S

E

A

M

Project

Industrial Pollution Prevention

Case Study: Food Sector

Recovery of Cheese Whey for Use as an Animal Feed

Misr Company for Dairy and Food, Damietta, Egypt

Under the SEAM Project, whey was recovered from cheese manufacturing in Misr Company for Dairy and Food, Damietta for use as a supplementary animal feed.

THE FACTORY

The factory is one of the largest public sector dairy producers in Egypt. It was built in 1966 and today has a workforce of 512. The production is seasonal and includes a wide variety of products. The factory processes raw milk (8,250 ton/year) to produce white cheese (1,250 ton/year), hard cheese (850 ton/year), processed cheese (700 ton/year), ghee (300 ton/year) and Mish (200 ton/year).

Whey Generation

Waste discharges generated from the factory primarily consist of product losses, washwaters and whey, a liquid by-product originating from cheese manufacture which constitutes the greater part of the resulting pollution loads, mainly biological.

Whey generated from cheese making and collected for use as animal feed

The factory produces substantial quantities of wheys of different characteristics (see Table 1):

1. Sweet whey is generated from hard cheese making during the seasonal swing for Grade A milk production from December to May. From 6 ton of milk processed there are approximately 5 ton of sweet whey for each 1 ton of hard cheese.
2. Whey permeate is generated throughout the year from the ultra-filtration process of white cheese production. From 2.5 ton of milk processed there are approximately 1.5 ton of permeate for each 1 ton of cheese.

POLLUTION PREVENTION OPPORTUNITIES

Whey dumped into the factorys disposal system has very high pollution loads caused by the protein and carbohydrates (see Table 1).

The factory disposes its final effluent into the citys sewers without treatment. Analysis of whey and of the final effluent are summarised in Table 1.

Table 1: Analysis of Whey and Final Effluent

Characteristics	Whey Characteristic			Effluent
	Sweet	Deprote-inised	Permeate	With Whey
Volume (m^3/year)	4,250	4,070	1,900	183,000
BOD (ppm)	73,300	57,400	55,000	2,300
COD (ppm)	90,400	73,580	72,400	4,050
TSS (ppm)	12,350	2,010	2,800	540
TDS (ppm)	49,280	47,810	4,460	2,290
Oil & Grease (ppm)	14,000	3,000	1,250	420

equivalent to the daily domestic waste produced by 18,000 people.

In addition to being a high environmental pollutant, disposal of the nutrient rich whey is a loss to the factory. Whey is a valuable source of carbohydrates, a good supply of energy, and contains high quality protein and minerals.

Nutrient Recovery:
Sweet whey is processed to recover 0.25 ton/day of fat by centrifugation and 0.25 ton/day of protein by settling. This volume is however reduced by only 4% and the factory is still left with a huge quantity of de-proteinised whey to dispose of or further process.

Whey Processing:
For the factory, options like whey drying, concentration and fractionation are too costly, and demand investment in technology and development requirements. As an example, it is not economically viable for the factory to invest in a large commercial drying facility which will cost close to LE1 million to produce dry whey products for human use as the market for such products does not presently exist in Egypt.

End-Of-Pipe-Treatment:
Effluent containing whey, whether treated alone or in conjunction with other processing or/and domestic wastes cause extensive treatment problems. In addition to processing high putrescibility, whey may present problems of pH control in biological treatment processes.

Ultra-filtration process used in white cheese making whey permeate separated and recovered

The factory is in the process of installing an industrial wastewater treatment plant which if whey was included would have to be large and costly, consisting of primary settling, multi-stage packed tower trickling filters, final settling, coagulation, chlorination, and sludge digestion. Finding an alternative to use the whey could reduce the environmental risks, costs and difficulties associated with end-of-pipe treatment.

CLEANER PRODUCTION APPLICATION

The use of liquid whey as an animal feed for ruminants has been implemented through the Cleaner Production Demonstration Projects of the SEAM Project and is briefly outlined below.

Liquid Whey Versus Other Animal Feeds

In Egypt, cane and beet molasses has been used for many years as the basis for liquid feeds for ruminants. Like molasses liquid whey can be a carrier of non-protein nitrogen components such as urea or ammonium salts to make crude protein supplements. Unlike molasses whey has a good supply of minerals especially calcium and phosphorus.

