1.00 ml
Flour	25.00 g	—
Salt	.62 g	.62 g
Soda	.37 g	.37 g
Oats	28.00 g	28.00 g
Apple pie spice	—	.50 g
Yeast-whey protein (dry)	—	25.00 g

Table 12.—Experimental recipe for cheese-type crackers using yeast-whey protein material

Ingredient	Basic pie crust recipe	Experimental recipe
Flour	42.00 g	25.50 g
Salt	.05 g	1.00 g
Baking powder	—	.50 g
Shortening	14.50 g	14.50 g
Grated sharp cheddar cheese	—	25.00 g
Yeast-whey protein (dry)	—	35.00 g
Water	10.00 ml	10-20.00 ml[1]

[1]Sufficient water added to obtain desired dough consistency.

Table 13.—Compositional comparison of selected snack foods containing yeast-whey protein material versus similar type commercial products

Product	Protein		Fat		Solids	
	USDA[1]	Expt.	USDA[1]	Expt.	USDA[1]	Expt.
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Vanilla wafers	5.4	20.9	16.1	14.2	97.2	96.8
Chocolate wafers	7.1	20.5	15.7	16.7	96.0	96.8
Oatmeal cookies	6.2	21.7	15.4	23.8	97.2	97.6
Cheese-type cracker	11.2	26.3	21.3	33.8	96.1	91.8

[1]Values from "Composition of Foods," Agriculture Handbook No. 8, Agricultural Research Service, USDA, Washington, D.C. 1963.

Commercial Plant Systems

Commercial plant systems are developed for a 150,000- and a 300,000-pound-a-week cottage cheese whey-processing plant, utilizing the fermentation procedure described in this report. The systems are planned as additions to existing facilities or as a part of new ones, and are located adjacent to the cottage cheese processing rooms. This arrangement eliminates the need for providing additional employee welfare areas, laboratory services, and supervisory and managerial support. It also simplifies the operations performed, permits good cross-utilization of labor, and minimizes operating costs.

The plants are constructed of reinforced concrete and steel and finished in brick or other material of similar value. They are rectangular and have a flat roof design and a minimum interior ceiling height of 20 feet. The individual areas in both plants include a fermentation room, utility room, drying and packaging room, cooler and dry storage rooms, and a covered dock. The 20-foot ceiling height is needed in the fermentation and utility rooms to allow for the installation of equipment and to provide sufficient headspace to facilitate the removal of a greater than normal volume of air. The remaining areas have a 12-foot interior ceiling height, accomplished by installing a drop ceiling. This installation reduces the cost of utilities, and leaves the space above available for other purposes should it become necessary in the future. A vestibule serves as an entrance to avoid direct access between the whey-processing areas and other areas of the plant. It helps in controlling the environmental conditions in the rooms, and substantially reduces the possibility of microbial contamination that can be a serious problem in processing cottage cheese. The only differences between the two plants are the size of the buildings and the additional and larger capacity equipment required to process the greater volume.

Although whey-processing plants of this type do not presently exist, they presumably would be required to meet the same regulatory standards as other food-processing facilities. Therefore, many design and operational characteristics must be incorporated into the planning and construction of the new plants. The floors must have smooth surfaces that are impervious to moisture, easily cleaned, and of sufficient strength to support the weight of the equipment. The type, size, and location of floor drains and the slope of the floor must be adequate for removing the spent water and liquid effluent that is associated with the whey-processing operation. The walls and ceilings must be smooth, washable, light in color, and moisture resistant. Hot and cold water outlets and handwashing facilities must be conveniently located in those areas where needed.

Safety features must be incorporated into the plant design for employee protection. Also, the construction material used must have the ability to absorb sound in order to minimize the noise level and comply with the standards (*28*). Adequate lighting, heating, ventilation, plumbing, and electrical facilities must be provided throughout the plant. Provisions must also be made to handle the effluent discharged from the plant. Good handling practices are essential; however, in some instances, waste treatment facilities may be required to comply with the guidelines (*20*). Because of the complex issues involved, qualified personnel should be consulted to determine these requirements.

The plants are designed and equipped for processing whey three periods each week to coincide with a 3-day-a-week cheese-processing operation. The whey-processing periods are restricted to three times a week because of the approximately 44 hours of total elapsed operating time required for each batch. Therefore, the only alternative available for handling an increase in volume is the installation of additional or larger capacity equipment.

The recovered yeast-whey protein material is processed and packaged: 50 percent as pressed cake and the remainder in dry form. This ratio was selected to provide the flexibility needed to meet changing market demands. The pressed cake is packed for storage and shipping in polyethylene-lined fiberboard barrels containing approximately 275 pounds each, while the dried material is placed in plastic-lined paper bags in 100-pound quantities.

Good used or reconditioned equipment, common to the dairy industry, is utilized to the fullest extent possible in equipping the plants. Since this equipment can be purchased at a substantially lower cost, acquiring the optimum sizes for processing a given volume is not absolutely essential as long as the minimum requirements are met. In those instances where specialized equipment is required and not available, it must be either fabricated or purchased new to meet plant requirements.

Caution must be exercised in the planning and construction of whey-processing plants. The facility design and operating methods must meet the regulatory requirements of all responsible government agencies. The appropriate authorities must approve the finished products prior to their use in the preparation of commercial food or other similar products. Also, a dependable and profitable market must be established for the finished products.

Description of the 150,000-Pound-A-Week Whey-Processing Plant

The 150,000-pound-a-week whey-processing plant is designed and equipped to handle the whey obtained in processing 56,250 pounds of skim milk each day, 3 days a week, into cottage cheese. The daily volume of skim milk, processed in three 2,000-gallon cheese vats, produces approximately 5,625 pounds of cheese curd and 50,000 pounds of whey. The whey, excluding all rinse waters, represents the volume to be processed during each of the three weekly processing periods.

Layout of Facilities and Equipment. The layout of the 150,000-pound-a-week whey-processing plant shows the proposed arrangement of the individual areas and equipment (fig. 2). A breakdown of usable floorspace by individual areas and a detailed description of each are as follow:

	Sq ft
Fermentation room	1,757
Utility room	280
Drying and packaging room	632
Cooler storage room	198
Dry storage room	248
Covered dock	280
Total	3,395

Fermentation room—The fermentation room, which is rectangular except for an area in one corner occupied by the utility room, is located next to the cheese-processing room. It is the largest single area of the plant, providing space for installing and operating the equipment needed to ferment the whey and for draining and pressing the recovered yeast-whey protein material. A section of semipermanent wall 8 feet high and 10 feet wide provides access for moving equipment into or out of the room.

