Utilization of cottage cheese whey as dairy cattle feed

UTILIZATION OF COTTAGE CHEESE WHEY
AS DAIRY CATTLE FEED

by

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ABSTRACT

Liquid whey contains approximately seven per cent solids which include lactose, protein, ash, fat, and lactic acid. It is a waste product of cheese manufacturing and has been disposed of in sewage systems. A literature review gave insight into the possibilities of using whey as a feedstuff for dairy and beef animals to solve the disposal problem. Whey can substitute for part or all of the feed intake of dairy and beef animals. Considerable cost savings were available to Arizona dairymen when liquid cottage cheese whey was substituted for grain. However, a loss was incurred when whey was substituted for hay. A linear programming model was used to evaluate liquid cottage cheese whey with other feedstuffs. Results were in line with literature values for amount of whey that could be included in the dairy ration.

The basic costs involved in disposal of cottage cheese whey as sewage are, water to dilute whey to acceptable pollution levels and sewage treatment. These costs were found to be an indirect cost of cottage cheese production to the consumer. An even greater possible impact of these indirect costs may be realized by the year 2000. Thus, by diverting whey from the "sewer" to the feed trough, cost savings to the taxpayer and dairyman could be realized.

CHAPTER 1

INTRODUCTION

Liquid whey is a by-product of "cheese" production with each type of cheese having a distinct kind of whey. Whey varies as to lactose, minerals, protein, and fat content. This variation of nutrient content, and other factors such as the acidity determine the "quality." Whey is utilized in many forms, as a liquid, or it may be dehydrated or condensed in feeds, candies, bakery goods, and plastics. Sometimes the processing costs to dehydrate liquid whey, as well as other types of processing, become prohibitive. When this happens, liquid whey is simply disposed of as a waste product, where laws permit. This creates disposal and environmental problems due to the high amount of oxygen required to decompose whey by bacterial organisms.

Raw liquid whey comes mainly from two sources, casein and cheese manufacturing. Casein is a white, tasteless, and odorless phosphoprotein of milk and is used chiefly in the manufacturing of paints, adhesives, and plastics. Casein whey is the by-product of casein manufacture. Figure 1 shows the "typical composition" of liquid casein whey.

Acid whey is derived from cottage and bakers cheese while sweet whey is a by-product of Cheddar cheese production. Both types tend to have a strong and distinctive taste, with acid whey being more tart. The typical composition of cheese whey is given in Figure 2.

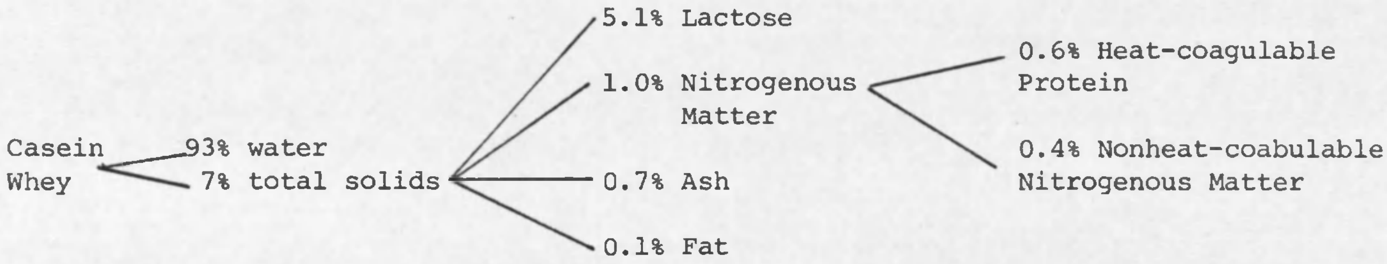

Figure 1. Average Composition of Liquid Casein Whey

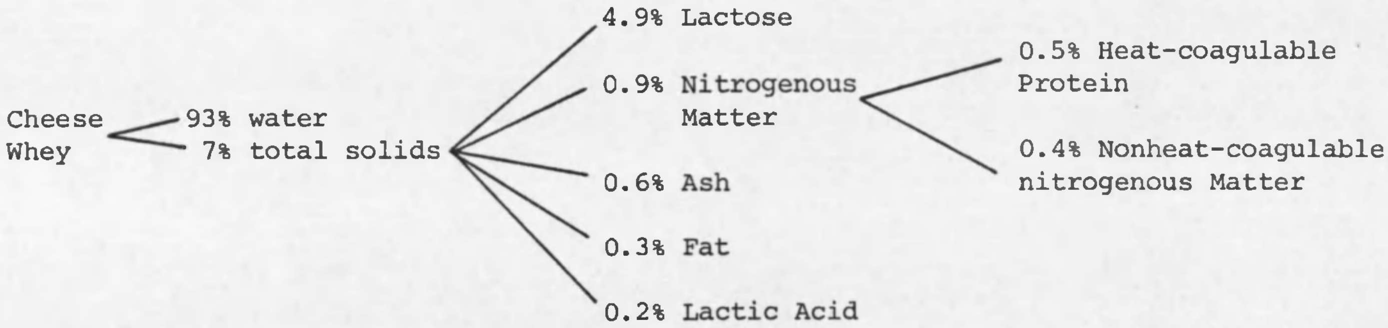

Figure 2. Average Composition of Liquid Cheese Whey

Liquid raw whey contains a five per cent solution of lactose, with traces of nitrogenous materials, salts, and fat as well as a high amount of riboflavin. Of the cheese wheys, acid whey is somewhat richer in calcium and phosphate due to the solvent action of hydrogen ions in the calcium phosphate of casein. Casein whey is generally considered of higher "quality" than cheese whey.

Liquid raw whey can be utilized in different forms for various products, as shown in Figure 3. Some of the forms are: pasteurized liquid whey, concentrated (e.g., condensed or dried whey), fermented whey for increased riboflavin, and reverse osmosis for lactose and milk sugar. It can also be used directly as a feedstuff. These are only a few of the different ways of using whey.

Tables 1 and 2 summarize production statistics of whey and whey products for the United States (Production of Manufactured Dairy Products, 1955-74). For example, in 1974 approximately 35.4 billion pounds of whey were produced, with about 11 per cent being cottage cheese whey and 89 per cent other types of cheese whey including Cheddar, Swiss, Muenster, Italian, and Bleu. The amount of liquid whey utilized, however, is about one-half the amount of that produced. Table 2 indicates the amounts of whey that have been utilized as condensed, dried, milk sugar, and lactose for the years 1955 through 1974. During 1974, approximately 35.4 billion pounds of liquid whey was produced with 17.0 billion pounds of liquid utilized, leaving 18.4 billion pounds of liquid whey that is disposed of as waste.

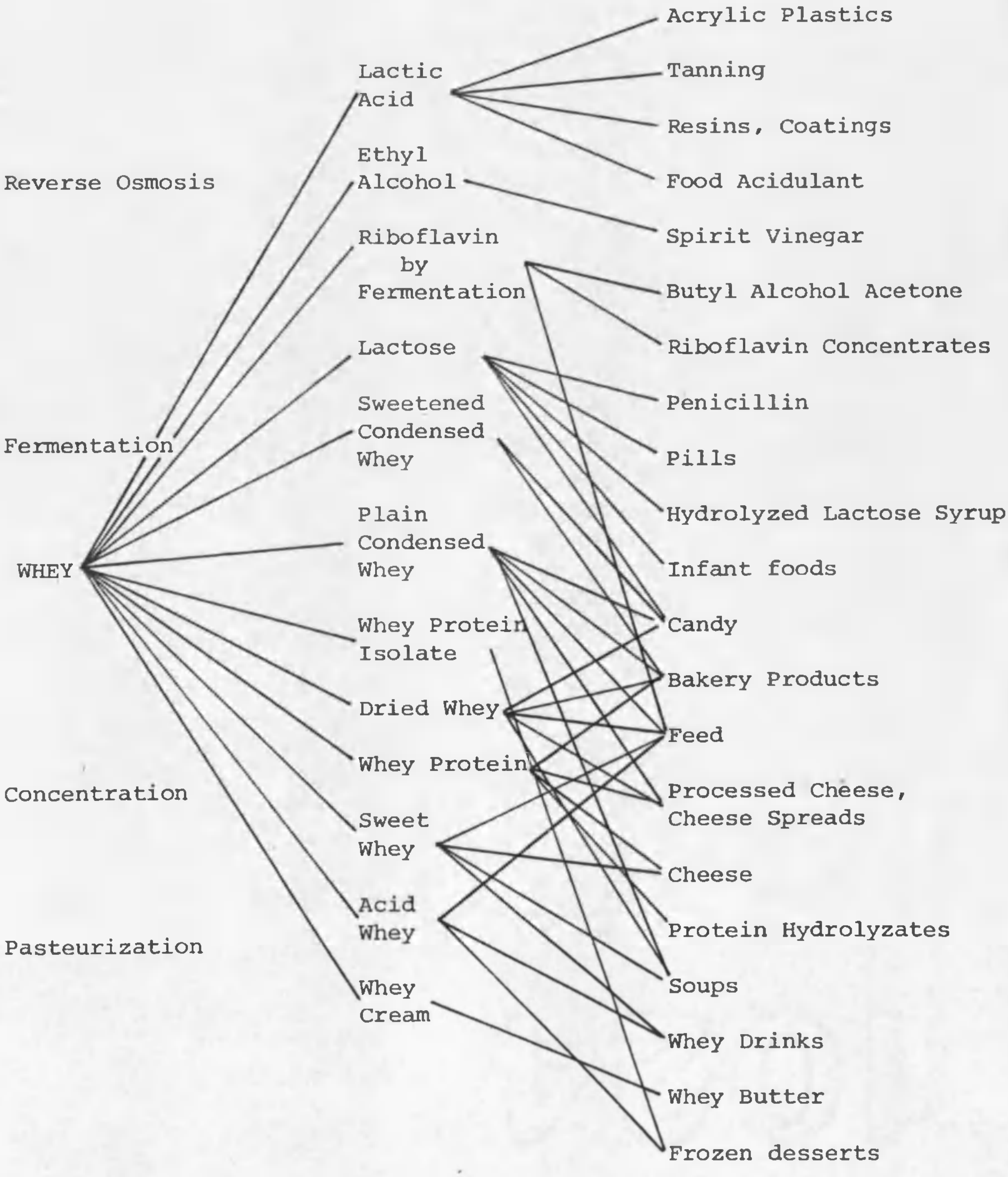

Figure 3. Whey, Products from Whey, and Uses for Whey Products

Table 1. Total Liquid Whey Produced from 1955 to 1974

Year	Cottage[a] Cheese Whey	Other[b] Cheese Whey	Total Whey (1000 lb)
1955	2,612,703	13,222,185	15,834,888
1956	3,047,586	14,937,481	17,985,067
1957	3,114,901	15,149,871	18,264,772
1958	3,156,589	15,063,337	18,219,926
1959	3,289,224	14,887,632	18,176,856
1960	3,382,482	15,908,321	19,290,803
1961	3,293,162	17,594,241	20,887,403
1962	3,366,941	17,134,037	20,500,978
1963	3,443,575	17,565,307	21,008,882
1964	3,550,804	18,553,671	22,107,475
1965	3,587,467	18,896,189	22,488,656
1966	3,564,034	19,956,964	23,520,998
1967	3,571,150	20,654,790	24,225,940
1968	3,698,657	20,863,380	24,562,037
1969	3,869,105	21,416,459	25,285,564
1970	4,137,717	23,696,749	27,834,466
1971	4,221,734	25,557,750	29,779,484
1972	4,443,082	28,044,187	32,487,269
1973	4,323,037	28,905,813	33,228,850
1974	3,892,000	31,543,897	35,435,897

[a]Skim milk on average produces 15 pounds of cottage cheese cwt and 85 pounds of acid whey. To convert pounds of cottage cheese into whey: lbs of cottage cheese/.1765 = lbs acid whey.

[b]Skim milk, on the average, produces 8.5 pounds of cheese and 91.5 pounds of whey. To convert pounds of cheese into whey: lbs of cheese/0.0929 = lbs whey.

Table 2. United States Liquid Whey Utilization as Condensed Whey, Dried Whey, and Milk Sugar

Year	Condensed Whey 1,000 lbs	Dry Whey 1,000 lbs: Human Food	Dry Whey 1,000 lbs: Animal Feed	Dry Whey 1,000 lbs: Total	Milk Sugar and Lactose[a] 1,000 lbs
1955	1,788,575			2,722,776	1,037,429
1956	1,757,246			2,740,721	951,657
1957	1,353,161			2,933,862	1,071,771
1958	1,179,897			3,232,331	1,011,714
1959	1,103,981			3,427,273	1,350,257
1960	844,754			3,836,488	1,431,314
1961	963,424			3,762,006	1,015,086
1962	831,844			3,947,138	1,495,257
1963	1,109,711			4,391,647	1,126,371
1964	1,417,538			5,154,261	1,181,257
1965	1,466,683			5,602,457	1,858,457
1966	1,880,958			6,525,758	1,861,400
1967	1,726,879			6,829,008	2,264,828
1968	1,538,228			6,861,683	2,371,000
1969	1,551,682	3,204,408	3,952,445	7,156,853	2,655,457
1970	2,478,134	4,072,046	4,533,669	8,605,715	2,789,685
1971	2,787,242	4,420,664	4,994,530	9,415,194	2,433,343
1972	1,702,613	5,219,542	5,339,878	10,559,420	2,493,371
1973	1,687,439	5,314,907	5,388,904	10,703,811	3,233,457
1974	1,479,700	6,271,895	5,525,397	11,797,292	3,738,114

[a] Webb and Whittier (1948:148); 3.5-4 lbs of lactose per 100 lb of whey. Assume yield of 3.5%/100 lbs of whey.

Arizona Situation

Cottage and Cheddar cheese liquid whey production comes mainly from four plants in the Phoenix metropolitan area. Three of these produce acid whey from cottage cheese and the fourth, sweet whey from Cheddar cheese. Each has a somewhat different seasonal and long-term production trend.

Cheddar cheese whey is fractionated, condensed, and dehydrated for human food use. Acid whey is presently disposed of as industrial waste. Its pollution effect is measured by Biological Oxidation Demand (BOD). Manual for Milk Plant Operators (1957) states that each 100 pounds of whey is equivalent to the daily waste of 21 people. For example, figures from the Market Administrator's Office (1974) show that Arizona usually produces 58.8 million pounds of acid whey per year. This quantity has a pollution effect of about 34,000 people per day and places a high BOD demand on municipal sewage systems.

The disposal of acid whey as industrial waste may not be permitted indefinintely. The capacity of such facilities have been continually stressed due to rapid growth in the domestic and commercial sectors. Food processing operations such as cheese making may eventually be required to assume these direct costs involved in handling the contributed BOD load. This has occurred in a number of other areas in the country.