Whey has seldom been used in feedstock operations and surveys where carried to evaluate the acceptance of Egyptian farmers. General interest in a low or no cost high quality supplement was concurrent and the common concerns were related to safety, storage life, nutritional value and feed efficiency. These concerns were addressed in detail and are discussed below.

Methodology and Application

Substantial effort was devoted to the applicability of recovering whey for ruminant feed and the methodology of demonstrating its suitability. Important issues that were addressed included:

- Whey characterisation and preservation.
- Selection of farm for whey utilisation.
- Experimental feeding trials.
- Whey pricing.
- Factory and farm staff training.
- Full-scale feeding trials.
- Whey segregation and factory-to-farm transfer.

Whey Characterisation and Preservation

Physical, chemical, and nutritional analyses of the whey was undertaken. For comparison, molasses characteristics were also examined.

Table 2: Whey Characteristics

Characteristics	Sweet Whey	Whey Permeate	Cane Molasses
Chemical Composition (as fed)			
Specific Gravity (kg/litre)	1.025	1.030	1.262
pH	6.40	6.55	5.5
Titratable Acidity	0.05	0.089	n/a
Water (%)	91.95	94.45	25
Dry Matter DM (%)	8.05	5.55	75
- Solids Not-Fat (%)	7.55	5.55	75
- Fat (%)	0.50	0.00	0.1
Crude Protein CP (%)	1.10	0.25	3.2
Soluble Carbohydrates (%)	5.20	4.90	62.75
Total Ash (%)	0.52	0.50	9.2
Nutritient Content (dry matter basis)			
Total Nitrogen (%)	1.30	0.26	0.66
Non Protein Nitrogen (%)	0.34	0.24	-
Calcium (%)	0.058	0.055	0.89
Phosphorus (%)	0.052	0.045	0.082
Net Energy Lactation (Mcal/lb)	0.90	0.85	0.65
Total Digestible Energy (Mcal/lb)	1.86	1.7	1.4
Gate Price (LE/ton)	n/a	n/a	220

Whey characteristics were assessed against limit values which might cause possible animal health problems. Whey feeding problems may occur if:

1. pH values of whey drop below 4.5 or exceed 8.5.
2. Total microbial count exceeds ($1x10^6$/100ml).
3. Total coliform count exceeds (1/100ml) for calves and (30/100ml) for cows.

Storage life of whey may be affected by both time and temperature. Temperature increase may cause problems and could be conducive to mould growth. As whey becomes acidic and less palatable after being stored, keeping whey fresh was examined by cooling, pasteurising, or by adding preservatives:

1. Permeate from ultra-filtration is pasteurised by the process itself, however hard cheese whey will require preservation if it is to be stored or delivered in hot weather conditions or to distant farms.
2. After storing fresh whey permeate (pH 6.5) for 24 hours, pH dropped to 4.8,

3. Time-temperature pH values were determined for preserving whey permeate using different concentrations of various preservatives. It was found that formaldehyde (0.01%) and hydrogen peroxide (0.02%) were the most economical and effective preservatives to add, maintaining a pH value above 6 even at high temperatures reaching

ton of whey, respectively.

Farm Selection

Damietta Governerate is the heart of

factory enjoys the advantage of being close to many dairy farms. Field reviews were conducted to find suitable farms to receive the whey and criteria were developed for such selection.

The Animal Wealth Society Farm, located 10km away from the factory, was chosen out of seven nearby medium to large farms in view of its location, size, facilities, and management capabilities.

The farm has 725 head of Holestein, Brown Swiss and Friesian breeds managed under a sophisticated dairy feedlot operation where all cows are penfed and breeds are carefully evaluated for milk yield and diets adjusted according to yield.

Municipal water is the only liquid source, and 60 ton are used daily amounting to an annual cost of LE13,200.

1,825 ton/year of concentrate mix feed valued at LE1 million, and 900 ton of roughage valued at LE360,000 are fed annually at a daily rate of 7 kg and 3 kg per head, respectively.

Experimental Feeding Trials on Sheep

Sheep were judged as a suitable alternate ruminant to carry out preliminary trials to allow scientific investigation of the suitability and the value of the whey. Also these trials were used to demonstrate to farmers the potential benefit of using whey in their feeding diets and to answer any preliminary concerns.