The three 2,500-gallon, horizontal, cylindrical, fermentation tanks are installed on a 3-foot high platform to facilitate the removal of the recovered solid material. A sparging line configuration composed of stainless steel sections of pipe connected by sanitary fittings is installed along the inside bottom of each tank (fig. 3). The pipes are of 1-inch inside diameter with a row of 3/16-inch holes spaced at 2-inch intervals over the entire bottom surface. The six portable drain racks are box-like, fabricated units, 5 feet long, 2½ feet wide, and 8 inches deep, with wire-mesh bottoms lined with duck cloth, and are mounted on wheels for easy maneuverability. The racks, which can be positioned directly beneath the tank discharge valves, have an overall height of 42 inches, each with a holding capacity of approximately 400 pounds of material. A prefabricated walk-in cooler, 6 feet by 11½ feet, is provided for storing the forty 10-gallon cans of starter used each processing period to ferment the three tanks of whey. The 85 perforated and nonperforated 30-gallon capacity plastic containers used for the initial pressing operation are stored after cleaning in the wash area, alongside the utility room wall.

Space is also available across the front of the fermentation tanks for filling the containers and in the corner next to the starter cooler for holding the material while it is being pressed. Two work tables 3 feet wide and 6 feet long are provided for transferring the material from the plastic containers into 75 cheese hoops for final pressing. The single-row cheese press, which is 24 feet long, is installed parallel with the wall on the side of the room opposite the tanks. It has the capacity for pressing in two separate periods the total volume of material obtained from all three tanks. A reach-through window is installed in the wall next to the press for transferring the hooped material into the drying and packaging room.

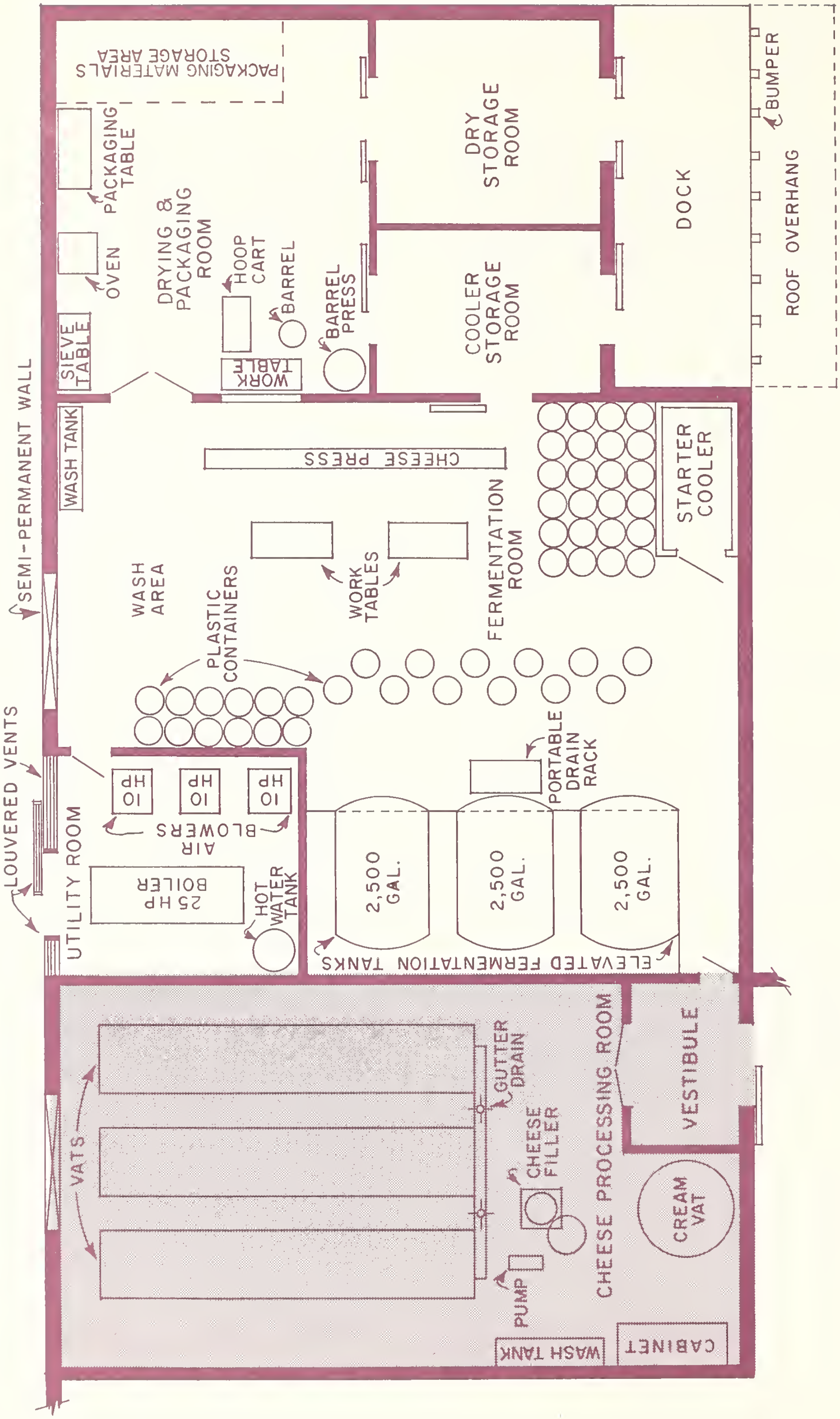

Figure 2.—Layout of a 150,000-pound-a-week cottage cheese whey processing plant.