The whey disposal situation is the key issue of this research. The problem can be summarized with two questions: first, "If liquid whey, either acid or sweet, has such a high pollution effect, what will be the impact of continued liquid whey production in the future?";

and second, "What are costs and returns of the alternatives to disposing of acid whey as waste?"

Objectives of the Study

There are many alternatives for the disposal of liquid whey: feeding directly to animals, drying and selling the powder, utilizing liquid or dried whey in foods, growing single cell protein through whey fermentation, and disposal of whey as sewage. Feeding liquid whey, sweet or acid, directly to animals is the major concern of this research.

The first objective is an examination of literature dealing with whey as an animal feed in order to evaluate its practicality from a technical standpoint.

The second objective involves identifying anticipated costs and returns of feeding liquid whey to dairy animals for a typical Arizona herd of 375. These budgets include extra costs associated with whey feeding due to transportation and feeding equipment requirements. Finally, the costs and returns from ration supplementation with whey are compared to the normal grain and roughage alternative.

The last objective will be to estimate costs of whey disposal as waste in Arizona. This includes cost to firms producing cheese as well as costs passed on to society. These impacts will be projected to the year 2000 by using population forecasts to estimate cottage cheese production and the waste whey generated.

CHAPTER 2

REVIEW OF LITERATURE

Whey in its various forms has long been recognized as a potential feed for cattle, sheep, goats, poultry, and swine. Most studies deal with metabolic utilization and therefore include such factors as palatability, amount fed, toxicity, and nutritional value. This review of the literature deals with whey utilization as an animal feed.

Webb and Whittier (1948) reviewed the literature and reported that inclusion of whey in feeds increased the utilization of cobalt, magnesium, and phosphorus in young animals. Lactose and galactose were more effective in accelerating growth in young animals than any other carbohydrate. Whey contains riboflavin and vitamin B_6 and has prevented cataracts in rats through the fat required for the utilization of lactose. When fed to poultry, whey prevented coccidiosis and curled toe paralysis and increased growth and egg hatchability through its riboflavin content. Concentrated sweet or sour whey was useful in making silage, by adding nutrient value and lactic acid. The lactic acid acted as a preservative and increased the digestability of the silage.

Calf Feeding

The following researchers reported feedling large amounts of sweet whey powder (greater than 30 per cent) to calves for milk replacement. In general diarrhea and digestive upsets occurred. Weijers and

Vandekamer (1965) stated that larger proportions were undesirable because of high acidity caused by acetic and lactic acids, high levels of lactose, lack of coagulable protein necessary for proper digestion, lowered intake, and possible damage due to microbial invasion. Five hundred mg per day of lactose was the upper limit if diarrhea was to be avoided according to Blaxter and Wood (1953). Walker and Faichney (1964) claimed that more than 4.1 gram hexose equivalent per pound of liveweight caused loose feces. However, this problem was somewhat alleviated when 2.5 gram fat per pound body weight per day was fed, for a maximum 5.45 gram per pound live weight "hexose equivalent." Volcani and Ben-Asher (1974) suggested that the difficulites of feeding large amounts of whey powder to calves was influenced by the "quality" of whey. The type of cheese, methods of drying, degree of fermentation, and the chemical composition of the end product affect the compatability of whey as a feedstuff. It has also been found (Morrill et al., 1971) that sweet whey powder (56 per cent lactose and 10 per cent fat) could be included up to 76 per cent of the milk replacer formula with no harmful results.

Gorrill and Nicholson (1972) obtained satisfactory results in feeding neutralized acid whey powder in milk replacers. Raising the pH from 5.7 to 6.8 had a beneficial effect on a 23 per cent acid whey milk replacer with body weight gains to 8 weeks of age increasing 15 per cent. Growth was nearly equal with the acid whey milk replacer as compared to a no-acid whey milk replacer. When dried whey was included in the diet at 52 per cent, weight gains were 28 per cent less than the no-acid whey milk replacer diet. Some diarrhea was noted, but with the addition of slaked lime (Brown, Read, and Willard, 1953) diarrhea can be prevented in calves fed acid whey milk replacers. The factor of pH was another predisposing element in the use of whey powder in milk replacers for calf feeding.

Post-colostrum four-day-old Holstein-Freisen herd replacement heifers were fed sweet whey powder (powder plus water) once a day for 27 days. Two groups of calves were fed: one with 11 pounds of low fat whey powder plus 11 pounds of commercial milk replacer, and the second with 22.4 pounds of low fat whey powder only. The above two groups were then compared with a control group fed 22.4 pounds of commercial milk replacer. All groups were fed hay, water, and a concentrate grain mixture, ad libitum. Body weight gains for the respective groups were: 17.2, 16.3, and 19.4 pounds. Total weight gain for 45 days were: 55.3, 55.9, and 60.5 pounds for the respective groups. In a second trial, pounds of whey powder were increased, with treatment 1 receiving 3.3 pounds of soy-protein concentrate (60-63 per cent protein) and 26.4 pounds of low fat whey powder. Treatment 2 received 29.7 pounds of low fat whey powder. Body weight gains for the first 27 days were: treatment 1, 19.4; treatment 2, 10.8; and control, 16.5 pounds. Total weight gain for the 57-day period was 80.3, 64.2, and 70.2 pounds, respectively. Volcani and Ben-Asher (1974) concluded that sweet whey powder can replace all of the skim milk powder in the milk replacer. They also found that feeding heifers 400-500 grams per day of soy-protein concentrate as a part of the milk replacer prevented or alleviated scours. Some loose feces were encountered, but no animal care was required. Nitsan and associates (1971, 1972) showed the same results. Gorrill and

Nicholson (1969) concluded that the added bulk of the soy-protein concentrate also helped to prevent scours and diarrhea.

Muller et al. (1974) fed whey protein concentrate containing about 12 per cent crude protein, 20 per cent total solids, 1.1 per cent fat, and 3.5 per cent ash with a pH of 7.1 in whole milk to dairy calves. Weight gains were not significantly affected by the additon of whey protein concentrate over whole milk only.

Lynch, Poos, and Hargrove (1974) investigated the nutritional value of whey permeate blocks containing 70 to 72 per cent lactose, 12 per cent ash, and .6 per cent nitrogen as a feed for calves. Sixteen calves averaging 100 pounds were randomly assigned to the following treatments: no blocks, unsupplemented blocks, ammonium supplemented blocks (1.7 per cent nitrogen), and urea supplemented blocks (1.7 per cent nitrogen). The blocks were fed with a pelleted ration of 70 per cent concentrate and 20 per cent wheat straw. The pelleted ration had a crude protein content of 9.3 per cent and was fed ad libutum. Feed conversion was 1.83, 2.74, 1.8, 2.5 pounds dry matter per pound gain and final weights were 344.7, 326.7, 363.2, and 336.4 pounds per respective treatment. Calves were able to obtain 14.9, 24.4, and 20.4 per cent of their total dry matter intake from blocks for treatments 2, 3, and 4, respectively.

Whey permeate (deproteinized whey) was condensed into a solid animal feed block. Solidification of the whey permeate and binding properties were evaluated. Several factors influencing the solidification process were: total solids, temperature, pH, and agitation of the whey permeate. Binding properties were investigated when ammonium salts, urea, molasses, brewery and potato wastes, soybean meal, yeast, fats, and oils were added. Protein equivalent of liquid whey permeate based on total nitrogen increased from 8 to 12 per cent with the addition of .075 to .15 per cent of ammomium salts and urea. Molasses had to be added at .15 per cent to increase the palatability of some of the blocks. A maximum of 10 per cent soybean meal and 5 per cent potato soluble could be added to the blocks without solidification problems. Hargrove et. al. (1974) found that most blocks were readily consumed. No estimate was made as to their nutritional value.

Calves were fed whey blocks supplemented with ammonia and urea on an isonitrogenous basis. These calves were compared to calves fed unsupplemented whey blocks and calves fed a grain, hay diet. No differences in total dry matter intake or body weights of calves were observed by Waldo, Goering, and Lynch (1975). Approximately 24 per cent of total dry matter intake was obtained with ammonia supplemented blocks.

Hargrove (1975) developed a process to make animal lick blocks from deproteinized whey permeate resulting from ultrafiltration. Blocks were made by neutralizing cottage cheese permeate with ammonia, condensing to 65-70 per cent solids, forming into blocks, and solidifying. In a feeding trial, the blocks were readily consumed replacing up to 25 per cent of the normal ration. No estimates were given for feed value.

Holstein steer calves averaging 209 pounds were fed liquid whey permeate by Lynch, Hargrove, and Gordon (1973). Acid whey permeate (deproteinized whey) contained 5.7 per cent dry matter, .04 per cent nitrogen, 4.3 per cent lactose, and 7 per cent ash. The calves consumed up to 34.4 per cent of their total dry matter from whey permeate.

Daily weight gains were 2.75 pounds, feed conversion 3.37 pounds dry matter per pound gain.

Calves up to 6 weeks of age were fed different starter rations containing dried sweet whey. These diets were then evaluated by Morrill and Dayton (1974) to determine their palatability. Four rations were fed containing anywhere from 5 to 40 per cent whey in 6 different experiments. In addition, the rations contained in varying proportions ground alfalfa, soybean meal, beet pulp, rolled sorghum grain, ground oats, wheat bran, molasses, animal fat, dicalcium phosphate, and trace mineral salt. The ration containing 40 per cent whey affected palatability adversely but rations containing amounts up to 15 per cent whey did not affect palatability if mineral supplements were added. Consumption was also decreased in 3 out of 4 experiments, with rations containing 30 per cent whey. When mineral supplements were not added, consumption tended to increase when the starters contained 40 per cent whey. Since mineral in dried sweet whey did affect palatability, they recommended special attention should be given to the minerals in whey starter rations.

Dairy Animal Feeding

Liquid whey returned to the farm as an animal feed was reviewed by Groves and Graf (1965) and Webb and Whittier (1948). Liquid sweet whey was fed along with a complete ration and consumption averaged 55 to 132 pounds per cow per day. One animal in this feeding trial by Gordan, Lynch, and McDonough (1972) was afflicted with toxemia after a temporary exhaustion of the whey supply. Another dairy cow was fed liquid whey and consumption was over 220 pounds of whey per day in the first three months of lactation to less than 110 pounds in the latter part of the lactation. Water was not provided. Total milk production was not affected, but there was some depression of the milk fat content.

Welch and Nilson (1973) and Welch (1973) fed sweet whey both to dairy and beef cattle, with consumption averaging 141 pounds and 106 pounds of whey, respectively. Milk production was above average and no predominant flavor defects in the milk could be attritubed to whey. Peak consumption of whey was 300 pounds accompanied by excess urination with manure handling a problem. One hundred pounds of whey replaced 8.8 pounds of concentrate. In later findings (Nilson and Welch, 1975) it was shown that some cows would drink up to 400 pounds of whey per day. Cows on demonstration consumed 300 pounds of whey per day without showing any ill effects over a two-year period. These same cows had better milk production than their herdmates. Palatability was lowered if the pH content was lower than 4.0. Whey consumption was also lowered if cows were fed a good concentrate.

A 50:50 mixture of acid whey and water was used to attain an average intake of 100 pounds of liquid whey per day, with the pH ranging from 4.5 to 4.0. Some cows consumed as much as 300 to 400 pounds of whey per day. Nutritive value was estimated at 7 to 8 pounds of a low-protein, high-energy grain per 100 pounds of whey. Adams (1975) further stated that heifers could also be fed whey. Depending upon breed, heifers with body weight of 400 to 500 plus pounds could be fed whey free choice with a mineral supplement. Under 400-500 pounds of body weight, whey intake should be limited to 25-30 pounds per day supplemented with a concentration mix of 20-30 per cent crude protein and high quality forage. Calves should not be fed liquid whey until they are about 6-8 weeks of age, otherwise problems such as diarrhea and going off feed will occur.

Anderson et al. (1974) fed fresh sweet liquid whey to dairy cattle in replacement of the hay in the ration. Grain was fixed at 16.5 pounds per animal with hay being fed free choice. Hay consumption was reduced by feeding whey, while milk production and composition were not significantly changed. The cows, on average, consumed 140.8 pounds of whey per animal and 9.3 gallons of water per animal. Heifers 6 to 8 months of age were also fed whey, 5.06 pounds of grain, and alfalfa hay ad libitum. Average daily gains were the same for whey only and grain only rations. Animals fed both whey and grain had greater gains than either the whey only or grain only treatments during a 16-week trial. Average daily gains were 2.49 pounds per day as compared to 2.13 pounds per day for the whey only group and 2.09 pounds per day for the grain only group. The sweet whey that was consumed had an initial pH of 6.1 with a pH of 4.0 for the 24-hour-old whey. If the pH of whey was less than 4.0, cows would not readily consume it, thus some palatability problems for high acidic whey. Nutritive value of sweet whey was estimated to be equal in nutritive value to the dry matter of corn or barley. One hundred pounds of sweet whey in those terms would be equivalent to 7.7 to 8.3 pounds of grain.

All animals required an adjustment period to adapt the digestive system to whey. Slight diarrhea occurred in some cows if too much was consumed before the animals were fully adapted. Once adapted, fecal consistency was about the same as pasture feeding. Other health problems such as teeth erosion and reproductive problems were not noted.

Flies were a problem in feeding whey, if good sanitation was not followed. Spilled whey magnified the fly problem.

Lamb and Anderson (1976) fed lactating dairy cows concentrates at rations of 1:3, 1:4, 1:5, or 1:6 (pound concentrate per pounds of milk). Concentrate feedings were discontinued when lactation levels were at or below ten pounds of milk per day. The rest of the ration consisted of 25 pounds of corn silage, alfalfa hay and liquid sweet whey were fed ad libitum. Liquid sweet whey intake was not affected by the level of grain intake and consumption of whey was not as high as reported in a previous study by Anderson et al. (1974). The authors suggested that one cause for this lowered liquid sweet whey intake might have been due to extremely cold weather, which created a situation of the water being warmer than the whey. This temperature difference could have increased water intake over whey intake. Liquid sweet whey in the diet did not cause any differences in milk composition or production.

Thirty-five lactating Holstein cows were fed rations containing different levels of nitrogen addition to the concentrate: no addition, 17 per cent soybean meal, 2.5 per cent urea, 9 per cent fermented-ammoniated whey, and 18 per cent fermented-ammoniated whey. The fermented-ammoniated whey was condensed to 60 per cent with a crude protein content of 48 per cent. Corn silage (40 per cent dry matter) was fed as the only forage. Milk production was at 54.1 pounds of milk per day, the addition of nitrogen supplements increased milk yield persistence (treatment/standardization) averaging .77, .86, .85, .83, and

.83 for the respective groups. Silage and total dry matter intakes were not significant between the different treatments, with average intakes at 1.71 and 3.11 per cent of body weight. Huber, Boman, and Henderson (1974) further state that fermented ammoniated whey and urea are equal to soybean meal for increasing crude protein from 10 to 13.5 per cent in dairy rations.