Eight week experiments for a six pen trial of five sheep per pen were undertaken in which sheep 8-10 months old, weighing 37-39kg were fed free-choice six different liquid feeds next to ration components of roughage (berseem hay, DM: 87.4%, CP: 13.6%) and mix feed (cotton seed meal; yellow corn; wheat bran; salt; limestone, DM: 89.5%, CP: 17.3%).

In some diets protein was provided in the form of liquid urea mixed in as part of either the liquid whey permeate, the molasses or as part of their mixture.

Sheep feeding trial showed that whey permeate provides a good quality liquid intake

Growth data is represented below (see Table 3).

Table 3: Growth Data (64 days)

Liquid Feed	Average Liveweight per animal (kg)				
	Initial Weight	Final Weight	64-Day Gain	64-Day Gain %	Daily Gain
Water (as control)	38.14	48.60	10.46	28.22	0.163
Permeate (100%)	39.10	52.40	13.30	33.93	0.208
Permeate (95.5%) + Urea (0.5%)	38.50	49.50	11.00	28.89	0.172
Molasses(80%)	37.60	50.60	13.00	34.65	0.203
Molasses (7.5%) + Urea (0.5%)	38.70	50.0	11.30	28.95	0.177
Permeate (50%) +Molasses (4%) + Urea (0.5%)	38.70	49.40	10.70	27.68	0.167

Feed consumption and feed efficiency data is represented below (see Table 4).

Table 4: Feed Consumption and Efficiency

Liquid Feed	Average Daily Feed Intake (kg)			Feed
	Dry Matter		Liquid	Efficiency
	Roughage	Mix Feed		(feed/gain)
Water	0.52	1.10	2.70	9.91
Permeate	0.46	1.10	3.95	7.51
Permeate+Urea	0.47	1.07	3.68	8.94
Molasses	0.51	1.10	4.23	9.16
Molasses+Urea	0.51	1.10	4.31	7.96
Molasses+Whey+ Urea	0.51	1.10	5.34	9.66

The result of the trials indicate that liquid permeate:

- Can be fed satisfactory even without being supplemented with nitrogen.
- Can provide a good quality liquid intake and compares favourably to traditionally used liquid feeds such as molasses.
- When used alone it yielded the highest feed efficiency (i.e. kilogram whey fed per kilogram liveweight gain) in comparison to other diets.

Whey Pricing

Based on the feeding trials, an algorithm was developed to price the real nutritional benefit of the liquid whey to the farmer in terms of feed efficiency. The value of liquid whey was best determined by comparing its cost to the cost of protein and energy from other sources such as roughage and mix feed. Based on a direct cost-consumption comparison the true value of fresh liquid permeate was determined to be LE70/ton.

To make whey an attractive alternative for farmers, dairy factories may start by providing it for either the cost of hauling, the cost of water or at a very low price. After proving advantageous for the farmer, a price tag may be gradually attached over a period of time.

Factory and Farmer Personnel Training

A training programme for 5 factory production staff and 2 farm operators was completed. Training objectives were to ensure that the two parties fully understood the elements of using whey as animal feed.

This included training on whey control procedures, whey handling, cleaning activities, record keeping and taking measurements for whey and animal monitoring.

Feeding Whey to Dairy and Beef Cattle

The end results of the experimental trials has shown that feeding permeate can provide an effective diet and as such experiments were up-scaled to the farm in Damietta. Feeding liquid whey is being devised for full scale application where whey is fed to both dry and lactating cows in which cows are monitored on a weekly basis for feed intake, and liveweight gain or milk production.

Whey Segregation and Transfer System

Emphasis has been placed on developing an economical and easily used factory-to-farm distribution system. This covers transferring the whey from the source point in the factory to the drinking basins at the farm as explained below.

- Due to factory layout limitations it was difficult to develop a least-cost system consisting of mobile hoses and a portable pump and therefore whey had to be segregated and a stationary transfer system had to be designed.
- Investment (LE49,850) in corrosion resistant equipment consisting mainly of piping, pumps and collection tanks with a transfer capacity of ($10m^3$/hour) was required. Whey is delivered to an outside platform tank and pumped onto a lorry for transfer to the farm.
- Originally, in the farm water was pumped from the elevated piping network. Since whey can completely replace water intake provided the whey supply is consistent, it is unnecessary to have a separate water drinking system. Thus, whey can be pumped continuously from a storage tank through pipelines at no cost to the farm.