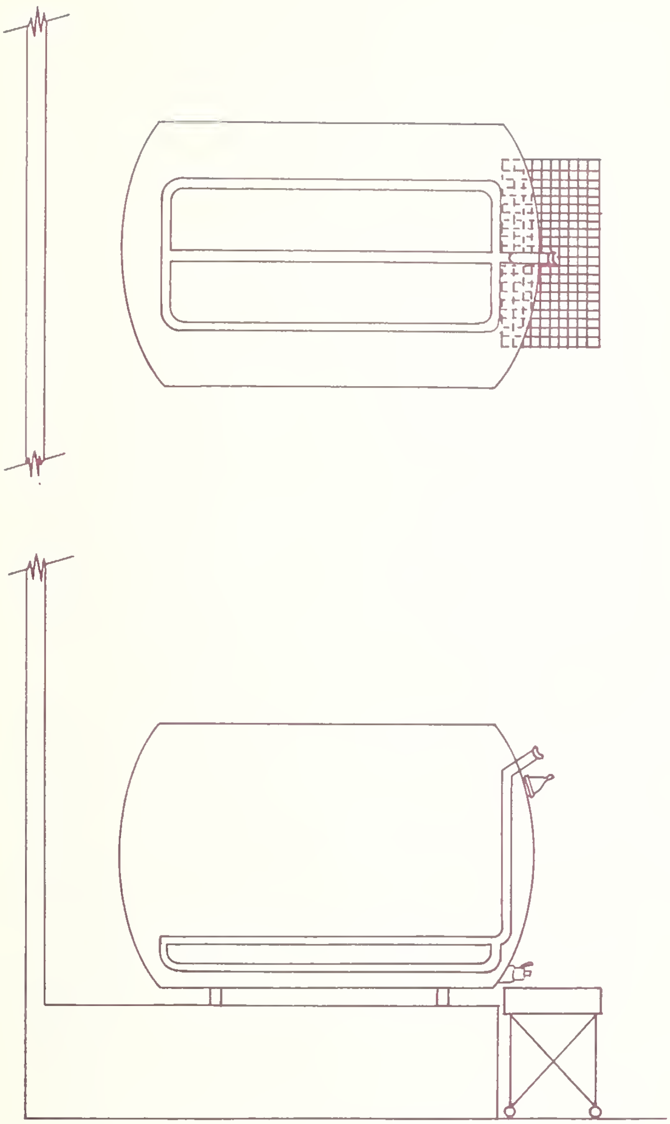

Figure 3.—A sparging line configuration in a fermentation tank.

Utility room—The utility room is 16 feet by 17½ feet and occupies an area directly adjacent to the fermentation tanks. This location next to the area of greatest need reduces installation cost and improves the operating efficiency of the equipment. The room is designed to house a 25-hp boiler and its supporting equipment and three 10-hp, positive displacement, rotary air blowers. The outside wall and the sliding door that provide access to the room are of louvered construction for dissipating heat, and to make available an unrestricted flow of air to the blowers. A doorway 6 feet wide and 8 feet high is provided to facilitate the movement of equipment into or out of the room.

The 25-hp boiler provides the hot water needed to clean the plant and equipment and the live steam for precipitating the solids in the whey. Based on an analysis of the heating requirements, sufficient boiler capacity is provided for steaming the whey in all three tanks simultaneously. In some instances surplus boiler capacity will already be available in the parent facility, thus eliminating the need for a separate boiler in the whey-processing plant.

The 10-hp air blowers are connected by overhead pipes to the sparging line configurations installed in each of the three fermentation tanks. They are designed to provide a variable capacity of 95 to 130 cubic feet of air per minute (CFM) at an operating pressure of 8-pounds-per-square-inch gage (PSIG). The pressure is required to offset that exerted by the depth of the whey in the tanks and to remove that portion which gets into the sparging lines as the tanks are being filled and the blowers are not in operation.

Drying and packaging room—The drying and packaging room, 23 feet by 27½ feet, provides the space needed for removing the hoops, packing the pressed cake, oven drying, and packaging. The equipment includes three work tables, a conventional barrel press used for pressing cheese curd, a portable hoop cart, and a forced air oven. The forced air oven, which has a temperature range of 100° (37.8°C) to 350°F (176.7°C) and an air velocity of 4 cubic feet a minute, is capable of drying in four separate batches the total volume of pressed cake scheduled each processing period.

Approximately 100 square feet of floorspace is set aside in the room for storing on pallets or similar structures the annual volume of barrel liners and plastic-lined bags used in packaging both the pressed cake and the dried material. Space is also available for storing an inventory supply of replacement plastic containers and fiberboard barrels.

Cooler storage room—The cooler storage room, 12 feet by 16½ feet, is located next to the drying and packaging room, and is used for storing the barrels of pressed cake. Space is provided for storing an 18-day processing inventory of 30 barrels of material weighing approximately 8,250 pounds. A 4-foot-wide aisleway, extending the length of the cooler, is used for moving the barrels by handtrucks into storage position and to the covered dock for shipping.

Dry storage room—The dry storage room, 15 feet by 16½ feet, is located next to the cooler storage room between the drying and packaging room and covered dock. Space is provided on each side of a 6-foot-wide center aisle for storing on pallets a 48-day processing inventory of ninety 100-pound bags of dried material. Space is also available for storing the cleaning materials, the cloth and muslin used for draining and pressing the recovered solids, and the sucrose that is added to each successive batch of starter. Handtrucks are used to move the bags of dried material from the packaging area to storage and shipping and to receive and handle supplies.

Covered dock—A covered dock 10 feet wide and 28 feet long provides direct access into both the cooler and dry storage rooms. It is 42 inches high to correspond to the average truckbed height of wholesale trucks, and protected by vertical bumpers spaced at 18-inch intervals along the facing. The roof extends 6 feet past the edge of the dock to protect the receiving and shipping operations.

Operating Procedures. The whey, excluding all rinse water, is pumped from the cheese vats in equal proportions of 1,852 gallons per tank into the three 2,500-gallon fermentation tanks. Hot water from the boiler or either cold tap water or sweet water from the parent facility is circulated through the jackets of the tanks to adjust the temperature of the whey to 35°C. Approximately 100 ml of the antifoam solution is added to each tank of whey to control excessive foaming. After the initial preparation and use of the fresh culture, 123 gallons of starter (withdrawn from the previous batch) are added to each tank and allowed to incubate for 24 hours with continuous aeration. The starter is added to each tank by pumping it from the 10-gallon cans through one of the open portholes at the top front of the tanks. An aeration rate of 100 cubic feet of air per minute (0.4 volume of air per volume whey per minute) is sparged into each of the three tanks of whey. After the whey has been aerated for 16 hours, the 123 gallons of starter needed to inoculate the next batch are withdrawn from the discharge valve of each tank, 1 percent sucrose is added, and the mixture is placed in storage at 5°C. Aeration is discontinued at the end of the 24-hour period, and live steam is injected through the sparging line configuration until the temperature of the fermented whey reaches 88°C. Approximately 5 hours of steaming time is required to raise the temperature of the volume of material in each tank from 35°C to 88°C. After the steaming operation is completed, a minimum period of 14 hours is required to allow the precipitated solids to settle out of the mixture.

After the solids have settled, the supernatant liquid (effluent) above the sludge line (separation point between solids and effluent) is siphoned off by inserting a drainage pipe through one of the top outlets of each tank. The removal of the effluent can be simplified by installing an outlet valve in the tank heads at a level slightly above the normal sludge line. The highly viscous solids material (sludge) is then manually removed from the tanks through the manholes and placed in the lined racks. The effluent initially removed from the tanks and the drainage from the sludge in the racks are permitted to flow directly into the drainage system. The material is allowed to remain on the racks for a 4-hour draining period, before being transferred into the plastic containers for initial pressing. The estimated volume of 2,469 pounds of material obtained from the 3 tanks is placed in the plastic containers in 70-pound quantities and pressed for 14 hours by the procedure used in the pilot plant.