Preliminary studies (Welch, Nilson, and Smith, 1974) indicated that whey concentrate of 40 to 50 per cent dry matter was not acceptable to dairy cattle. Mixing molasses in ratios of 50:50 to 90:10 with whey increased the consumption of whey concentrate. There were some problems of lactose precipitation at the higher level of whey concentrate. Dry cows and lactating cows were fed either acid whey or sweet whey concentrate. Consumption by the dry cows of the 50:50 mixture was 11 pounds per day. Lactating cows were fed the 50:50 mixture on top of silage with consumption averaging 8 pounds per day. Mixtures of whey concentrate, molasses, and urea containing liquid protein supplements (16 per cent crude protein) were readily consumed up to 11 pounds per day. No problems of feed consumption, production, or health were noted.

When high quality protein is fed to dairy cattle, a large portion of the dietary protein is degraded by rumen microbes to amino acids and ammonia. The ammonia, in turn, is utilized by the microbes in the rumen to synthesize microbial protein. The microbial protein is the protein that is then utilized by the dairy animal for its protein requirements. This, in effect, is beneficial when low quality proteins are fed, because the microbial protein will be of higher biological value than the dietary protein. However, if the diet protein is of high quality, it is then downgraded in biological value to that of the microbial protein. Whey proteins are usually high in quality or have high biological values. If such protein is allowed to bypass the rumen, it is more efficiently utilized. One method for allowing whey protein to bypass the rumen is to treat it with one per cent formaldehyde as suggested by Muller, Rodriguez, and Schingoethe (1975). Formaldehyde treated whey protein concentrate (WPC) was prepared by adding 1.54 quarts of commercial grade formalin (37 per cent) to 290.4 pounds of WPC in 38 gallons of water (equivalent to one gram formaldehyde/100 grams of protein). This protected WPC from ruminal degradation, yet permitted utilization post ruminantly. Lactating dairy animals were fed treated WPC (T-WPC) as compared to untreated WPC (U-WPC). No differences were significant in dry matter and energy intake or dry matter, nitrogen, and energy digestibility. The T-WPC ration tended to have a decreased nitrogen digestibility, due in part to the magnitude of the protein protection.

Cows fed the T-WPC ration had a higher milk nitrogen and production nitrogen (milk nitrogen plus retained nitrogen) expressed as a percentage of absorbed nitrogen. This indicates, to some extent, a more efficient utilization of absorbed nitrogen. The lactating dairy cattle also tended to have increased milk yields, milk fat, milk protein, and milk solids with the T-WPC ration.

Whey is important in the prevention of milk fat depression in high-grain rations. Schingoethe, Stake, and Owens (1973) reviewed the role of whey in its effect on milk fat depression. Their results showed that whey minerals were most effective in preventing milk fat depression in high-concentrate rations although lactose was also partially effective. Milk yield was not affected.

Dried whole whey (DWW), partially delactosed whey (PDW), partially demineralized whey (PMW), or lactose (L), were added to a control (C) grain ration of cows fed a high-grain, limited roughage ration. Results by Schingoethe, Voelker, and Baker (1975) indicated that whey minerals and lactose prevented milk fat depression. The lactose had a lesser effect on the prevention of milk fat depression. Milk fat composition was more unsaturated in the C ration than with rations containing whey. However, the fatty acid composition of milk fat of whey fed cows was similar to that of the C ration. Milk was more susceptible to oxidized flavor in all high-grain rations. When one per cent DWW was added to corn silage containing a 0.5 per cent urea, the digestibility of the silage was improved. Cows produced more milk, heifers gained slightly more weight, and digestibility by steers was slightly improved over performances of animals fed silage without adding whey. Adding 1, 2, or 10 per cent DWW or 1.4 and 7 per cent haylage or reconstituted haylage improved the apparent digestibility and quality of haylage dry matter and fiber constituents. Weight gains on heifers and cows were grater with whey treated haylage. Milk production was not affected.

Adding dried whey to alfalfa haylage (a forage high in protein but low in energy) improved the haylage quality and digestibility according to Dash et al. (1974a, 1974b). Schingoethe, Beardsley, and Muller (1974) indicate that when dried whole whey, partially delactosed whey, or lactose was added to urea-treated corn silage, ammonia nitrogen and acid detergent fiber were reduced with no reduction in total nitrogen in the corn silage. This indicated that adding dried whey or its fractions to urea-treated corn silage may help reduce nitrogen losses from the silage and improve the feeding value of the silage. Dash et al. (1974c) state that the addition of whey in alfalfa haylage is utilized for its lactose as a readily available carbohydrate for lactic acid production, thus the higher digestibilities through the improved fermentation of the haylage.

Dried whey has been added as an acidulant for grass soilage. In vitro digestibility studies (Watrous, Dimick, and Keeney, 1975) showed that the experimental soilage had slightly higher digestible dry matter. Milk production and composition were not significantly different as related to soilage fed.

Schingoethe and Beardsley (1975) evaluated the addition of urea and whole dried whey to corn silage (UWCS) as compared to urea and corn silage (UCS). Cows fed UWCS produced 6.5 per cent more milk and were more persistent in maintaining a higher level of milk production. Milk composition was not altered by feeding UWCS. Cows tended to consume more daily dry matter intake with feeding UWCS. Heifers also tended to have a greater daily dry matter intake and therefore weight gains were greater with UWCS by 7 per cent. When fed to steers in a digestion trial, dry matter digestibility increased by 2 to 3 per cent and apparent nitrogen digestibility by 16 per cent.

Beef Feeding

Ammoniated whey was made by infusing ammonia into cottage cheese whey. The product contained an average 65.5 per cent solids, 7.15 per cent nitrogen, or 44.6 per cent protein and had a pH of 6.3. This product was then compared to a soybean meal and a molasses-urea mixture as 18 per cent of complete ration of 60 per cent corn silage and 40 per cent grain (per cent dry matter basis).

In the first trial, the above ration was fed to 3, 880 pound fistulated steers at 2.5 per cent of body weight and to 6 wether sheep to determine digestibility. Apparent digestibility of the 18 per cent ammoniated whey was 75 per cent of the dry matter, which according to McCullough, Neville, and Monson (1972) is in the category of rations which would be expected to be well consumed and utilized. There were no palatability problems noticed as all of the steers and sheep readily consumed the ration.

The second trial was designed to compare 3 soures of protein supplementation in a complete ration for young beef animals. The 3 protein sources were: soybean meal (SBM), a molasses-urea (MU) mixture, and ammoniated cottage cheese whey (ACCW). In addition to the protein supplement, the ration consisted of 20 per cent cottonseed hulls and 65 per cent ground corn. There were 15 Hereford heifers and 3 Hereford steers averaging 8.7 months in age and 440 pounds in weight in this trial. These animals were divided into 3 equal groups. At the conclusion of the second trial, nearly identical feed efficiency and average daily gains were obtained. Average daily gain was 2.178, 2.178, and 1.848 pounds; feed efficiencies were (lb. rations/lb. gain) 141.82, 138.64, and 158.64 for the respective SBM, MU, and ACCW protein supplemented rations. No problems with palatability were reported.

Toxicity has been reported in some steers when a nitrogen source was infused intraruminately by means of a cannulated rumen. Crickenberger, Henderson, and Reddy (1974) stated that when fermented condensed ammoniated whey (FCAW) was infused at 400 mg nitrogen per kg, blood ammonia levels were .75 mg (%); volatile fatty acids, 1,381 mg (%); and pH, 6.33. Toxicity was encountered in 2 out of 4 steers.

Henderson, Reddy, and Crickenberger (1974) fed 96 yearling Hereford steers a full 136 days on a basal ration of 60 per cent shelled corn, 40 per cent corn silage with vitamin and mineral addition. The basal ration was supplemented with 6 different crude protein (CP) levels and/or sources: no crude protein source; 1/2 x Fermented Ammoniated Condensed Whey (FACW, analyzed 50 per cent CP at 60 per cent total solids); 1 x FACW; 1-1/2 x FACW; 1 x Urea; and 1 x Soybean Meal. Average daily gains were 2.574, 2.838, 2.926, 3.036, and 3.124 pounds, and gain to feed ratios of .1, .154, .333, .353, .098, and .353 for the respective groupings. No significant differences were noted in carcass grade, marbling, or fat thickness.

Henderson, Crickenberger et al. (1974) fed fermented, ammoniated, and condensed whey (FACW) at the rate of .857 pounds daily to yearling steers. Increased gain of 6.5 per cent and feed efficiency of 10.8 per cent were noted over negative controls receiving no protein supplement. The feeding of 1.75 pounds of FACW per day did not increase daily gain or feed efficiency over the .875 pounds per day level.

Thirty, 212 pound, 14 week old steers have been successfully fed liquid acid whey up to market weights of 900 pounds. Steers in 2 out of 3 treatment groups on liquid acid whey diets showed little if any reluctance to consume liquid acid whey. Treatments consisting of 10 steers each were fed: acid whey plus restricted grain, acid whey plus ad libitum grain, and water plus ad libitum grain. The feeding trial lasted 52 weeks (three 14-week periods), after which the steers were slaughtered and carcasses evaluated. This research was conducted by Lynch et al. (1975).

Initial ajustment to liquid acid whey was rapid with some problems of bloat. Timothy hay at 0.4 per cent of the ration eliminated the bloat problem. The calves in treatments 1 and 3 were started on a 20 per cent crude protein dry ration for 7 weeks and reduced to 16 per cent crude protein (CP) for 7 weeks. These calves tended to gain faster and were heavier at the end of the first 14-week period than calves that were on 30 per cent CP and reduced to 20 per cent CP. Dry matter intake among the groups were not different. Acid whey high protein (treatment 2) increased average feed conversion 25.3 per cent and acid whey moderate protein (treatment 1) increased average feed conversion by 11.2 per cent when compared to the water control. Liquid intakes averaged 43.6-52.8 pounds per day, or 30-31 per cent of the total dry matter from acid whey.

In the second 14-week period, steers consumed more acid whey than was necessary for just their liquid requirements. Intakes of whey dry matter almost doubled, with intakes of 4.8 pounds per day for treatment 2 and 7.0 pounds per day for treatment 1. Steers obtained

28 and 48 per cent of their total dry matter from acid whey in the above respective treatment. Treatment 2 increased in average daily gain, total dry matter intake, and decreased in average feed conversion. There were no differences in body weights at the end of the period.

In the last period, treatment 1 decreased in average daily gain and final body weights. Treatment 1 had the optimal acid whey intake (122 pounds), indicating that ad libitum fed grain with acid whey feeding, does not give an optimum acid whey intake. Treatments 1 and 2 obtained 57 and 20 per cent respectively of their total dry matter intake from acid whey.

Acid whey fed steers had leaner carcasses which attributed to lowered hot carcass weights, rib fat cover, and loin eye area. Treatment 1 was graded with an average grade of Standard; 2, Low Good; and 3, Good. Lower carcass scores were also given in treatment 1 for carcass fat thickness, round confirmation, and rib eye leanness. A taste panel also rated treatment 1 steers lower for desirability of aroma and quantity of juice with no difference in overall carcass desirability or tenderness.

Two main problems which have been encountered with the feeding of liquid acid whey are: tooth erosion and bloat. Tooth erosion as measured in tooth weights was not noticed in feeding acid whey. Some bloat problems did occur when the acid whey supply was depleted for a short time. The steers would over drink and then bloat. Two steers were lost during the experiment, one of which was fed acid whey.

Boren, Ibbetson, and Chyba (1976) found that when Hereford heifers were fed rolled sorghum grain, water reconstituted grain (28 per cent moisture), or whey reconstituted grain (28 per cent moisture) in a finishing ration, there were no significant differences in animal performance. Tendency for better feed conversion was shown by cattle fed the reconstituted grain.

In vitro digestibility studies were made on selected paper/whey combinations. Eleven types of paper were used: telephone directory yellow pages (YP), white pages (WP), feed sacks (FS), glossy magazines (NW), brown bags (BB), telephone book covers (ST), daily newsprint (CM), cardboard boxes (CB), computer punch cards (CC), computer printout sheets (PO), and coasters (CO). These 11 papers were then divided into 2 groups, chopped in one-half inch squares, or ground in a mill using 20 mesh screen. Cheddar cheese whey was then added to the respective papers. Squared papers absorbed increasing amounts of whey as soaking time increased, but ground papers absorbed the maximum amount of whey in one to five minutes. Coasters absorbed the most whey (70 per cent); the medium absorption group (43-60 per cent) consisted of WP, BB, FS, CB, and YP; the lowest absorption group (30-41 per cent) consisted of CM, PO, CC, NW, and ST. Becker, Campbell, and Martz (1975) stated that the in vitro digestibility of unsoaked paper ranged from 37.7 per cent for white pages to 81.7 per cent for computer cards. Soaking in sweet whey increased digestibility in seven (YP, WP, NW, BB, CM, CB, and CO). In the other papers (CC, FS, ST, and PO) whey soaking either had no effect or decreased digestibility.

CHAPTER 3

ECONOMIC ANALYSIS OF FEEDING LIQUID WHEY TO ARIZONA DAIRY ANIMALS

A synthesis of a liquid whey feeding system for an average size Arizona dairy enterprise is developed in this chapter. The associated costs and returns, and the effects on the financial position are estimated.

Three budgets and a linear programming feed mix problem are discussed. A transportation budget is constructed to emphasize the costs of whey at the farm. The impact of substituting whey for hay and for grain is budgeted followed by a whole budget for the synthesized system. The linear programming feed mix analysis provides information on the quantities of whey used at various costs.

Limitations or Assumptions

Welch (1973) states that 400 pounds of liquid sweet whey substitutes for 32 pounds of concentrate. However, the substitution effect of liquid (sweet or acid) whey for either hay or concentrates has not been precisely determined. In addition, the effects of ambient temperature and other such variables on whey-feed substitution rates have not been researched. Therefore, the use of Welch's substitution rates and their impact on milk production make the budgets constructed tentative. Explicit assumptions made for the budgets are stated as each budget is developed.

No price information was available for whey at the dairy plant. However, acid whey has usually been disposed of as waste. The budgets developed price whey at transportation costs ignoring the costs for plant equipment, labor, and the initial refrigeration to 32°F.

Acid whey was assumed to be equivalent to 7.5 pounds of concentrate as sweet whey (Anderson et al., 1974). In reality this may not be so, because liquid whey consumption decreases as the pH increases as indicated by Welch (1973). Whey acidity can be lowered by adding basic materials; however, this has not been researched.