Monitoring Whey for Safety and Acceptance

LE8,500 was invested in portable pH meters and thermometers to allow continuous monitoring of the whey at 4 key locations: at factory gate, during transfer to farm, at farm gate, and in farm drinking basins.

Upon whey arrival in the farm, it is tested for pH and if accepted it is delivered to the concrete drinking basins. Farm gate whey acceptance criteria was based on a pH value of 5.5 to 6.

In the farm drinking basins, pH is not allowed to drop below 4-4.5 and is disposed to the drain within 24 hours of being generated at the factory.

ECONOMICS

Costs associated with whey feeding were mainly segregating, setting up and running a factory-to-farm trucking and transfer system.

Table 5: Cost Benefit Summary (LE)/Year

Cash Flow	Factory	Farm
Year 1 (Feeding Whey to 412 beef cattle)		
Whey Transfer and Storage Equipment	(49,850)	-
Monitoring Equipment and Meters	(4,250)	(4,250)
Operational Cost of Whey Transfer to Farm	(5,000)	-
Capital Investment Savings on Industrial Wastewater Treatment Plant	100,000	-
Sale of $6,000m^3$ of Whey at LE1/ton	6,000	(6,000)
100% Savings in Water (40kg/head/day)	-	6,000
75% Savings in Dry Feed (2kg/head/day)	-	138,300
Net Savings	**46,900**	**134,050**
Payback Period (months)	**<10**	**<1**
Year 2 (Feeding Whey to 412 beef cattle)		
Operational Cost of Whey Transfer to Farm	(5,000)	-
Sale of $6,000m^3$ of Whey at LE7.5/ton	45,000	(45,000)
100% Saving in Water Consumption	-	6,000
75% savings in Dry Feed Consumption	-	138,300
Net Savings	**40,000**	**99,300**
Year 3 (Feeding Whey to 412 beef cattle)		
Operational Cost of Whey Transfer to Farm	(5,000)	-
Sale of $6,000m^3$ of Whey at LE15/ton	90,000	(90,000)
100% Saving on Water Consumption	-	6,000
75% savings in Dry Feed Consumption	-	138,300
Net Savings	**85,000**	**54,300**

Note: Figures in brackets indicate an increase in cost

Financial benefits to the factory are mainly the reduction in whey disposal and treatment costs in addition to potential revenues from selling the whey to the farmers. Farmers can enjoy substantial direct savings in feeding costs and increased animal productivity.

Cost benefits for both the factory and the farm are presented below based on a 3-year marketing plan (see Table 5). The 3-year target price of whey is LE15/ton, 78% below its true value and at 6.8% of molasses price.

BENEFITS AND ACHIEVEMENTS

For Farms:

- Whey replaces 100% of water intake at the farm.
- Whey provides a low-cost alternative to liquid feeds, at a fraction of the cost (less than 10% of molasses).
- 19 litres of liquid whey permeate can replace the same amount of energy and protein as provided by 2.4 kilogram of a 88% crude protein feed mix/roughage.
- Roughage intake per kg gain can be reduced from 3kg to 1kg (75% weighing (200kg/head) being fattened to 400kg, an additional income of LE200/head will be achieved.
- Whey can improve the feed palatability, texture, and dust control of feedlot rations. It provides a balanced nutrition of energy, protein, minerals, and a safety factor to compensate for poor or variable quality diets.
- Being a pumpable supplement, whey can save on feeding overheads as it requires less labour and feeding and mixing equipment, and can provide an economic and convenient method to feed urea supplements, vitamins, minerals and feed additives.

Whey feeding system at the farm

For Dairy Factories:

- 100% recovery of a previously wasted by-product which needs no development requirements and low capital investment.
- Eliminating or reducing whey disposal at the factory has significantly reduced the environmental pollution, namely BOD, COD, TSS, TDS, and Oil and Grease by 415 ton, 522 ton, 58 ton, 218 ton, and 62 ton, respectively. This has allowed the factory to move towards compliance with industrial wastewater discharge Law 93. Discharge volume reduced by 5970m^3/year.
- Up to 25% reduction in wastewater disposal and end of-pipe treatment requirements costs.