At the end of the initial 14-hour pressing period, the resulting 1,505 pounds of paste material is manually removed from the plastic containers and placed in the gauze-lined, 25-pound capacity cheese hoops for final pressing. The hoops are placed in the cheese press and pressed in two separate 4-hour periods. During each period the pressure is gradually increased from 8 to 15 pounds per square inch. The estimated 900 pounds of pressed cake obtained from the two pressing periods is transferred to the drying and packaging room for further processing.

The 900 pounds of pressed cake is manually removed from the cheese hoops, and one-half is pressed into the lined barrels and stored in the cooler for future shipment. The empty hoops are transferred on carts into the fermentation room for washing and storage. The other 450 pounds is cut with a wire sieve into ¼-inch particles and spread evenly on pans at a depth not to exceed 2 inches for drying in the oven. Based on the texture and moisture content of the pressed material, an oven temperature of 180°F (82.2°C) for up to 2 hours is required for drying each batch. The material, which is dried in four separate batches, is placed in the bags and moved into storage until ready for shipment. The pans used for drying are transferred by cart and washed in the fermentation room. After cleaning they are stored in the oven.

A suggested schedule showing each of the three processing periods is provided for processing the weekly volume of whey (fig. 4). It is designed with the periods overlapping to create a continuous operation, and to permit good cross-utilization of labor. The operations conducted in each period are categorized into two phases: the fermentation procedures and remaining operations. The fermentation procedures include tank cleaning and preparation, sparging and steaming the whey, and allowing the solids to settle, for a total elapsed time of 44 hours. The remaining operations include draining, pressing, drying, and packaging the material for a total elapsed time of 36 hours.

Initial Investment Cost. The initial investment cost for the 150,000-pound-a-week whey-processing plant includes the facilities, the equipment, and necessary operating capital. The estimated cost of building the plant is $85,753 (table 14). It is based on an average cost of $23.23 per square foot of floorspace. The value of the land is excluded from the building cost, since the plants represent additions to existing facilities normally having sufficient space available for expansion. However, it does include the cost of preparing the site, and installing the sewer, water, and electrical systems.

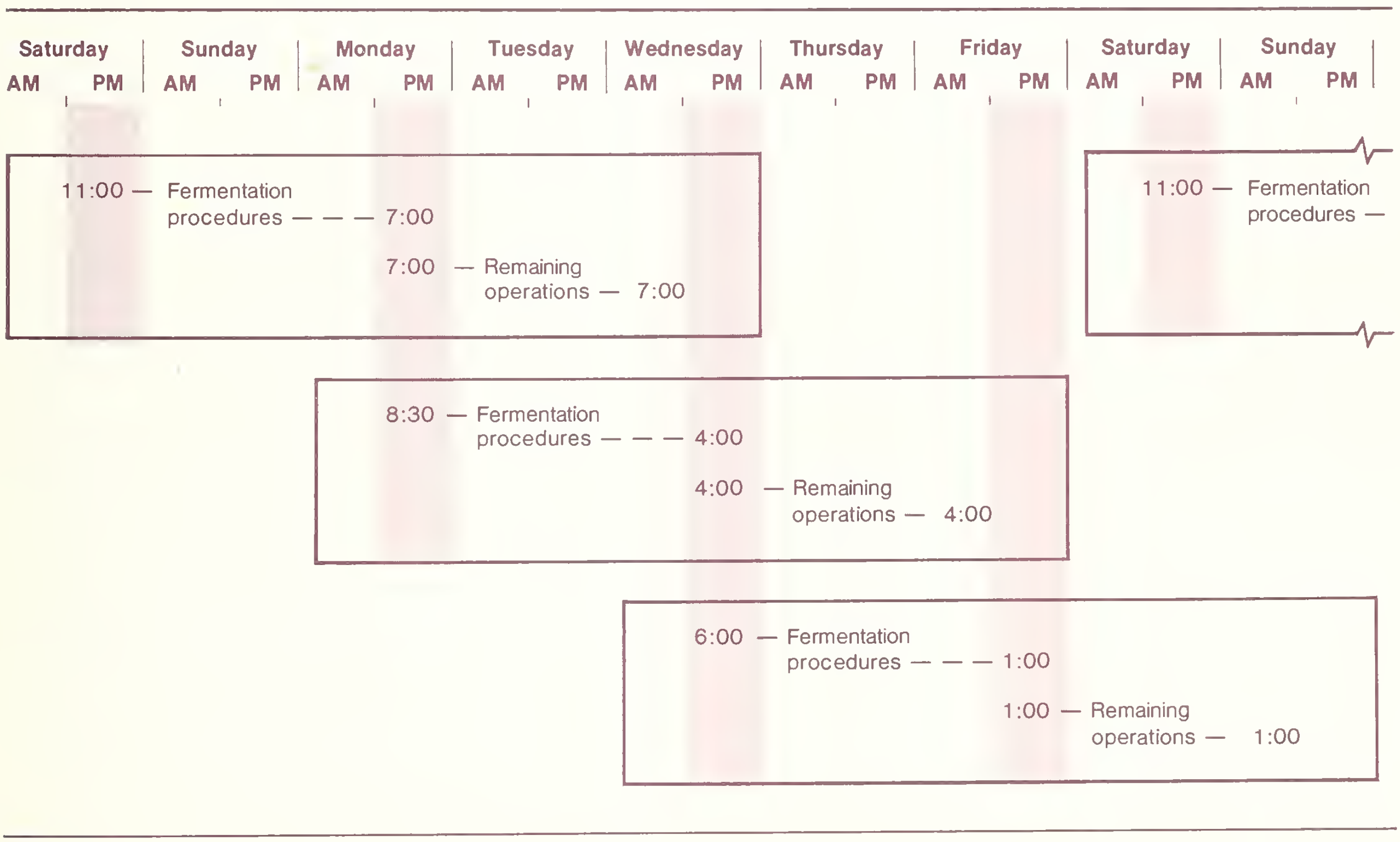

Figure 4.—Suggested weekly schedule for processing 150,000 pounds of whey

The estimated equipment cost for the plant is $74,030, and includes the following:

	Dollars
Starter cooler, walk-in box—6′ × 11½′ (new)	3,650
Stainless steel cans (40), 10 gal each (used)	1,800
Stainless steel, insulated, water-jacketed, horizontal tanks (3), 2,500 gal each (used)	13,725
Stainless steel sparging system (3), 1″ diameter lines with 3/16″ holes spaced at 2″ intervals each (new)	2,250
Boiler, 25-hp (new)	21,350
Air blowers (3), 10-hp, 100 cubic feet per minute (new)	19,500
Portable drain racks (6), 5′ × 2½′ × 8″ (new)	900
Plastic containers (85), 30 gal each (new)	1,020
Cheese press, single row (used)	1,200
Cheese hoops (75), 25 lbs each (used)	900
Hoop carts (2) (used)	300
Wash tank (used)	1,450
Tables (5) (used)	875
Barrel press (used)	750
Forced air oven (new)	2,260
Handtrucks (2) (used)	100
Miscellaneous (equipment, installation, etc.)	2,000
Total	74,030

"New" refers to 1980 manufacturers' suggested retail price, including transportation and installation where applicable.