On the farm, feeding of liquid whey was budgeted, assuming that the whey would be fed through a pressurized, refrigerated system where whey is kept at 38°F in a storage tank. The whey feeding method was budgeted using a self-feeding water-type system. Other methods of feeding were not analyzed.

Transportation Budget

The purchase price of the tractor, truck type was $36,800. Equipment included on the tractor was: 300 hp diesel engine, live axle, 38,000 lb tandem springs, and a 160 inch wheel base for tractor maneuverability. The purchase price was with all equipment on the truck, including air conditioning.

Insurance was calculated on the following basis: coverage of bodily injury, $100,000 per person; liability, $300,000 per occurrence; property liability, $100,000 per occurrence; uninsured motorist, $15,000 per person or $30,000 per occurrence; fire and theft, $66,000, or the total tractor and trailer purchase price; and collision of $1,000 deductible. Insurance costs ranged from $2,600 per year to $5,600 per year. Other costs included were plates and license for unit, $2,200 per year; road and use tax, $1,000 per year; repairs, an average of $.03 per mile with a unit estimated life of 400,000 miles before overhaul; fuel and oil costs, assumed on an average of 4.5 miles per gallon of diesel, with diesel at $.45 per gallon, oil change, $75 per oil change, and interest on investment at 10 per cent per annum. All costs were current as of January, 1976.

The bulk milk trailer purchase price was $30,000. Capacity of the trailer was 5,600 gallons of milk or liquid whey. Equipment on the trailer included a 70 gpm pump with a two hp 220 volt electric motor as well as other equipment.

The computer program BIGMAC, developed by Hawthorn and Wright (1975), was used to calculate the projected annual costs and cost per hour of use for the tractor, truck type, and milk bulk stainless steel trailer. Annual costs were classified into two major categories: fixed and variable costs. Fixed costs are those costs that do not vary with the extent of the machine use and variable costs are those that do vary with the extent of the machine use. The specific costs that fall into each category as follows:

Fixed Costs	Variable Costs
Depreciation	Repairs
Taxes, housing, interest, and insurance (THII)	Fuel and oil

The computer program BIGMAC projects annual costs for depreciation, THII, and repairs over a range of annual use by using methods developed by American Society of Agricultural Engineers (1972). Equations used in the program are:

1. Depreciation = Purchase Price - Remaining Farm Value (RFV)/yrs of useful life. RFV = Purchase Price x 10 per cent.
2. Repairs = TAR x Purchase Price/yrs to trade. TAR = .00096 $(\text{per cent use})^{1.4}$. Per cent use = (hrs of annual use x years to trade x 100)/hrs to wear out.
3. THII = Rate x (Purchase Price + RFV/2). Rate = Percentage of average investment charged to THII annually as listed in Table 3.

Table 3. Percentage of Average Investment to Charge for THII[a]

Equipment Group	Taxes[b]	Housing	Interest	Insurance[c]	Total
Tractor, truck type	2.0	1.5	10	19.6	33.1
Milk bulk stainless steel trailer	2.0	1.5	10	19.6	33.1

[a]Average Investment = (Purchase Price + Remaining Farm Value)/2.

[b]Equipment is assessed at 18% of its market value for tax purposes.

[c]Insurance, (1) liability insurance/average investment, (2) collision insurance/average investment.

4. Fuel Cost = Gal/hr x Price x yrs of use. Oil Cost = Fuel cost x 1.15.

Tables 3 through 6 show how the transportation cost was figured. Transport costs per cwt of liquid whey ranged from $0.0585 per cwt to $0.1928 per cwt. Comparisons as to what was actually being charged for milk hauling during this same time period indicate that the per cwt transport costs for central Arizona were $.25 per cwt or approximately $0.06 per cwt greater than what was actually budgeted in Table 6, for a 120 total mileage from the cheese plant and return. This difference may have been due to the fact that no overhead or return on investment was figured in the transportation budget.

Partial Budgeting Analysis of Feeding Liquid Whey to Arizona Dairy Animals

The partial budget, Table 7, was constructed following the research of Anderson et al. (1974) at the Utah State University. Whey replaced hay and water with the amount of grain offered remaining constant. Anderson et al. (1974) stated that whey replaced 13 pounds of hay per day. Milk production declined but not significantly.

For the purpose of this budget, the milk production decrease will be assumed at five lbs per day. Additional assumptions pertaining to all of the budgets were: liquid whey cost per cwt equals $.25; labor cost at $3.50 per hour; and electricity, miscellaneous, which includes supplies for washing the system, brushes, etc., was figured at $2,150.00 per year. Depreciation, interest, repairs, taxes, and insurance charges (per cent of cost) are given in Table 8. The budget summarized by Table 7 indicates that when whey replaces hay and water

Table 4. Total Tractor and Trailer Hours of Use Per Year

Total Mileage from Cheese Plant and Return	Man Hours/ Day	Trips/Day	Tractor and Trailer Hours of Use/Day[a]	Trailer Load and Unload Time Hrs/Day[b]	Total Tractor and Trailer Hours of Use/Year[c]
20	8.05	5	2.20	5.85	686.40
20	16.10	10	4.40	11.70	1372.80
40	8.24	4	3.56	4.68	1110.72
40	16.48	8	7.12	9.36	2221.44
60	7.50	3	3.99	3.51	1244.88
60	15.00	6	7.98	7.02	2489.76
80	8.85	3	5.34	3.51	1666.08
80	14.75	5	8.90	5.85	2776.80
100	6.78	2	4.44	2.34	1385.28
100	9.50	5	11.10	5.85	3463.20
120	7.68	2	5.34	2.34	1666.08
120	15.36	4	10.68	4.68	3332.16

[a] Hours of use/day calculated on a 45 mph average speed.

[b] Takes an average of 70 min/load to load and unload the trailer, including hookup time, actual whey unloading, etc.

[c] Using an average of six days/week for 52 weeks.

Table 5. Projected Annual Costs and Cost per Hour of Use for 1976

Hours of Use	Yrs to Trade	Depreciation	THII	Repairs	Fuel + Oil	Total	Cost per Hr
			Tractor Truck Type[a]				
500	10.0	3312	6699	1154	2872	14038	28.08
600	10.0	3312	6699	1490	3447	14948	24.91
700	10.0	3312	6699	1849	4021	15881	22.69
800	10.0	3312	6699	2229	4595	16836	21.04
900	8.9	3726	6699	2508	5170	18103	20.11
950	8.4	3933	6699	2647	5457	18736	19.72
1050	7.6	4347	6699	2926	6031	20004	19.05
1150	7.0	4761	6699	3204	6606	21271	18.50
1250	6.4	5175	6699	3483	7180	22538	18.03
1350	5.9	5589	6699	3762	7755	23805	17.63
1450	5.5	6003	6699	4040	8329	25072	17.29
1550	5.2	6417	6699	4319	8904	26339	16.99
1650	4.8	6831	6699	4597	9478	27606	16.73
1750	4.6	7245	6699	4876	10052	28873	16.50
1850	4.3	7659	6699	5155	10627	30140	16.29
1950	4.1	8073	6699	5433	11201	31407	16.11
2050	3.9	8487	6699	5712	11776	32674	15.94
2150	3.7	8901	6699	5991	12350	33941	15.79
2250	3.6	9315	6699	6269	12925	35208	15.65
2350	3.4	9729	6699	6548	13499	36475	15.52
2450	3.3	10143	6699	6826	14073	37742	15.41
2550	3.1	10557	6699	7105	14648	39009	15.30
2650	3.0	10971	6699	7384	15222	40276	15.20
2750	2.9	11385	6699	7662	15797	41543	15.11
2850	2.8	11799	6699	7941	16371	42811	15.02
2950	2.7	12213	6699	8220	16946	44078	14.94
3050	2.6	12627	6699	8498	17520	45345	14.87
3150	2.5	13041	6699	8777	18094	46612	14.80
3250	2.5	13455	6699	9055	18669	47879	14.73
3350	2.4	13869	6699	9334	19243	49146	14.67
3450	2.3	14283	6699	9613	19818	50413	14.61
3550	2.3	14697	6699	9891	20392	51680	14.56
3650	2.2	15111	6699	10170	20967	52947	14.51
3750	2.1	15525	6699	10449	21541	54214	14.46
3850	2.1	15939	6699	10727	22115	55481	14.41
3950	2.0	16353	6699	11006	22690	56748	14.37
4050	2.0	16767	6699	11285	23264	58015	14.32
4150	1.9	17181	6699	11563	23839	59282	14.28
4250	1.9	17595	6699	11842	24413	60549	14.25
4350	1.8	18009	6699	12120	24987	61816	14.21

Table 5.--Continued Projected Annual Costs and Cost per Hour of Use for 1976

Hours of Use	Yrs to Trade	Depreciation	THII	Repairs	Fuel + Oil	Total	Cost per Hr
4450	1.8	18423	6699	12399	25562	63083	14.18
4550	1.8	18837	6699	12678	26136	64350	14.14
		Milk Bulk Stainless Steel Trailer[b]					
500	10.0	2700	4373	533	0	7606	15.21
600	10.0	2700	4373	689	0	7761	12.94
700	10.0	2700	4373	854	0	7927	11.32
800	10.0	2700	4373	1030	0	8103	10.13
900	10.0	2700	4373	1215	0	8287	9.21
950	10.0	2700	4373	1310	0	8383	8.82
1050	10.0	2700	4373	1507	0	8580	8.82
1150	10.0	2700	4373	1712	0	8785	7.64
1250	9.6	2813	4373	1893	0	9078	7.26
1350	8.9	3038	4373	2044	0	9454	7.00
1450	8.3	3263	4373	2196	0	9831	6.78
1550	7.7	3488	4373	2347	0	10207	6.59
1650	7.3	3713	4373	2499	0	10584	6.41
1750	6.9	3938	4373	2650	0	10960	6.26
1850	6.5	4163	4373	2801	0	11336	6.13
1950	6.2	4388	4373	2953	0	11713	6.01
2050	5.9	4613	4373	3104	0	12089	5.90
2150	5.6	4838	4373	3256	0	12466	5.80
2250	5.3	5063	4373	3407	0	12842	5.71
2350	5.1	5288	4373	3559	0	13219	5.62
2450	4.9	5513	4373	3710	0	13595	5.55
2550	4.7	5738	4373	3861	0	13971	5.48
2650	4.5	5963	4373	4013	0	14348	5.41
2750	4.4	6188	4373	4164	0	14724	5.35
2850	4.2	6413	4373	4316	0	15101	5.30
2950	4.1	6638	4373	4467	0	15477	5.25
3050	3.9	6863	4373	4619	0	15854	5.20
3150	3.8	7088	4373	4770	0	16230	5.15
3250	3.7	7313	4373	4921	0	16606	5.11
3350	3.6	7538	4373	5073	0	16983	5.07
3450	3.5	7763	4373	5224	0	17359	5.03
3550	3.4	7988	4373	5376	0	17736	5.00
3650	3.3	8213	4373	5527	0	18112	4.96
3750	3.2	8437	4373	5679	0	18489	4.93
3850	3.1	8663	4373	5830	0	18865	4.90
3950	3.0	8888	4373	5981	0	19241	4.87
4050	3.0	9113	4373	6133	0	19618	4.84
4150	2.9	9338	4373	6284	0	19994	4.82
4250	2.8	9562	4373	6436	0	20371	4.79

Table 5.--Continued Projected Annual Costs and Cost per Hour of Use for 1976

Hours of Use	Yrs to Trade	Depreciation	THII	Repairs	Fuel & Oil	Total	Cost per Hr
4350	2.8	9788	4373	6587	0	20747	4.77
4450	2.7	10013	4373	6739	0	21124	4.75
4550	2.6	10238	4373	6890	0	21500	4.73

[a]Purchase price, quoted 1/3/76 = 36800; RFV group number = 5; tar equation number = 3; hours to wearout or 10 years to trade = 8000; fuel price per gallon for diesel = .450; gallons of fuel consumed per hour = 11.1; per cent of average investment charged for THII annually = 33.1.

[b]Purchase price, qyoted 1/3/76 = 30000; RFV group number = 5; tar equation number = 3; hours to wearout or 10 years to trade = 12000; per cent of average investment charged for THII annually = 26.5.

Table 6. Transport Cost per Cwt of Liquid Whey

Total Mileage from Cheese Plant & Return	Man Hours/ Day	Total Tractor and Trailer Hours of Use/Yr[a]	Semi-Variable Costs/Yr			Fixed Costs/Yr		Total Cost		Gal of Whey Delivered/ Day[e]	Trans. Cost Cwt of Liquid Whey[f]
			Tractor	Trailer	Wages[b]	Outside Washing	Inside Washing[c]	Total Cost/Yr	Total Cost/Day[d]		
20	8.05	690	15,788	7,910	13,828	208	6,240	43,974	140.94	28,000	0.0585
20	16.10	1,380	24,185	9,568	27,656			67,857	217.49	56,000	0.0452
40	8.24	1,120	20,890	8,723	14,279			50,340	161.35	22,400	0.0838
40	16.48	2,230	34,955	12,767	24,603			78,773	252.48	44,800	0.0655
60	7.50	1,250	22,538	9,078	12,523			50,587	162.14	16,800	0.1122
60	15.00	2,490	38,249	13,745	25,046			83,488	267.59	32,600	0.1161
80	8.85	1,670	27,859	10,659	15,726			60,692	194.53	16,800	0.1346
80	14.75	2,780	41,924	14,838	24,452			87,662	280.97	28,000	0.1167
100	6.78	1,390	24,311	9,605	10,824			51,178	164.03	11,200	0.1703
100	16.95	3.470	50,666	17,435	33,628			108,177	346.72	28,000	0.1440
120	7.68	1,670	27,859	10,659	12,950			57,916	185.63	11,200	0.1928
120	15.38	3,340	49,019	16,945	25,948	208	6,240	98,360	315.26	22,400	0.1637

[a]See Table 4, hours in this column rounded upwards to nearest ten hours.

[b]Interpolated from Table 5, total column for tractor, truck type, and milk bulk stainless trailer.

[c]Inside washing costs of the bulk milk trailer were assumed to be once per day. Outside washing costs of the entire unit were assumed to be $4 per week.

[d]Total cost = Variable cost + Fixed Cost, figures based on 312 day use.

[e]Gal of whey delivered/day = Trips/Day times 5,600 gal. Trips/day, see Table 4.

[f]Transport cost/cwt of liquid whey, calculated by taking; Total cost ÷ 312 days = Total cost/day. Total cost/day ÷ [gal of whey delivered x 8.6 lbs/gal ÷ 100 = cwt] = Transport cost/cwt of liquid whey.