RECOMMENDATIONS AND TIPS

- For dairy factories it is most cost effective to return whey to farmers on its milk procurement routes.
- Significant attention should be given to quality assurance when handling whey to assure minimum contamination, extended storage life and satisfactory feeding performance are maintained.
- Fresh delivery of whey from the dairy factory to farms is highly recommended and if whey storage is necessary it is recommended to use a preservative such as hydrogen peroxide. Formaldehyde is not recommended in feeding lactating cows because it is carried over into the milk.
- Corrosion-resistant equipment should be used as the acids in the whey can quickly rust and corrode metals or pit concrete. Stainless steel pipes and tanks or fibre-glass-lined tanks are recommended for transfer, feeding and storage.
- The piping network must be thoroughly cleaned at least once a week between whey deliveries to avoid microbial contamination and off flavours in the whey.
- Whey fed to animals should be introduced over a few weeks period to avoid digestive disorders manifested by diarrhoea, bloat, depressed appetite or reduced productivity. This can be achieved by starting with a blend of 20% whey and 80% water, then increasing the whey proportion by 20% every 3 days until diet is of full strength whey. Digestive disorders can also be avoided by sustaining a fresh supply of good quality whey, not allowing animals to run out of whey for extended periods of time, and feeding at least 3-4 kg of roughage per head daily.
- The amount of whey offered should be adequately controlled to prevent exhaustive consumption of whey in a short time and thus avoiding possible bloat problems.
- The accumulation of flies attracted to the whey was observed as the only operational difficulty, and may present aesthetic rather than health concerns. Fly control measures are recommended.

CONTACTS

For more information on this project or the SEAM Project, please contact:

- **Misr Company for Milk and Food**
  Head Office: 25 Sawah Street, Sawah, Cairo, Egypt
  Engineering Affairs and Projects Department
  Tel.: (20) 2 257 1417/9450 Fax.: (20) 2 257 7207
  Damietta Factory: Damietta, Egypt
  Tel.: (20) 57 32 9907 Fax.: (20) 57 32 2170

- **Egyptian Environmental Affairs Agency (EEAA)**
  Technical Co-operation Office for the Environment (TCOE)
  30 Misr Helwan Agricultural Road,
  5th floor, Maadi, Cairo, Egypt
  Tel.: (20) 2 525 6452 Fax: (20) 2 525 6457
  E-mail: EEAA2@idsc.gov.eg

- **SEAM Project/*En*tec UK Ltd.**
  30 Misr Helwan Agricultural Road,
  4th floor, Maadi, Cairo, Egypt
  Tel.: (20) 2 525 6452 Fax: (20) 2 349 9795 / 5246162
  E-mail: entecegy@eis.com.eg

July 1999

The SEAM Project

Support for Environmental Assessment and Management (SEAM), is a multi-disciplinary

Department for International Development (DFID). This project is being implemented by the Egyptian Environmental Affairs Agency (EEAA) through the Technical Co-operation Office for the Environment (TCOE) and *En*tec, a UK engineering and environmental consultancy.

SEAM: Pollution Prevention

This is being implemented under the National Industrial Pollution Prevention Programme (NIPPP). NIPPP focuses on the introduction and promotion of low-cost improvement measures, which can be easily and quickly implemented by factories. It also emphasises the importance of economic benefits of any such intervention, particularly those with short pay-back periods.

Methodology - A Description

Pollution prevention opportunities can be identified through an industrial audit[1]. This

and processes, focusing on reducing waste, improving efficiency and alleviating pollution. This aims to identify and prevent losses from occurring in the first place, rather than resorting immediately to a treatment facility.

The SEAM Project has carried out audits in 32 factories in the food, textile and oil and soap sectors, which identified a wide range of low-cost pollution prevention opportunities, including water and energy conservation, the importance of good housekeeping, in-process modification and hazardous materials substitution. The SEAM Project is presently implementing 23 of these opportunities as demonstration projects.

Benefits of Pollution Prevention

It can ***REDUCE :***

- production costs;
- losses of valuable raw materials;
- on site treatment costs;
- energy and water costs;
- the volume of solid and liquid wastes generated;
- the risk of spills and accidents.

. . . and ***IMPROVE :***

- overall operating efficiency;
- generation of income through reuse and recycling of wastes;
- this approach can be easily replicated in sister factories to achieve similar savings;
- safety of employees;
- legislative compliance;
- company image.

1 Guidelines for Industrial Audits have been prepared by the SEAM Project.