"Used" refers to 1980 costs of used or reconditioned equipment, including transportation and installation where applicable, supplied by various equipment sales companies.

Table 14.—Estimated construction cost for the 150,000-pound-a-week whey-processing plant

Component	Area	Average cost per square foot[1]	Total cost
	Sq ft	*Dollars*	*Dollars*
Fermentation room	1,895	25.00	47,375
Utility room	315	20.00	6,300
Drying and packaging room	685	18.00	12,330
Cooler storage room	216	40.00	8,640
Dry storage room	296	18.00	5,328
Dock area[2]	285	8.00	2,280
Miscellaneous (site preparation, sewer, water, and electrical systems)	—	—	3,500
Total or average	3,692	23.23	85,753

[1]Based on 1980 cost of similar type of facilities built in areas with comparable construction cost.
[2]Includes roof and extension.

Approximately 71 percent of the total equipment cost is for new equipment compared with 29 percent for used or reconditioned equipment. This relationship of new to used equipment was made arbitrarily to illustrate the combination that would normally be available to plant operators in equipping such facilities. The initial investment can be substantially reduced by purchasing used or reconditioned equipment. Since most of the equipment is of a low-maintenance type, buying it used or reconditioned does not have an adverse effect on maintenance cost.

An operating capital of $7,814 (table 15) is required before starting an operation. It provides the initial supplies and funds necessary to get the business underway.

Table 15.—Estimated initial investment and total annual ownership and operating cost in the 150,000-pound-a-week whey-processing plant

Cost item	Initial investment	Annual ownership and operating cost
	Dollars	*Dollars*
Facilities	85,753	13,978[1]
Equipment	74,030	15,991[2]
Supplies	—	4,419
Utilities	—	13,708[3]
Labor	—	24,708
Contingency	—	3,640[4]
Operating capital	7,814[5]	—
Total	167,597	76,444

[1]Based on 20 years' depreciation, 12 percent interest on investment, and 5 percent for taxes, insurance, maintenance, etc. Capital recovery formula used to compute cost:

$$\text{Depreciation: } \frac{\$85{,}753}{20} = \$4{,}288$$

$$\text{Average interest: } \$85{,}753 \times \frac{(0.12)}{(2)} \times \frac{(21)}{(20)} = \$5{,}402$$

$$\text{Taxes, insurance, etc.: } \$85{,}753 \times (0.05) = 4{,}288$$

[2]Based on 10 years' depreciation, 12 percent interest on investment, and 5 percent for taxes, insurance, maintenance, etc. Computed by previous formula using 10-year depreciation scale.
[3]Based on usage requirements provided by a major public utilities company computed at $0.40 a therm for natural gas, $0.05 a kilowatt hour for electricity, and $3.11 per 1,000 gallons of water.
[4]Based on 5 percent of total annual ownership and operating cost.
[5]Includes 2-week volume of supplies plus 10 percent of total annual ownership and operating cost.

Annual Ownership and Operating Cost. The estimated total annual ownership and operating cost in the 150,000-pound-a-week whey-processing plant is $76,444 (table 15). It includes all of the items to be incurred in the operation and the impact each has on the total annual cost. Labor is the largest single cost item representing approximately 32 percent of the total.

The annual cost of supplies ($4,419 f.o.b. at plant dock) includes duck cloth and muslin, starter ingredients, packaging containers, cleaning materials, and the replacement of plastic containers and other reusable items subject to damage. This cost is relatively low since many of the items are reusable in the processing operation.

Approximately 4,118 annual staff-hours of labor are required to operate the plant at a cost of $24,708 (table 16). An estimated 63 percent of the total labor cost is devoted to the pressing, cubing, drying, and packaging operations. Except for the latter three and the storing and shipping operations, two employees are required to conduct the plant operations.

The operating cost per pound of finished products based on the 1:1 ratio of pressed cake to dried material is $0.77 in the 150,000-pound-a-week plant, compared with $0.62 in the 300,000-pound-a-week plant (table 17). Also, as the volume of products processed is reduced to the break-even points at the three different price levels, the operating cost per pound is increased from $0.82 at the lowest value to $0.97 at the average, and to $1.12 at the highest. This trend of increased volume versus reduced unit cost is expected in a properly planned processing operation.

A cost comparison showed that the profit of total annual sales is 24.55 percent in processing and packaging the product in 100-percent pressed cake form, 22.08 percent in a 1:1 mixture of pressed cake to dried, and 16.24 percent in dried form. Therefore, the greater the volume of product marketed as pressed cake, the higher the profit margin per pound of product sold. This is due to the additional cost involved in drying the material.

Table 16.—Estimated total annual labor requirements and cost in the 150,000-pound-a-week whey-processing plant based on the weekly schedule shown in figure 4

Operation	Time per period	Employees involved	Staff-hours per period	Total annual staff-hours	Total annual[1] cost
	Hours	*Number*	*Hours*	*Hours*	*Dollars*
Fermentation procedures (preparing tanks, transferring whey, adding starter, sparging, steaming, and settling)	1.250	2	2.50	390	2,340
Removing solids from tanks and draining	.750	2	1.50	234	1,404
Pressing solids:					
Barrels with water	1.750	2	3.50	546	3,276
Cheese hoops and press	3.625	2	7.25	1,131	6,786
Cubing, drying, and packaging	6.000	1	6.00	936	5,616
Storing and shipping	.250	1	.25	39	234
Cleaning and maintenance (facilities and equipment)	1.500	2	3.00	468	2,808
Spare and relief	—	—	—	374[2]	2,244
Total	15.125	—	24.00	4,118	24,708

[1]Based on an average wage rate of $6.00 per hour including fringe benefits.
[2]Represents a 10-percent additional staff-hour allowance.