Table 7. Partial Budget I, Liquid Cottage Cheese Whey Replacing Alfalfa Hay in a Dairy Ration

Profitability-Annual Costs

Credits

Added Return -0-

Reduced Cost
- Feed purchased 13 lb hay @ $.038 (Hay = $75/ton) x 375 = 185.25 x 365 = $67,616
- Labor (1 hr) 365 days @ $3.50/hr = $1,278

Total Annual Reduced Cost = $68,894

Total Credits = $68,894

Debits

Added Cost
- SS Tank ($27,210[a] x 35.5% DIRTI) = $9,660
- Waters & Pipe (35.5% x $1,533 DIRTI) = $544
- Accessory Equip. (45.5% x $5,790[b] DIRTI) = $2,634
- Total Added Annual Investment = $12,838
- Feed purchased ($.25/cwt x [750 cwt] x 365 days) = $68,438
- Elect, Misc. = $2,150.00
- Labor, 100 hrs @ $3.50 = $350.00
- Total Ann. Operating Costs = $70,938
- Total Added Costs = $83,776

Reduced Return
- 5# milk x 375 cows x 365 days @ $.10/lb = $68,438

Total Debits = $152,214

TOTAL CREDITS - TOTAL DEBITS = CHANGE IN INCOME = -$83,320

[a]Cost of stainless steel tank includes the tank, concrete slab, erection cost, and labor involved in these items.

[b]Cost of Accessory Equipment includes washing pump and tank, 5 hp air compressor, electrical hookup, and pipe.

Table 8. Charges for Depreciation, Interest, Repairs, Taxes, and Insurance

Equipment Group	Per Cent of Average Investment					
	Depreciation	Interest	Repairs	Taxes	Insurance	Total
S.S. Tank	10	10	11	2	2.5	35.5
Waterers and Pipe	10	10	11	2	2.5	35.5
Accessory Equipment	20	10	11	2	2.5	45.5

with a five pound decrease in milk production, a loss of $83,320 occurs.

Budget II, Table 9, was constructed using data in which whey was substituted for grain. Welch (1973) indicates that cows will drink up to 400 lbs of whey per day. This is equivalent to about 32 lbs of concentrate. In other words, 100 lbs of whey is about equivalent to 8 lbs of concentrate.

In another report, Welch and Nilson (1973) stated that cows fed whey produced above the average of the herd. It is assumed for the budgets constructed that the cows consume an average of 200 pounds of whey per day replacing 15 pounds of concentration. Milk production was held constant. With these assumptions, profitability increased by a positive $45,822, with the repayment capacity a positive $50,514. Return per dollar of investment was 146.3 per cent. Years to pay back the investment were calculated at 0.684 years. Break-even analysis for whey cost per cwt was $0.417.

Table 10 was set up with 100 pounds of liquid whey replacing 7.5 pounds of concentrate and milk production held constant. Profitability, repayment capacity, return per dollar of investment, and years to pay back were respectively $15,242, $19,934, 57.72 per cent, and 1.73 years.

Whole Budget Analysis of Feeding Liquid Whey to Arizona Dairy Animals

Whole budget, Tables 11 and 12, and Appendix A, were constructed using data in which whey substituted for grain (Table 9). The whole budget was used to determine the impact of feeding whey to dairy

Table 9. Partial Budget II, Liquid Cottage Cheese Whey Replacing Grain in a Dairy Ration

Profitability--Annual Costs

Credits	Debits
Added Return -0-	
Reduced Cost	
Feed purchased 15# Concentrate @ 6.25¢/lb x 365 days x 375 cows = $128,320	Added Costs (see Table 7) Total Added Cost = $83,776
Labor (1 hr @ $3.50 x 365 days) = $1,278	
Total Reduced Cost = $129,598	
Total Credits = $129,598	Total Debits = $83,776

TOTAL CREDITS - TOTAL DEBITS = CHANGE IN INCOME = $45,822

Repayment Capacity--Annual Costs

Credits	Debits
Added Return -0-	
Reduced Cost--same as above	Added Costs New Investment SS Tank $27,210 x ITI 23.5% = $6,394 Waterers etc. $1,533 x ITI 25.5% = $391 Accessory Equip. $5,790 x ITI (23.5%) = $1,361 Total Added Annual Investment = $8,146
Total Reduced Cost = $129,598	Total Annual Operating Costs (see Table 7) = $70,938
Total Credits = $129,598	Total Added Cost = $79,084 Reduced Return = 0 Total Debits = $79,084

TOTAL CREDITS - TOTAL DEBITS = CHANGE IN NET INCOME = +$50,514

Table 9.--Continued Partial Budget II, Liquid Cottage Cheese Whey Replacing Grain in a Dairy Ration

Financial Analysis

Total Added Investment	=	$34,533
Returns/$Investment ($50,514 ÷ $34,533) 100	=	146.3%
Yrs required to pay back ($34,533 ÷ $50,514)	=	.684

Breakeven Analysis

Cost of Whey $129,598 = X_1 (750 cwt x 365 days) + $15,338

X_1 = $0.417

Table 10. Partial Budget III, Liquid Cottage Cheese Whey Partially Replacing Grain in the Ration

Profitability--Annual Costs

Credits

Added Return -0-

Reduced Cost

Feed Purchased
7.5 lbs Concentrate @ 6.25¢/lb x 365 days x 375 cows = $64,160

Labor (1/2 hr @ $3.50/hr x 365 days) = $639

Total Reduced Cost = $64,799

Total Credits = $64,799

Debits

Added Costs

Total Added Annual Investment (see Table 7) = $12,838

Feed Purchased ($.25/cwt x 1 cwt/ day x 365 days x 375 cows = $34,219

Elect., misc. = $2,150

Labor 100 hrs @ $3.50 = $350

Total Annual Operating Costs = $36,719

Total Added Costs = $49,557

Reduced Return = -0-

Total Debits = $49,557

Total Credits - Total Debits = Change in Income = $+15,242

Repayment Capacity--Annual Costs

Added Return -0-
Reduced Cost--same as above
Total Reduced Cost = $64,799
Total Credits = $64,799

Added Costs
Total Added Annual Investment = (see Table 9) = $8,146
Total Annual Operating Costs (same as above) = $36,719
Total Added Cost = $44,865
Reduced Return = -0-
Total Debits = $44,865

Total Credits - Total Debits = Change in Net Income = +$19,934

Financial Analysis

Total Added Investment	= $34,533
Returns/dollars Investment ($19,934/$34,533) x 100	= 57.72%
Yrs Required to pay back ($34,533/$19,934)	= 1.73 yrs

Table 11. Arizona Budget Summary--375 Cow Dairy Herd

Receipts (375 cows)	Non-whey (Dollars)	Whey (Dollars)
Milk		
15,250 lbs per cow x 375 cows = 57,187.5 cwt		
@ $10.00/cwt =	571,875	571,875
Calves (6% death loss)		
176 bull calves @ $10 =	1,760	1,760
176 heifer calves @ $30 =	5,280	5,280
Total	578,915	578,915
Expenses		
Feed: Hay--2,546 tons @ $75/ton	190,969	190,969
Concentrates--915 tons @ $125/ton	114,375	
Whey--273,750 cwt @ $0.25/cwt		68,438
	305,344	259,407
Labor		
3 hired hands	27,600	27,600
Fringe benefits ($27,600 x 18%)	4,968	4,968
	32,568	32,568
Operation and Maintenance		
Repairs	16,109	19,908
Vet and breeding	12,525	12,525
Utilities	11,250	11,250
Supplies	10,500	10,500
Miscellaneous	3,750	3,750
Production testing	2,925	2,925
Milk hauling	13,725	13,725
Coop and check-off	4,575	4,575
Vehicle expense	7,655	7,655
Whey feeding equipment		
Electricity		1,150
Misc.		1,100
Sub-total	83,014	88,963
Interest on 1/2 variable costs		
($420,926 @ 9% x .5) ($380,938 @ 9% x .5)	18,942	17,142
Insurance and taxes	3,469	5,023
Depreciation	54,876	58,636
Management and Supervision	12,000	12,000
Interest on capital investment items		
$858,099 @ 8%	68,648	
$876,726 @ 8%		70,138

Table 12. Investment Expense and Return Comparisons Between Whey and Non-whey Feeding

	Non-whey (Dollars)	Whey (Dollars)
Investment		
Capital Investment	1,057,400	1,057,400
Machinery and Equipment	31,800	31,800
Whey Investment		34,533
Expenses[a]		
Feed	305,344	259,407
Labor	32,568	32,568
Operation and maintenance	83,014	88,963
Insurance and taxes	3,469	5,023
Depreciation	54,876	58,636
Management	12,000	12,000
Interest on:		
Variable costs	18,942	17,142
Capital investment	68,648	70,138
Total expenses	578,861	543,877
Milk Income	571,875	571,875
Cost/cwt of milk--57,187.5 cwt	$10.12	$9.51

[a]See Table 11 for breakdown of expenses and income, and also Appendix A.

animals on the overall dairy farm financial picture. By feeding whey, Cost/cwt of milk (Table 12) was reduced from $10.12 to $9.51, a difference of $0.61 per cwt. Another important factor was that the total annual profit for the dairy farm was increased from $54 per year to $35,038 per year by feeding liquid cottage cheese whey. The whole budgets were constructed by following the format and cost structures as presented by Wright and Angus (1976).

Linear Programming Cost and Feed Value Analysis of Liquid Cottage Cheese Whey

The model was formulated by Harsh, Hillman, and Schoonaert (1972) and considered the requirements for feed level intake, net energy for lactation, fiber, crude protein, calcium, phosphorus, magnesium, salt, and certain restrictions on feeds to insure palatability. Dairy animal maintenance and production level requirements, as well as feed ingredients, were from the National Research Council (1971). Feed level restrictions are listed in Appendix B. Other restrictions included were:

1. The calcium:phosphorus ratio with a lower limit of 1.4:1.0 and an upper limit of 3.5:1.0 for lactating dairy animals.
2. Dry matter intake was dependent upon a milkfat test of 3.5 per cent, production level of 50 pounds per animal and the size of the animal at 14 cwt.
3. The amount of nonprotein nitrogen was restricted to 30 per cent of the total crude protein equivalent. If the urea level in the concentrate ration exceeded 0.8 per cent, the model added molasses to insure palatability.

4. Fiber was set at a minimum of 15 per cent for milking cows. Finally, cottonseed products were limited to 35-36 per cent of the total ration.

These restrictions are based on preliminary studies by Brown (1976) in which total cottonseed (e.g., cottonseed hulls, meal, and whole cottonseed) has been included in dairy rations without a significant decrease in milk production. One of the problems with feeding cottonseed products is gossypol, a toxic phenolic pigment which can create palatability problems in the dairy ration.

Analysis of Liquid Cottage
Cheese Whey as a Feed

Feed nutrient values and prices are given in Appendix B. All prices were current as of June, 1976. Cottage cheese whey was included in the ration on a 93 per cent dry matter basis (DM) and then converted to an as-fed basis of 7 per cent DM. Table 13 indicates that at a zero price, whey on an as-fed basis (7 per cent DM) was included at 382.36 pounds per animal per day. At transport costs of $0.1928 per cwt, whey was included at 305.57 pounds per animal per day. These results support those of Nilson and Welch (1975) in which cows would drink up to 400 pounds per animal per day (Adams, 1975) of liquid whey.

Another important result of the linear programming analysis was the reaction of the model to increases in whey costs, Figure 4 (see also Table 13). Cost ranges where whey remained in the ration at constant per cent of DM were $0.0-0.158/cwt, $0.158-0.334/cwt, $0.3342-0.34/cwt, and $0.34-0.3447/cwt. The amounts of whey used for the cost

Table 13. Amounts of Liquid Cottage Cheese Whey Fed Per Dairy Animal Per Day at Various Costs

Cost/Cwt of Dried Whey (93% Dry Matter)[a]	Cost/Cwt of Liquid Cottage Cheese Whey (7% Dry Matter)	Pounds/Head/Day (100% Dry Matter)[b]	As Fed Basis, Pounds (7% Dry Matter)[c]
$0.00	$0.0000	26.76	382.36
2.10	0.1580	21.39	305.57
2.56	0.1928	21.39	305.57
3.19	0.2400	21.39	305.57
3.32	0.2500	21.39	305.57
3.45	0.2600	21.39	305.57
3.59	0.2700	21.39	305.57
3.72	0.2800	21.39	305.57
3.85	0.2900	21.39	305.57
3.98	0.3000	21.39	305.57
4.12	0.3100	21.39	305.57
4.25	0.3200	21.39	305.57
4.38	0.3300	21.39	305.57
4.43	0.3334	21.39	305.57
4.44	0.3342	19.98	285.43
4.52	0.3400	19.98	285.43
4.54	0.3417	12.57	179.57
4.56	0.3432	12.57	179.57
4.58	0.3447	0.00	0.00
4.65	0.3500	0.00	0.00

[a]This column is based on the price of liquid whey per cwt. To calculate: $0.1928 divided by 7 lb solids = $0.0275/lb solid times 93 lb solids = $2.56/cwt of dried whey.

[b]Per cent dried whey in ration times concentrate (or complete feed) to be fed (lbs/head/day) = Amount dried whey fed times 93 per cent D.M. basis = Pounds/Head/Day. Example: (60.08%) 47.9 lbs = 28.78 lbs times 93% D.M. = 26.76 lb.

[c]One hundred per cent dry matter basis whey is equivalent to liquid acid whey as follows: Solve for X. 26.76 lbs (100% D.M.) = X lbs (7% D.M.), X lbs = 382.36.

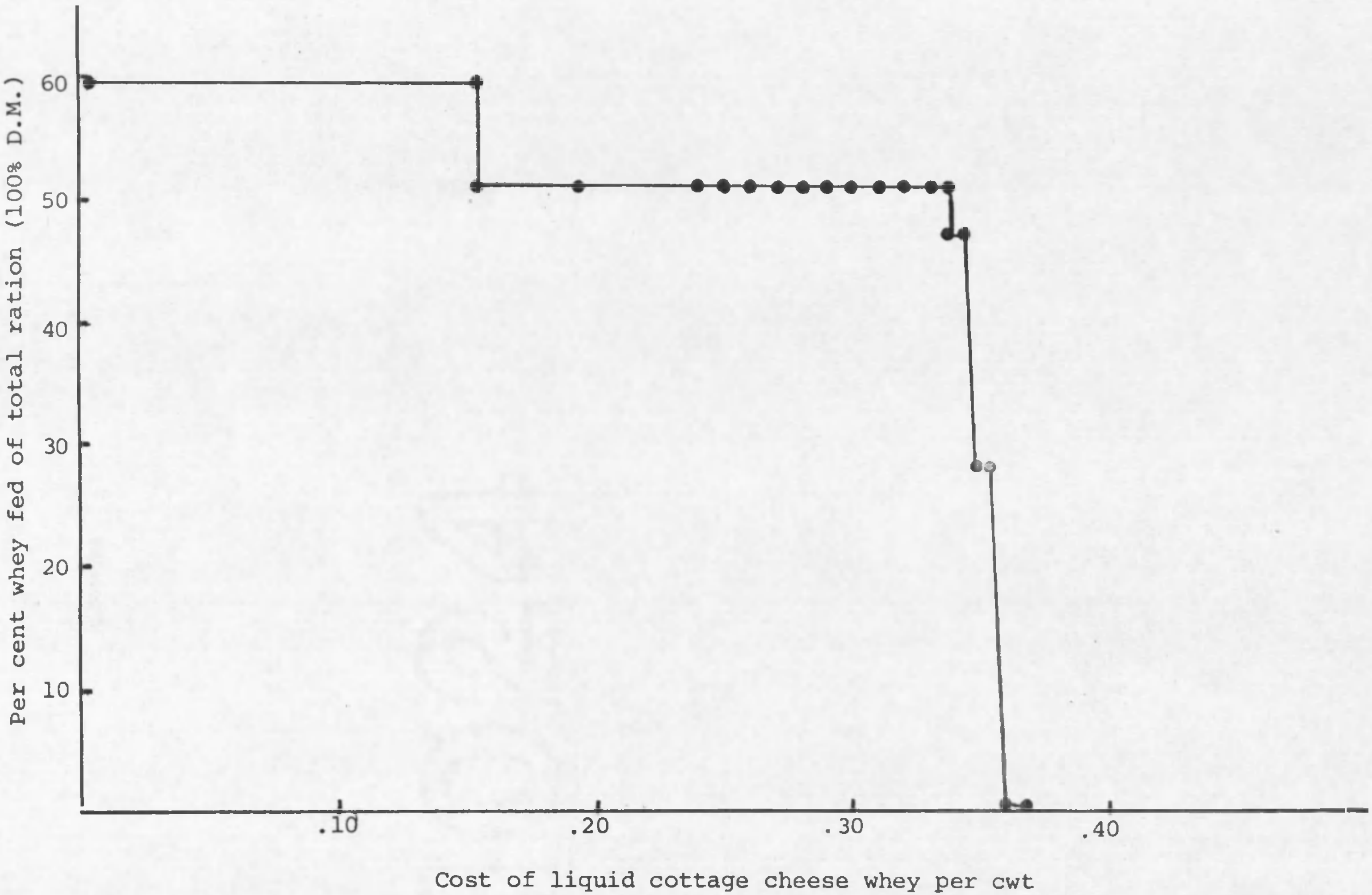

Figure 4. Per Cent Whey (100 Per Cent Dry Matter Basis) Fed in Total Ration at Varying Whey Costs

ranges were 60, 52, 48, and 28 per cent, respectively. Whey dropped out of the ration when the cost was entered at $0.3447/cwt.

CHAPTER 4

COTTAGE CHEESE WASTE ECONOMICS: WHEY AS A POLLUTANT

Biological Oxidation Demand (BOD) is technically defined as the amount of oxygen per time period that is required to oxidize by a biological organism the organic solids of waste. To illustrate the Biological Oxidation Demand of cottage cheese whey, a five-day BOD value (BOD_5) of 42,000 parts per million, as given in Table 14, requires 42 pounds of oxygen to biologically oxidize the organic solids in one thousand pounds of cottage cheese whey. Another indicator, the ratio of pounds of BOD_5 to pounds of organic solids, is used to indicate the relative completeness of biological oxidation in five days. For cottage cheese whey, this figure is 90 per cent, as stated by the Water Pollution Control Research Series (1971). Table 14 shows the literature and calculated BOD_5 values of cottage cheese whey. The mean value was chosen for the calculations of this study.

Sources of Dairy Food Plant Wastes

Estimation of dairy food plant wastes in cottage cheese production necessitates the evaluation of unit operations and their potential role as sources of waste water refractory compounds and milk solids. Flow diagrams for the processing of skim milk into cottage cheese, waste generation processes, and the general nature of the waste for each type of unit operation are presented in Tables 15 and 16.

Table 14. Five-Day Biological Oxidation Demand, Values for Cottage Cheese Whey

Source	Pounds BOD_5[a] per 1,000 Pound Milk Processed	BOD_5 (ppm) Cottage Cheese Whey
Water Pollution Research Series (1971)[b]		
Firm A	35.4	42,000
Firm B	33.7	40,000
Firm C	54.8	65,000
Firm D	59.0	70,000
Average	45.7	54,250

[a]See Appendix C for calculations.

[b]Reported by various industrial firms based on BOD_5 determined by Standard Methods.

Table 15. Cottage Cheese Processing, Unit Process Operations, Waste Generating Processes and the Nature of Wastes for Cottage Cheese

Plant Process	Waste Generating Process	Nature of Waste
Milk receiving	Cleaning tank trucks	Milk + detergents
Separation	Sludge removal	High protein cellular matter + detergent + sanitizer
Skim storage	Cleaning lines + storage tanks + sanitizing	Milk waste + detergent + sanitizer
Skim milk from storage	Cleaning lines + sanitizer	Skim milk wastes + detergent + sanitizer
HTST pasteurization	HTST start-up shut down cleaning + sanitizing	Milk waste + detergent + sanitizer
Starter manufacture	Cleaning starter, lines + tank	Starter (pH 4.6) + detergents + sanitizer
Settling, cutting cooking, draining	Whey draining	Whey not excluded from drain + fine curd particles
Washing--three times	Wash water draining	Diluted whey = 0.5-1.0 of orig. whey solids + fine curd particles
Cooling	Curd transfer + cheese vat cleaning sanitizing	Curd particles + detergents + sanitizer
Cream from past. storage	Cleaning cream lines + storage tank	Cream waste + detergents + sanitizers
Creaming	Cleaning creaming tank or vat curd transfer	Curd + creaming mixture + detergents + sanitizer
Packaging	Filling machine jamming, overfill, cleaning	Cottage cheese curd + cream + detergents + sanitizer
Storage and delivery	Broken packages, returns	Cottage cheese cream

Table 16. Cottage Cheese Processing, Pound of Waste Water Per Pound of Milk Processed and Pound BOD_5 Per 1000 Pounds Milk Processed

Plant Process	Lb Waste Water/lb Milk Processed	Lb BOD/1000 lb Milk Processed
Milk receiving	0.125	0.20
Separation	0.015	0.08
Skim storage	0.100	0.15
HTST pasteurization	0.150	0.30
Starter manufacture	0.100	0.30
Settling, cutting, cooking, draining	0.200	0.20 (no whey)
Washing three times	10.000	1.50
Cooling	0.500	0.10
Cream from past. storage	0.125	0.30
Creaming	0.100	0.30
Packaging	0.050	0.10
Storage and distribution	0.010	0.10
Total	11.840	3.28[a]

[a]Corrected for amount of starter and cream used.

The waste generating processes of major significance include:

1. Washing, cleaning, and sanitizing of all pipe lines, pumps, processing equipment, tanks, tank trucks, and filling machines.
2. Start-up and shut-down of HTST and UHT pasteurizers.
3. Loss in filling operations through equipment jams and broken packages.
4. Lubrication of casers, stackers, and conveyors.
5. Whey.

Tables 15 and 16 assume the piping associated with each unit process as an integral part of that operation; therefore, the waste generating process of tank truck washing would include the associated pumps, lines, and valves. The waste generating process would not include spillage and leakage in the production process. This type of waste is inherently controllable through good management control and thus should not be counted in the waste load level.

Wastewater Volumes

Water usage of dairy processing in the United States exceeds 27 billion gallons per year according to Jones (1974). Increasing costs of waste treatment and water in an industry with a small profit margin make careful management of water and waste water necessary. The author indicated that a 50 per cent reduction in water usage in a small-size dairy plant is possible with an employee motivation program. It was also stated that water usage is approximately twenty-five times higher in "older technology" than the "advanced technology" plants and that BOD_5 generated is five times greater for the former. Relatively little information was available concerning the amount of water per unit weight of milk processed as utilized by the cottage cheese making process. Major processes utilizing water are wash water for cottage cheese, cooling water, and condensing water. Cooling waters are generally free from waste and could be separated from other operations to minimize hydraulic loading.

The strength of dairy waste waters is generally reported in terms of parts per million of BOD_5. These reports do not take into consideration the relationship of the amount of milk processed; the total waste water volume and waste volumes are often reported irrespective of the volume of product processed. Waste water (BOD_5) strength coefficients and volumes have been calculated from industrial and literature data with respect to the amount of milk, or milk produced. Units of waste water volume will be defined as pounds of waste water per pound of milk processed. Jones (1974) gives a range for waste water volume of .8 to 12.4 pounds with an average waste water volume of six pounds per pound of milk processed.

The Cost of Dumping Whey in Arizona

Cottage and Cheddar cheese liquid whey production comes from mainly four producers in the Phoenix metropolitan area. In the last four years, on the average, 58.8 million pounds of cottage cheese whey were produced annually. The latest figures show that the 1975 and 1976 production of acid whey will be above that figure. At the present time, three plants are dumping whey into two municipal sewage treatment plants located at 23rd Avenue and 91st Avenue with the exception of one of the three plants which was hauling some cottage cheese whey for feeding purposes. No estimate was available as to how much of this whey was being used, so all cottage cheese whey was assumed to be dumped into the Phoenix sewage treatment system.

The cost of whey disposal was estimated by collecting data on variable and fixed costs from the Phoenix Water and Sewer Accounting Department. Table 17 shows the variable costs or operational costs for each of the two plants. Table 18 shows the construction costs for each sewage treatment plant based on current construction data for a 30-million gallon per day addition to the 91st Avenue plant. It is estimated that there would be economies of size involved with the larger existing 65 million gallon per day 91st Avenue plast as to the construction costs, so these figures given in Table 18 could be toward the upper limits. Depreciation was based on a twenty-five year straight-line depreciation method. Land was assumed to be paid for in 30 years. Interest cost was based on the current Phoenix municipal bond rate of 5.77 per cent. Since whey is dumped into both plants with the final sewage treatment at the 91st Avenue plant, a weighted mean cost per pound of five day BOD was estimated at $0.0696 (Table 19).

The milk or milk equivalent used in cottage cheese manufacture in 1975 was 60,912,104 pounds. It is estimated (Water Pollution Control Research Series, 1971) that for every 1,000 pounds of milk or milk equivalent, there are 45.7 pounds of five day BOD (Table 14). In 1975, this was equivalent to 8.753 pounds of five day BOD per day, or $609 (8,753 lb BOD_5 at $0.0696) cost per day for cottage cheese manufacture. On a per cwt of liquid acid whey basis, this would be equivalent to

Table 17. Operational Costs of 91st Avenue and 23rd Avenue Activated Sludge Sewage Treatment Plants for Years 1973-74 and 1974-75[a]

	23rd Ave. Plant	91st Ave. Plant
Years 1973-74		
Personal Services[b]	$343,351	$383,568
Contracted Services[c]	250,162	356,834
Commodities[d]	55,303	54,120
Capital Outlay[e]	3,066	10,545
Total	$651,882	$805,067
Years 1974-75		
Personal Services	$393,783	$457,016
Contracted Services	305,509	404,739
Commodities	83,283	73,426
Capital Outlay	12,619	15,912
Total	$795,194	$951,849

[a] Phoenix Water and Sewer Accounting Department (1975).

[b] Personal Services = labor, administrative.

[c] Contracted Services = electricity, gas, etc.

[d] Commodities = chemicals.

[e] Capital Outlay = furniture, cars, parts, etc.

Table 18. Construction Costs of Activated Sludge Sewage Treatment Plant, Thirty Million Gallon/Day Addition, 1975[a]

30 Million Gallon/Day Addition		
Design		$ 535,000
Construction		13,099,700
Inspection		393,000
Contingency		400,000
Sub-total		14,427,700
Land @ $3,000/acre, 20 acres		60,000
TOTAL		$14,487,700
Extrapolated Construction and Land Cost of 65 Million Gallon/Day Plant, 91st Avenue		
($14,427,700 (2.1667[b])	=	$31,260,497
($60,000)(2.1667)	=	130,002
TOTAL		$31,390,499
Extrapolated Construction and Land Cost of 40 Million Gallon/Day Plant, 23rd Avenue		
($14,427,700)(1.333[c])	=	$19,236,452
($60,000)(1.333)	=	79,998
TOTAL		$19,316,450

[a] Phoenix Water and Sewer Accounting Department (1975).

[b] Factor is equal to 65 x 10^6 gal ÷ 30 x 10^6 gal = 2.1667.

[c] Factor is equal to 40 x 10^6 gal ÷ 30 x 10^6 gal = 1.3333.

Table 19. Standard Weighted Cost Per Pound of Five-Day Biological Oxidation Demand

91st Avenue Plant = \$0.0679/lb BOD_5

Depreciation - Construction Cost (see Table 18) 25 years (0 salvage value)	\$1,250,420
Interest @ 5.77%[a]	1,803,731
Operational Costs (see Table 17)	951,849
Land-interest cost[a]	7,501
Insurance[c]	15,000
TOTAL	\$4,028,501

\$4,028,501 ÷ 365 days = \$11,037/day ÷ Total capacity of BOD_5 flow of 162,500 lb[b] BOD_5/day = \$0.0679

23rd Avenue Plant = \$0.0725/lb BOD_5

Depreciation - Construction Cost ÷ 25 years (0 salvage)	\$ 769,458
Interest @ 5.77%	1,065,546
Operating Costs	795,194
Land-interest cost	4,616
Insurance	10,000
TOTAL	\$2,644,814

\$2,644,814 ÷ 365 days = \$7,246/day ÷ Total capacity of BOD_5 flow of 100,000[b] lb BOD_5/day = \$0.0725

Weighted Mean Cost/lb BOD_5 = [\$0.0696]

[a] See Appendix D for interest calculation.

[b] See Appendix C for Total capacity of BOD_5 flow.

[c] Phoenix Water and Sewer Accounting Department (1975).

$.377 per cwt per day. Calculating these figures on an average daily utilization of the sewage treatment plants as shown in Table 20, the cost per cwt of liquid acid whey basis is equal to $0.625. If these costs were charged to cottage cheese, costs would range from $0.0214 to $0.0354 per pound.