Table 17.—Economic evaluation and potential benefits of the various sizes of whey-processing plants

Plant size	Price levels for recovered material		
	Lowest $0.56/lb pressed cake $1.30/lb dried material	*Average* $0.67/lb pressed cake $1.55/lb dried material	*Highest* $0.78/lb pressed cake $1.80/lb dried material
	Dollars	*Dollars*	*Dollars*
150,000 lbs/week			
Income:			
Total annual sales	77,610.00	92,698.00	107,785.00
Reduction in surcharges	4,219.00	4,219.00	4,219.00
Total	81,829.00	96,917.00	112,004.00
Annual operating cost	76,444.00	76,444.00	76,444.00
Annual profit margin	5,385.00	20,473.00	35,560.00
Operating cost/pound	0.77	0.77	0.77
300,000 lbs/week			
Income:			
Total annual sales	155,225.00	185,400.00	215,575.00
Reduction in surcharges	8,438.00	8,438.00	8,438.00
Total	163,663.00	193,838.00	224,013.00
Annual operating cost	124,474.00	124,474.00	124,474.00
Annual profit margin	39,189.00	69,364.00	99,539.00
Operating cost/pound	0.62	0.62	0.62
137,250 lbs/week[1]			
Income:			
Total annual sales	71,040.00	—	—
Reduction in surcharges	3,861.00	—	—
Total	74,901.00		
Annual operating cost	74,901.00[2]	—	—
Annual profit margin	0	—	—
Operating cost/pound	0.82	—	—
105,000 lbs/week[1]			
Income:			
Total annual sales	—	64,894.00	—
Reduction in surcharges	—	2,952.00	—
Total		67,846.00	
Annual operating cost	—	67,846.00[2]	—
Annual profit margin	—	0	—
Operating cost/pound	—	0.97	—
73,500 lbs/week[1]			
Income:			
Total annual sales	—	—	52,765.00
Reduction in surcharges	—	—	2,067.00
Total			54,832.00
Annual operating cost	—	—	54,832.00[2]
Annual profit margin	—	—	0
Operating cost/pound	—	—	1.12

[1]Break-even volume at designated price.
[2]Plus or minus $100.

Potential Benefits. The cost of producing the material in dried form for use in animal feed cannot be economically justified at the selling price of $0.41 a pound either in the 150,000- or 300,000-pound-a-week plant. The total annual loss in the 150,000-pound-a-week plant is approximately $48,103, compared with $67,791 in the 300,000-pound-a-week plant. These figures represent the difference between total annual sales and reduction in sewage surcharges, and the total annual operating cost. The analysis indicated a trend showing that as the volume increases the losses also increase, but at a declining rate. Therefore, it is apparent that a break-even cost point cannot be reached at a realistic volume level.

The production of the finished products in a 1:1 ratio of pressed cake to dried material, for use as a supplement in human food preparations, can be economically justified at each of the three different price levels in the 150,000-pound-a-week plant (table 17). The total income, which includes annual sales and reduction in sewage surcharges minus total annual operating cost, provides an annual profit margin of $5,385 at the lowest value, $20,473 at the average, and $35,560 at the highest.

The break-even volumes, which represent the production levels where total annual income equals total annual operating cost, are 137,250-pounds-a-week at the lowest value, 105,000 at the average, and 73,500 at the highest (table 17). Therefore, the price received for the recovered products plays a major role in determining the minimum volume required to justify the construction of a whey-processing plant.

Description of the 300,000-Pound-A-Week Whey-Processing Plant

The 300,000-pound-a-week whey-processing plant is designed and equipped to handle the whey obtained in processing 112,500 pounds of skim milk each day, 3 days a week, into cottage cheese. The daily volume of skim milk which is processed in five 2,500-gallon cheese vats produces approximately 11,250 pounds of cheese curd and 100,000 pounds of whey. This represents the volume of whey to be processed during each of the three weekly processing periods.

Layout of Facilities and Equipment. The layout of the 300,000-pound-a-week whey-processing plant shows the proposed arrangement of the individual areas and equipment (fig. 5). A detailed description of the plant is not provided, since the only difference other than size between it and the 150,000-pound-a-week plant is the additional and larger capacity equipment required to handle the larger volume. A breakdown of usable floorspace by individual plant areas is as follows:

	sq ft
Fermentation room	2,596
Utility room	389
Drying and packaging room	1,134
Cooler storage room	533
Dry storage room	390
Covered dock	360
Total	5,402

The 25-hp boiler is adequate to handle the larger volume although it may be necessary to stagger the operations so that all tanks are not being steamed simultaneously. However, in most cases, this will not be necessary since surplus capacity in the parent facility will likely be available to take up the slack.

Operating Procedures. The operating procedures used in the 300,000-pound-a-week plant are the same as those for the 150,000-pound-a-week plant, except for quantitative differences in the treatment and recovery processes. The whey is transferred from the cheese vats into five 3,000-gallon fermentation tanks in equal proportions of 2,222 gallons or 74 percent of tank capacity. Approximately 125 ml of antifoam solution is added to each tank to control excessive foaming. An estimated 148 gallons of starter is added to the contents of each tank to ferment the whey. An aeration rate of 120 cubic feet of air a minute (0.4 volume of air per volume of whey per minute) is sparged into each of the five tanks of whey.