The Cost of Water Dilution in Arizona

In 1975, 69,362,325 pounds of skim milk were processed in Arizona into cottage cheese. Of this 58,957,976 pounds or 6,855,600 gallons (8.6 lb/gal) were whey. The City of Phoenix required that all effluent have a maximum load of .00250 pounds of BOD_5 per gallon. Acid whey has an average BOD_5 of .4518 pounds per gallon of whey. For every gallon of whey, it would require a dilution with water of 181 gallons to bring acid whey to the permissible limit of .00250 pounds of BOD_5 per gallon (Appendix C). Thus 1,240,863,600 gallons of water are required to dilute the annual production of whey. Total waste volume would be equivalent to the six pounds of water per pound of milk processed (Water Pollution Control Research Series, 1971, pp. 4-6) plus the water to dilute the whey, plus the liquid acid whey. Total waste volume for 1975:

Processing water	48,775,800 gal
Dilution water	1,240,863,600 gal
Whey	6,855,600 gal
Total Waste Volume	1,296,495,000 gal

Total water usage for the manufacture of cottage cheese from the above figures would total 1,289,639,400 gallons, or about 172,424,800 CF (cubic feet) of water. Diluting the liquid acid whey

Table 20. Standard Weighted Cost Based on Average Daily Utilization of Cast Study Sewage Treatment Plants

91st Avenue Plant

$170\ BOD_5/day^a - 67.046 \times 10^6$ gal/day

$170\ BOD_5/day = 0.00064345$ kg/gal

0.00064345 kg/gal $= 0.00141$ lb BOD_5/gal^b

$(0.00141$ lb $BOD_5/gal)$ $(67.046 \times 10^6$ gal/day$) = 94{,}535$ lb BOD_5/day

23rd Avenue Plant

$215\ BOD_5/day^a - 35.77 \times 10^6$ gal/day

$215\ BOD_5/day = 0.0008138$ kg/gal

0.008138 kg/gal $= 0.00179$ lb BOD_5/gal^b

$(0.00179$ lb $BOD_5/gal)$ $(35.77 \times 10^6$ gal/day$) = 64{,}028$ lb BOD_5/day

Average Cost/Pound of BOD_5/Day

$\$18{,}283^c \div (94{,}535 + 64{,}028)$ lb $BOD_5/day = \$0.1153/lb\ BOD_5/day$

[a] Expressed in mg/l.

[b] 1 kg = 2.2 pounds.

[c] See Table 19, $18,283, sum of per day costs for 91st and 23rd Avenue Plants.

in essence increases water costs by 95.8 per cent per pound of cottage cheese. Total water costs for processing vary from $0.033 to $0.0516 per pound of cottage cheese, Table 21. Whey dilution costs vary from $0.03189 to $0.0494 per pound of cottage cheese. As is shown above, and in Table 21, the costs for diluting whey are substantial when compared to the total water cost.

Simple Regression Analysis for the Projection of Acid Whey Production in Arizona

Cottage cheese and acid whey are product-product relationships. That is, for every one hundred pounds of skim milk, fifteen pounds of cottage cheese and eighty-five pounds of acid whey are produced or eighty-five per cent of the skim milk used in cottage cheese production is acid whey. Another way of stating the conversion is to use pounds of cottage cheese divided by a factor of .1765 and those results are approximately equal to the pounds of acid whey as derived by the first method.

Skim milk used in cottage cheese production has been increasing over the years 1965 to 1975. Using the conversion factor of .85 times skim milk gives the amount of acid whey that is produced per year from 1956 to 1975 as shown in Table 22. The column entitled "Acid Whey" of Table 22 lists the increases in acid whey production time period.

During a period of time in 1975, most of the acid whey was diluted with water to meet the suspended solids and five day BOD requirements for disposing of this type of whey as sewage in the Phoenix area. It was the purpose of this model to project the amount of

Table 21. Comparison of Water Usage Costs for Cottage Cheese Production in the Phoenix Metropolitan Area on a Yearly Basis

	Including Whey		Whey Only	
Item	Min.	Max.	Min.	Max.
Meter--6" @ $50/mo	$ 600			
@ $75/mo		900		
1,956,000 C.F.[a]				
@ $0.23/100 C.F.	4,499			
@ $0.36/100 C.F.		7,042		
170,468,800 C.F.				
165,903,500 (Whey Only)[b]				
@ $0.20/100 C.F.	340,938		331,807	
@ $0.31/100 C.F.		528,453		514,301
TOTAL COST	$[346,037]	[536,375]	[331,807]	[514,301]

Processing Waste Water Cost:

6,521,300 C.F. = $346,037 - 331,807 = $14,230
Whey Dilution Cost = $331,807/346,037 x 100 = 95.9%

Cost per Pound of Cottage Cheese (1975 = 10,404,400 lbs)
Minimum--$346,037/10,404,400 lb = $0.0333
Maximum--$536,395/10,404,400 lb = $0.0516

Whey Only:
Minimum--$331,807/10,404,400 lb = $0.03189
Maximum--$514,301/10,404,400 lb = $0.0494

[a]Depending upon location of a water user, these figures are charged for the first 163,000 cubic feet (C.F.) of water/mo or 1,956,000 C.F./hr.

[b]172,424,800 C.F. - 6,521,300 C.F. = 165,903,500 C.F. Total Water Usage = Processing Water + Whey Dilution.

Table 22. Acid Whey Production from 1956 to 1975 for Arizona

Year	Whole Milk[a] Pounds	Butter Fat Pounds[a]	Skim Milk Pounds	Acid Whey Pounds
1956	16,199,068	191,777	16,007,291	13,606,197
1957	23,228,329	204,312	23,024,017	19,570,414
1958	29,062,539	248,375	28,814,164	24,492,039
1959	30,521,556	246,405	30,275,151	25,733,878
1960	33,736,243	285,877	33,450,366	28,432,811
1961	40,061,777	346,604	39,715,173	33,757,897
1962	42,105,324	377,747	41,727,577	35,468,440
1963	41,877,738	344,558	41,533,180	35,303,203
1964	44,107,133	373,202	43,733,931	37,173,841
1965	43,994,492	354,259	42,640,233	37,094,198
1966	44,207,637	364,472	43,843,165	37,266,690
1967	45,512,919	371,210	45,141,709	38,370,452
1968	47,675,833	373,625	47,302,208	40,206,877
1969	55,240,379	439,520	54,800,859	46,580,730
1970	61,429,096	474,546	60,954,550	51,811,368
1971	64,053,614	499,998	63,553,616	54,020,574
1972	66,862,842	492,677	66,370,165	56,414,640
1973	70,891,769	537,897	70,353,872	59,800,791
1974	71,164,814	558,592	70,606,222	60,015,288
1975	69,912,104	549,779	69,362,325	58,957,976

[a]Computed by the Market Administrator's Office (1974) up to 1974. From 1974 through 1975 see <u>Market Information Bulletin</u> (1974-75). .85 (Whole milk lbs - butter fat lbs) = Acid whey lbs.

acid whey produced to the year 2000. The projections will be used to evaluate the problem of acid whey as a pollutant and its subsequent capacity requirements on the greater Phoenix metropolitan sewer system.

The simple regression considered two variables: whey and population in a linear relationship. Acid whey production was derived by using either one of the conversion techniques as described earlier (Water Pollution Control Research Series, 1971); Arizona population data figures were from Valley National Bank (1974). The assumption used to formulate the model were as follows:

1. Arizona as a closed market, with right to production.
2. Per capita consumption of cottage cheese is constant.
3. Constant technology.
4. All other things unchanged.

The relationship between acid whey and population was evaluated using Ordinary Least Squares (OLS). The regression constant and coefficient were estimated at -22210629.91 and b = 52.99 respectively, with a coefficient of determination of .96374.

Forecasts of acid whey production were based on the estimated equation, Acid Whey in lbs. The projections were calculated using projected population figures in Table 23. Only population projections were available for Tucson and Phoenix; therefore, the estimates given are likely to be low. For example, by the year two thousand, projected population figures for the Phoenix and Tucson metropolitan areas would be 2,683,100 people. When this population figure is used the forecast of annual acid whey production equals 119,966,839 pounds. Table 24

Table 23. Projected Population Figures of the Tucson and Phoenix Metropolitan Areas

Year	Tucson[a]	Phoenix[b]	Total
1975	473,500	1,138,600	1,612,100
1980	513,700	1,328,700	1,842,400
1985	567,700	1,487,000	2,054,700
1990	617,900	1,664,100	2,282,000
2000	752,200	1,920,900	2,683,100

[a]Personal communication with the Tucson Planning Department (1975) includes all of Pima County.

[b]Population and Economic Activity in the United States and Standard Metropolitan Statistical Areas (1972).

Table 24. Projected Liquid Acid Whey Figures for Arizona, 1975-2000

Year	Population[a]	Liquid Acid Whey lb[b]	Equivalent Population Daily BOD_5 Waste[c]
1975	1,612,100	63,214,549	36,370
1980	1,842,400	75,418,146	43,390
1985	2,054,700	86,667,923	49,860
1990	2,282,000	98,712,550	56,790
2000	2,683,100	119,966,839	69,020

[a]See Table 23.

[b]Pounds of Liquid Acid Whey = 22,210,630 lbs + (52.99 lbs) (Population), rounded to the nearest one hundred.

[c]One hundred pounds of liquid acid whey is equivalent to the daily waste of 21 people. Manual for Milk Plant Operators (1957, pp. 1-6).

illustrates that by the year two thousand the acid whey production would be equivalent to the daily waste of approximately 69,020 people.

CHAPTER 5

SUMMARY, EVALUATION, AND RECOMMENDATIONS

Summary

Cottage cheese whey is produced by three plants in the Phoenix metropolitan area. This whey is disposed of as an industrial waste into the Phoenix waste treatment system. As a pollutant, acid whey is considered of high BOD_5 value, with 100 pounds being equivalent to the daily waste of 21 people (Manual for Milk Plant Operators, 1957). At 1975 acid whey production levels, acid whey has the pollutability effect of about 34,000 people per day.

One alternative to the disposal of acid whey or any cheese whey is the feeding of whey to animals. Dried whey has been included in calf milk replacers and calf starter rations, resulting in satisfactory and improved growth with some diarrhea as a problem. Other researchers have found that whey could be included in dairy calf rations without any effects on calf health or performance. Morrill et al. (1971) concluded that especially sweet whey powder from cheddar cheese could be included in milk replacers at 76 per cent. Whey powders have been included in milk replacers in amounts as high as 52 per cent (Gorrill and Nicholson, 1972) resulting in reduced gain, but with slight or no diarrhea. Other forms of whey have been fed to dairy calves, including whey protein concentrate, whey permeate, whey lick blocks supplemented with ammonia and other nutrients. These forms of whey were found to replace part or all of the dairy calf ration.

Whey was also found to be fed as a liquid feed to dairy animals and beef steers. Sweet whey can supplement grain in a dairy ration, with 100 pounds of whey being equivalent to 7 to 9 pounds of concentrate (Adams, 1975; Welch, 1973; Anderson et al., 1974). However, the consumption of liquid whey varied widely from 55 up to 400 pounds per animal per day in respective studies by Gordan et al. (1972) and Nilson and Welch (1975). Practical problems included manure handling and flies.

The addition of dried whey and other whey products (Nilson and Welch, 1975, p. 22) to haylages was noted to improve apparent digestibility (Schingoethe et al., 1975) and quality (Dash et al., 1974a, 1974b). In one study (Schingoethe and Beardsley, 1975), the addition of whole dried whey to a urea treated corn silage ration increased milk yield by 6.5 per cent and improved milk yield persistently. Whey has been fermented, ammoniated, and condensed into a protein supplement for beef cattle rations. Henderson, Crickenberger, et al. (1974, p. 23) found that this fermented-ammoniated-condensed whey (FACW) would replace other protein sources such as soybean meal with nearly identical average daily gain and feed efficiency. When FACW was fed at higher levels, toxicity was reported in some steers (Crickenberger et al., 1974).

Budgets constructed in this study indicate that when 200 pounds of liquid whey replaced 13 pounds of hay there is a subsequent decrease in milk production and profits are reduced by $83,320. However, when 200 pounds of liquid whey replaced 15 pounds of grain in the dairy ration, profits increased by $45,822, with repayment capacity at a positive $50,514. Returns per dollar of investment were 146.3 per cent. These results were transferred into a whole dairy farm budget with whey feeding resulting in an increased total annual profit of $34,984. Liquid whey costs to the dairy farm were estimated at transportation costs of $0.25/cwt, with actual costs to operate the tractor and trailer at $0.1928/cwt for a 120 total mileage from cheese plant and return. Whey was obtained at no cost from the cheese plant.

A linear programming model was then used to evaluate costs of feeds and feed ingredients in a least-cost dairy ration. With the given feed prices in Arizona as of June, 1976, liquid whey was included at 382.36 to 179.57 pounds per animal per day at costs of $0.0 to $0.3432/cwt, respectively. Other feeds included in these rations were whole cottonseed at $6.50 per cwt, alfalfa hay at $3.75 per cwt, and cottonseed hulls at $2.55 per cwt. If liquid whey cost was greater than $0.3447 per cwt, liquid whey was excluded from the linear programming model.

The disposal of liquid whey as waste has certain direct costs. These costs include water dilution to meet maximum BOD_5 level as required by the City of Phoenix and those expenses for the treatment of that sewage. The Phoenix Water and Sewer Accounting Department (1975) requires that all effluent have a BOD_5 level of 0.00250 pounds of BOD_5 per gallon. Acid whey has a BOD_5 level of 0.5418 pounds of BOD_5 per gallon. To dilute acid whey to meet maximum BOD_5 levels per gallon requires 181 gallons of water per gallon of whey. About 1.241 billion gallons of water was required for the 6.856 million gallons of liquid acid whey produced in 1975. Water costs were from \$0.03189 to \$0.0494 per pound of cottage cheese or \$0.5628 to \$0.8723 per cwt of liquid cottage cheese whey. Sewage treatment costs for whey as a waste product varied depending upon utilization of the waste treatment plant by other users of the treatment facility. In essence, the greater the utilization of the treatment plant the more volume over which fixed plant overhead can be spread, thus decreasing per unit of BOD_5 treatment cost. Treatment cost per pound BOD_5 was calculated at both peak and average pound BOD_5 flow for cottage cheese whey and was equivalent to \$0.0696 to \$0.1153 per pound BOD_5, respectively. In 1975 at 8,753 pounds of BOD_5 per day, sewage treatment costs were equivalent to \$0.377 to \$0.625 per cwt of liquid cottage cheese whey or \$0.0214 to \$0.0354 per pound of cottage cheese. The above figures are based on the respective peak and average daily utilization of the treatment facilities. Total treatment cost (sewage treatment and water dilution cost) for cottage cheese whey ranged from \$0.938 to \$1.4973 per cwt of liquid cottage cheese whey.

Evaluation

The transportation budget was formulated assuming that the tractor and trailer could be owned either by the farmer or by the cheese plant. The explicit assumption was that the tractor and trailer would be utilized to full capacity. The partial budgets and whole dairy farm budgets were constructed assuming that cottage cheese (acid) whey would be a like substitute for cheddar cheese or sweet whey. However, as acidity in liquid whey increases, palatability and thus consumption decreases. High ambient temperatures could present problems not foreseen in the budgeting techniques or assumptions used in formulating a least-cost dairy ration. One possible problem might be rapid spoilage of liquid whey in the feeding trough.