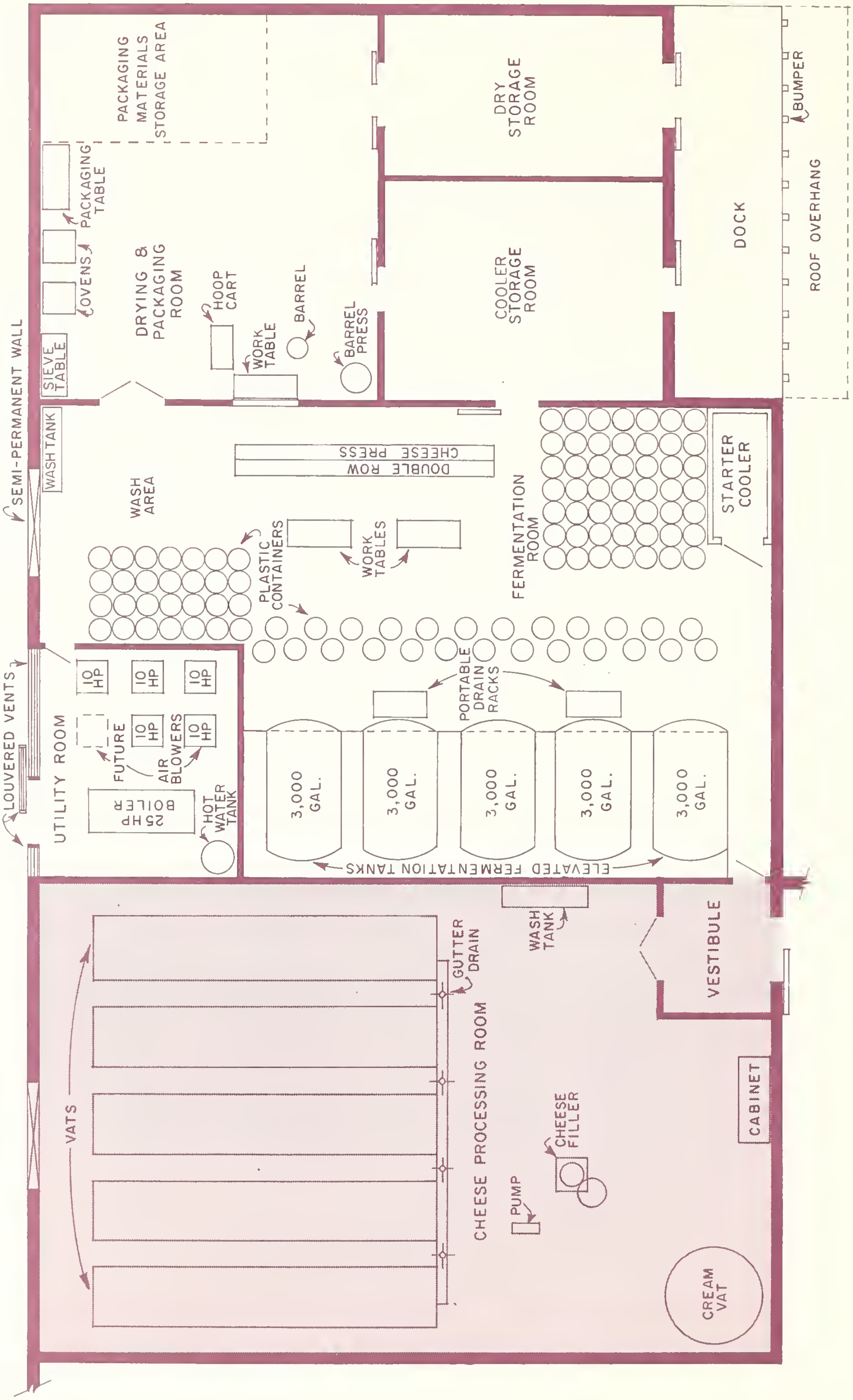

Figure 5.—Layout of a 300,000-pound-a-week cottage cheese whey processing plant.

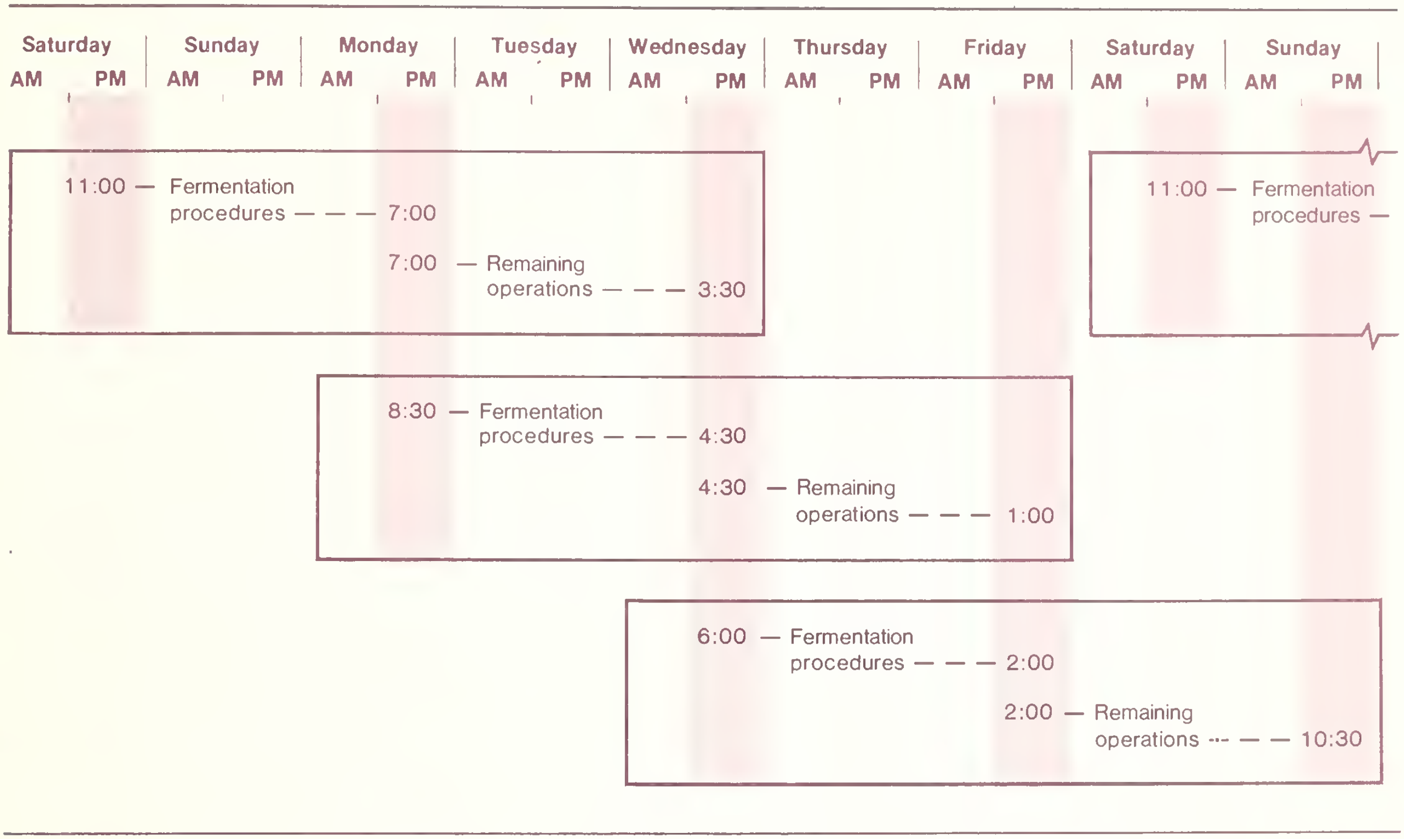

Figure 6.—Suggested weekly schedule for processing 300,000 pounds of whey

Figure 6 shows a suggested schedule for processing the weekly volume of whey (300,000 pounds) in three separate processing periods. It is designed to meet the same criteria as the one developed for the 150,000-pound-a-week plant. The fermentation procedures require a total elapsed time of 44 hours, the same as in the smaller plant, but an increase from 36 to 44½ hours for the remaining operations.