The technology used in this study to estimate the product-product relationship between skim milk and cottage cheese, between cottage cheese and liquid acid whey has been established for a long period of time. However, the technological coefficients used in arriving at an average BOD_5 level are not as clear as a product-product relationship.

An important assumption made was that whey production had a constant daily and yearly flow. However, cottage cheese production is a somewhat seasonal product since more cottage cheese is produced in the spring and fall. The extra capacity for these peak flows was not included in the sewage treatment plant.

The aspects of liquid cottage cheese whey as a dairy feed or as a pollutant have several important implications. First of all, given that the results accurately describe what is going on in Arizona at the present time (1975-1976), considerable cost savings are available to the public sector for not treating liquid cottage cheese whey ($0.377-0.625/cwt). The private industry sector would have saving only if the whey cooling costs for the cheese plant operator are less than water dilution costs of $0.5628-0.8723 per cwt of liquid cottage cheese whey. Secondly, if 100 pounds of liquid cottage cheese whey were to substitute for 7 to 8 pounds of concentrate, considerable cost savings are available to dairymen in reduced feed costs, if whey can be provided to the dairy farmer at transportation cost and feed costs remain at the 1975-76 levels. Third, the magnitude of these cost savings would depend upon the amount that could be supplied to Arizona dairy animals, the consumption level by these dairy animals, and the acceptance of such technology by Arizona dairymen.

Recommendations

To obtain a better understanding of whey utilization as an animal feed and its disposal as a waste product, several specific recommendations for additional research are suggested:

1. Do a feeding trial in Arizona to establish the effects of high ambient temperatures on the actual consumption of liquid whey and thus its effects on the cost and return structure for the Arizona dairyman.
2. Establish more clearly the substitution effect of liquid cottage cheese whey for concentrates and roughages.
3. Evaluate the milk production of animals fed liquid whey to determine factor-product relationship.
4. Establish the technical relationship between BOD_5 and sewage containing whey to clearly evaluate the social cost of whey disposal in Arizona.
5. Evaluate the alternatives of cottage cheese whey disposal other than dairy animal feeding to determine the opportunity cost of whey utilization and find these alternatives that minimize the cost of whey disposal to society.

APPENDIX A

WHOLE FARM BUDGET ANALYSIS FOR A 375 COW DAIRY HERD--CENTRAL ARIZONA

		Non-Whey (Dollars)	Whey (Dollars)
Receipts			
152.5 cwt/cow @ $10/cwt = $1525/cow		571,875	571,875
Calves (6% death loss)			
176 bull calves @ $10/head =	$1760		
176 heifer calves @ $30/head =	5280		
	$7040	7,040	7,040
		578,915	578,915
Expenses			
Feed:			
Hay 6.39 tons/cow @ $75/ton		179,719	179,719
Concentrate 2.44 tons/cow @ $125/ton		114,375	
Whey 750 cwt x 365 days @ $0.25/cwt			68,438
Hay 1.20 tons/heifer @ $75/ton		11,250	11,250
		305,344	259,407
Labor			
2 men @ $9,600/year			
1 man @ $8,400/year		27,600	27,600
Fringe benefits @ 18%		4,968	4,968
		32,568	32,568
Operation and Maintenance			
Repairs			
Corrals (2.5% of cost/yr)		5,269	5,269
Milking Facilities (7% of cost/yr)		8,610	8,610
Other equipment (2.5% of cost/yr)		2,230	2,230
Whey feeding equipment (11% of cost/yr)			3,799
		16,109	19,908
Vet and Breeding--$15/cow		5,625	5,625
AI $8.00/service x 2.3 services/cow = $18.40/cow		6,900	6,900
		12,525	12,525
Utilities--$2.50/cow/month		11,250	11,250

	Non-Whey (Dollars)	Whey (Dollars)
Whey Feeding Equipment		
Electricity		1,150
Misc.		1,000
Taxes and Insurance		1,554
Taxes and Insurance	3,469	3,469
Supplies--$28/cow/yr	10,500	10,500
Misc. Cash Expenses--$10/cow/yr	3,750	3,750
Production Testing--$7.80/cow/yr	2,925	2,925
Milk Hauling --$0.25/cwt x 152.5 cwt = $36.60/cow	13,725	13,725
Coop dues--fees--checkoff ($0.20 less $0.12 rebate) 152.5 cwt x $0.08 = $12.50/cow/yr	4,575	4,575
Vehicle Expenses		
Pickup--700 hrs @ $4.75/hr	705	705
Tractor--1000 hrs @ $2.95/hr	2,950	2,950
Tractor and accessories--1000 hrs @ $4/hr	4,000	4,000
	7,655	7,655

Replacement Heifers

125 purebred heifers @ $650/head = $81,250
110 cull cows @ $300/head = -33,000
$48,250/3 =

$16,083

3 year life in milking herd

375 ÷ 3 = 125 replacement heifers/year
15 (4% death loss)
110 cull cows to sell every 3 years

cull cows 1200# @ $.25/lb = $300/cull cow

Interest on Investment in Capital Items

Depreciable Items:

			Non-Whey	Whey
Original Cost =	$422,950			
+ Salvage Items =	33,348			
	$456,298	x .5 =	228,149	
Original Cost =	$457,483			
+ Salvage Items =	36,069			
	$493,552	x .5 =		246,776

			Non-Whey (Dollars)	Whey (Dollars)
Livestock:				
Value of 375 cows @ $600/head =	$225,000			
Value of 42 heifers @ $650/head =	27,300			
Salvage Value of 417 animals @ $300/head =	125,100			
	$377,400	x .5	188,700	188,700
Land--80 acres @ $2000/acre			160,000	160,000
Milk base @ $750/cow x 375			281,250	281,250
Interest on Investment			858,099	876,726
$858,099 @ 8% = $68,648			68,648	
$876,726 [8% = $70,138				70,138

Capital Investment

Corrals (Complete) @ $562/head Shades, coolers, bunks, etc.		$ 210,750
Milking Facilities (Complete--Double 8 Herringbone)		
Equipment	63,000	
Facilities	40,000	
Construction	20,000	123,000
Waste Management System		18,000
Wells (2 @ $12,000/well + $7,000 Pressure System)		31,000
Electricity to dairy from main line		6,000
Fence 1-1/2 miles @ $1,600/mile		2,400
Milk base 50#/day/cow @ $15/#		281,250
Land 80 acres @ $2000/acre		160,000
Cows @ $600/head		225,000
		$1,057,400

Machinery and Equipment

Hay Wagon @ $1300 each	$ 2,600
3/4 Pickup	6,200
Stock trailer--20 ft gooseneck	2,500
Feed wagon	6,500
Tractor (used)	4,000
Tractor and equipment	10,000
	$ 31,800

Summary of Equipment Needed for Feeding Liquid Whey:

13,000 Gallon Stainless Steel Silo Tanks		
F.O.B. Tucson, Arizona		$25,400
5 hp Freon condensing unit, 115/230 volt 1 phase		1,865
Erection of the tank		1,500
Pipe and Freon for refrigeration unit		1,600
Concrete slab--3500 pound test, 15' x 12' x 1'		
6.7 cubic yards @ $30/cubic yard	= $210	
Labor	= 100	
	$310	310
Electrical Hookup--100' from source		
Material	= $800	
Labor	= 250	
	$1050	1,050
Air Compressor--1-1/2 hp, 3 phase, 2 stage		
60 gallon ASME rated storage tank		
Magnetic start	= $800	
Labor and misc. material	= 100	
	$900	900
Washing pump and tanks	= $275	
Labor and misc. material	= 100	
	$375	375
875 feet of plastic pipe, installed @ $1/foot		875
Cattle waterers--4 @ $127/waterer	= $508	
Labor and misc. material	= 150	
	$658	658
TOTAL		$34,533

Depreciation Schedule

Item	New Cost	Salvage Value	Difference	Life	Charge Per Year
Corrals	$210,750	$10,538	$200,212	15	$13,348
Milking Facilities	123,000	12,300	110,700	7	15,814
Waste Management	18,000	1,800	16,200	7	2,314
Electricity to dairy	6,000	600	5,400	15	360
Fence	2,400	100	2,300	15	153
Wells	31,000	3,000	28,000	10	2,800
Hay Wagons	2,600	260	2,340	10	234
3/4 ton pickup	6,200	2,500	3,700	3	1,233
Stock trailer	2,500	250	2,250	10	225
Feed Wagon	6,500	500	6,000	8	750
Tractor & Accessories	10,000	1,000	9,000	8	1,125
Tractor (used)	4,000	500	3,500	8	437
Replacement heifers (125)	81,250	33,000	48,250	3	16,083
			Total (non-whey)		$54,876
S.S. tank	27,210	2,721	24,489	10	2,449
Waterers and Pipe	1,533	0	1,533	10	153
Accessory Equipment	5,790	0	5,790	5	1,158
			Total (whey)		$58,636

APPENDIX B

NUTRIENT CONTENTS AND PRICES OF FEEDS INCLUDED IN LINEAR PROGRAMMING ANALYSIS

Feed Description	Feed Price Per cwt (Dollars)	Feed Code	Moist.	Net Energy (Lactation)	Protein	Non-Protein Nitrogen	Fiber	Ca.	Phos.	Mg.	Salt	Max. Share of Conc.	Max. Share of Total Ration
			%	m cal/lb									
			---100% D.M.---		----------------Percentage on a 100% Dry Matter Basis----------------								
Barley	8.45	05	11.0	0.99	13.3		6.1	0.07	0.44	0.15		60	80
Shelled Corn	8.97	10	15.0	1.13	10.2		2.4	0.02	0.26	0.12		100	100
Cotton Seed Meal	6.98	18	7.0	0.75	44.7		11.2	0.20	0.99	0.72		100	17.5
Beet Molasses	6.41	26	22.0	0.86	10.0		0.0	0.11	0.02	0.03		a	05
Ground Oats	9.00	27	10.0	0.87	13.3		12.2	0.09	0.33	0.16		75	100
Urea	8.50	32			281.0	281.0						1.5	a
Soft Wheat	8.65	33	11.0	1.07	11.5		2.4	0.29	0.64	0.16		35	55
Wheat Bran, soft	8.90	36	10.0	0.82	16.2		9.7	0.04	0.29	0.66		25	45
Wheat Middlings	7.15	38	10.4	0.78	20.2		7.3	0.09	0.93	0.36		20	40
Milo--9% C.P.	9.03	53	11.0	0.86	10.0		2.8	0.04	0.35	0.23		100	100
Ground Whole Cotton Seed	6.50	13	7.3	1.21	24.9		18.2	0.15	0.73	0.00		100	17.5
Whey	b	41	7.0[c]	0.60	13.3			1.00	0.80	0.14		99.9	99.9
Alfalfa Hay--Prebloom	3.75	101	10.0	0.49	21.2		26.0	1.50	0.30	0.26		100	100
Cottonseed Hulls	2.55	220	9.3	0.32	4.3		50.0	0.14	0.07	0.14		100	100
Di-Calcium Phosphate	7.00	85						26.5	20.0				
Mono-Sodium Phosphate	11.00	87							22.0				
Limestone	1.50	88						38.3					
Salt	3.00	89									99.9		
Magnesium Oxide	14.00	90								54.0			

[a]Level is controlled by the model.

[b]Price included at several different levels.

[c]Whey included in model at seven per cent moisture, then converted to 93 per cent moisture on an as fed basis.

APPENDIX C

CONVERSION FIGURES FOR CASE STUDY

Maximum Plant Capacity = 300 mg/l BOD_5

3.785 l = 1 gal--Table 19
(100 mg/l)(3.785 l/gal) = 1135.5 mg/gal BOD_5
1 mg = 0.000001 kg (1135.5 mg/gal)(.000001 kg/mg) = 0.0011355 kg/gal
(0.0011355 kg/gal)(2.2 kg/lb) = 0.00250 lb/gal BOD_5
(0.00250 lb/gal)(65 x 10^6 gal/day, 91st Ave. Plant Capacity) = 162,500 lb BOD_5/day
(0.00250 lb/gal)(40 x 10^6 gal/day, 23rd Ave. Plant Capacity) = 100,000 lb BOD_5/day

TOTAL = 100,000 + 162,500 lb BOD_5/day
= 262,500 lb BOD_5/day

From Table 14--Average BOD_5 (ppm) Cottage Cheese Whey = 54,250 ppm

(54,250 ppm = 54,250 mg/l)
(54,250 mg/l)(3.785 l/gal) = 205,336.25 mg/gal or 0.20533625 kg/gal
(0.20533625 kg/gal)(2.2 lb/kg) = 0.4518 lb BOD_5/gal

$$\frac{0.0025 \text{ lb BOD}_5}{\text{gal}} = \frac{0.4518 \text{ lb BOD}_5}{\text{x gal}}$$

x gal (equals water to dilute whey to ∿ BOD_5 strength of 0.0025 lb BOD_5/gal) = 180.7 gal

Example of conversion from pound BOD_5 per 1000 pounds cottage cheese whey to pounds BOD_5 per 1000 pounds whole milk equivalent--Table 14

Given: 42 lb BOD_5/1000 lb cottage cheese whey
Since: 1000 lb cottage cheese whey is equivalent to 1186.084 lb whole milk
Find: y lb BOD_5:
42 lb BOD_5/1186.084 lb wm = y lb BOD_5/1000 lb wm
y lb BOD_5 = (42 lb BOD_5)(.8431)
= 35.4 lb BOD_5/1000 lb whole milk

APPENDIX D

INTEREST AND PRINCIPAL PAYMENT SCHEDULE FOR THE FIRST THREE YEARS OF OPERATION OF THE 91st AND 23rd AVENUE SEWAGE TREATMENT PLANTS

Year	Remaining Principal Balance	Principal Payment[a]	Interest Cost[b]
	91st Avenue Plant		
Plant:			
1	$31,260,498	$1,250,420	$1,803,731
2	30,010,078	1,250,420	1,731,582
3	28,757,658	1,250,420	1,659,432
Land:			
1	130,002	4,333	7,501
2	125,669	4,333	7,251
3	121,335	4,333	7,001
	23rd Avenue Plant		
Plant:			
1	19,236,452	769,458	1,109,943
2	18,466,994	769,458	1,065,546
3	17,697,536	769,458	1,021,148
Land:			
1	79,998	2,667	4,616
2	77,331	2,667	4,462
3	74,664	2,667	4,308

[a]Plant cost (0 salvage value) ÷ 25 yrs = Principal Payment; Land cost ÷ 30 yrs = Principal Payment.

[b]Interest Cost at 5.77%.

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