Initial Investment Cost. The estimated initial investment cost for the 300,000-pound-a-week whey-processing plant includes a facility cost of $135,833 (table 18), an equipment cost of $108,690, and a beginning operation capital of $12,750 (table 19). The estimated equipment cost of $108,690, which includes 65 percent new and 35 percent used or reconditioned equipment, is listed as follows:

	Dollars
Starter cooler, walk-in box—6′/11½′ (new)	3,650
Stainless steel cans (80), 10 gal each (used)	3,600
Stainless steel, insulated, water-jacketed, horizontal tanks (5), 3,000 gal each (used)	25,925
Stainless steel sparging systems (5), 1″ diameter lines with 3/16″ holes spaced at 2″ intervals each (new)	3,750
Boiler, 25 hp (new)	21,350
Air blowers (5), 10-hp, 120 cubic feet per minute (new)	32,500
Portable drain racks (10), 5′/2½′/8″ (new)	1,500
Plastic containers (173), 30 gal each (new)	2,075
Cheese press, double row (used)	1,750
Cheese hoops (145), 25 lbs each (used)	1,740
Hoop carts (4) (used)	600
Wash tank (used)	1,450
Tables (5) (used)	875
Barrel press (used)	750
Forced air ovens (2) (new)	4,075
Handtrucks (2) (used)	100
Miscellaneous (equipment, installation, etc.)	3,000
Total	108,690

"New" refers to 1980 manufacturers' suggested retail price, including transportation and installation where applicable. "Used" refers to 1980 costs of used or reconditioned equipment, including transportation and installation where applicable, supplied by various equipment sales companies.

Table 18.—Estimated construction cost for the 300,000-pound-a-week whey-processing plant

Component	Area	Average cost per square foot[1]	Total cost
	Sq ft	*Dollars*	*Dollars*
Fermentation room	2,685	25.00	67,125
Utility room	430	20.00	8,600
Drying and packaging room	1,220	18,00	21,960
Cooler storage room	554	40.00	22,160
Dry storage room	446	18.00	8,028
Dock area[2]	370	8.00	2,960
Miscellaneous (Site preparation, sewer, water, and electrical systems)	—	—	5,000
Total or average	5,705	23.81	135,833

[1]Based on 1980 cost of similar type of facilities built in areas with comparable construction cost.
[2]Includes roof and extension.

Table 19.—Estimated initial investment and total annual ownership and operating cost in the 300,000-pound-a-week whey-processing plant

Cost item	Initial investment	Annual ownership and operating cost
	Dollars	*Dollars*
Facilities	135,833	22,141[1]
Equipment	108,690	23,478[2]
Supplies	—	8,139
Utilities	—	22,321[3]
Labor	—	42,468
Contingency	—	5,927[4]
Operating capital	12,750[5]	—
Total	257,273	124,474

[1]Based on 20 years' depreciation, 12 percent interest on investment, and 5 percent for taxes, insurance, maintenance, etc. Capital recovery formula used to compute cost:

$$\text{Depreciation: } \frac{\$135{,}833}{20} = \$6{,}792$$

$$\text{Average interest: } \$135{,}833 \times \frac{(0.12)}{(2)} \times \frac{(21)}{(20)} = \$8{,}557$$

Taxes, insurance, etc.: $135,833 × (0.05) = $6,792

[2]Based on 10 years' depreciation, 12 percent interest on investment, and 5 percent for taxes, insurance, maintenance, etc. Computed by previous formula using 10-year depreciation scale.
[3]Based on usage requirements provided by a major public utilities company computed at $0.40 a therm for natural gas, $0.05 a kilowatt hour for electricity, and $3.11 per 1,000 gallons of water.
[4]Based on 5 percent of total annual ownership and operating cost.
[5]Includes 2-week volume of supplies plus 10 percent of total annual ownership and operating cost.

Annual Ownership and Operating Cost. The estimated total annual ownership and operating cost in the 300,000-pound-a-week whey-processing plant is $124,474 (table 19). Labor, the major cost item, is approximately 34 percent of the total annual operating cost, slightly more than the smaller plant. An estimated 7,078 annual staff-hours of labor are required to operate the 300,000-pound-a-week plant at a cost of $42,468 (table 20). However, at any given time only two employees are needed to operate the plant.

Potential Benefits. The production of the finished products in a 1:1 ratio of pressed cake to dried material in the 300,000-pound-a-week plant provides an annual profit margin of $39,189 at the lowest value, $69,364 at the average, and $99,539 at the highest (table 17). These determinations, which are based on total income minus annual operating cost, indicate that the feasibility is greatly enhanced as the volume of production is increased.

Conclusions

A reliable and efficient whey treatment and recovery system is essential to the dairy industry, because of the problems associated with the disposal of cottage cheese whey and the need for a high-grade protein supplement to improve the nutritional value of various food preparations.

Although the fermentation procedure described in this report is not the ultimate answer to the whey disposal problem, it does make a major contribution. With the significant reduction in the solids content (BOD) of the whey (approximately 50 percent), and the yield of a high-quality material containing 73.75 percent yeast-whey protein, the construction of whey processing plants becomes highly desirable. In those instances where the value of the recovered material and the reduction in sewage surcharges offset operating cost, the plants represent sound economic investments. This determination is predicated on the approval of the material for human consumption, and the development of a reliable market with a realistic price structure for the finished products.

Table 20.—Estimated total annual labor requirements and cost in the 300,000-pound-a-week whey-processing plant based on the weekly schedule shown in figure 6

Operation	Time per period	Employees involved	Staff-hours per period	Total annual staff-hours	Total annual[1] cost
	Hours	*Number*	*Hours*	*Hours*	*Dollars*
Fermentation procedures (preparing tanks, transferring whey, adding starter, sparging, steaming, and settling)	2.250	2	4.50	702	4,212
Removing solids from tanks and draining	1.250	2	2.50	390	2,340
Pressing solids:					
Barrels with water	3.625	2	7.25	1,131	6,786
Cheese hoops and press	7.000	2	14.00	2,184	13,104
Cubing, drying, and packaging	8.000	1	8.00	1,248	7,488
Storing and shipping	.500	1	.50	78	468
Cleaning and maintenance (facilities and equipment)	2.250	2	4.50	702	4,212
Spare and relief	—	—	—	643[2]	3,858
Total	24.875	—	41.25	7,078	42,468

[1]Based on an average wage rate of $6.00 per hour including fringe benefits.
[2]Represents a 10-percent additional staff-hour allowance.

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