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APPLICATION OF MEMBRANE TECHNOLOGY IN THE PRETREATMENT OF CHEESE DAIRIES WASTES AND CO-TREATMENT IN A MUNICIPAL CONVENTIONAL BIOLOGICAL UNIT

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ABSTRACT

A great number of cheese dairies and dairy industries in Greece are disposing their wastes, mainly cheese whey, either on land or in surface receivers, in large quantities creating a major environmental problem. A typical agricultural and pastoral provincial town of 70,000 inhabitants, Trikala, became the starting point of this research. A co-treatment of the urban sewage and the dairy wastes in the municipal treatment plant was recommended. The successful application of the above statement is based primarily on the pretreatment of the cheese dairies wastes. So far for cheese whey the recovery of the lactose serum in the contemporary central unit applying membrane technology has been suggested. As far as the wastewaters of the washing and refrigeration are concerned a pretreatment is required for the defatting in a grease trap, the grating, the adjustment of pH and the equalisation in an appropriate tank. Finally, this research has also focussed on the importance of membrane technology in improving the quality of milk and cheese production. © 1997 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Cheese dairies; cheese whey; conventional biological unit; co-treatment; membrane technology; pretreatment.

INTRODUCTION

In the modern industrial society adequate pretreatment of effluents from industrial sources is essential in order to prevent the pollution of our limited water resources. The liquid wastes produced by dairy industries and cheese dairies constitute one of the most important industrial pollutants in Greece. These wastes can be divided into two main categories. The first one refers to washing and pasteurisation waters which constitute almost two-thirds of the effluents and are mainly harmless. The second category refers to the cheese whey classified into raw whey and milk sugar. The raw whey - a greed yellowish liquid - is produced after removing fat and casein from the milk. Milk sugar derives from the partial processing of the raw whey for the production of special kinds of cheese (cream cheese and skim-milk cheese).

The main characteristic of the cheese whey is its high biological load due to its high nutrition content, e.g. proteins and lactose. Consequently, the biological oxygen demand of milk sugar and raw cheese is over 37,000 mg/l and 46,500 mg/l respectively. Therefore, its immediate disposal to a biological process of sewage disposal plants causes the disruption of this procedure.

In most of the Greek units, cheese whey is stored in drain tanks and the greatest amount is absorbed by the ground. However, its long-term disposal might cause environmental pollution. Ben-Hassan and Ghaly (1994) reported that nitrogen in cheese whey is water soluble and may be subject to leaching into ground water, thus becoming a threat to human and animal health. Furthermore continuous disposal can endanger the physical and chemical structure of the soil, decrease the crop yield and lead to serious water pollution problems. In addition very often large amounts of cheese whey are channelled into natural surface receivers causing haziness in the waters, bad odours and the death of fish.

The aim of this research is the application of membrane technology in order to prevent environmental pollution caused mainly by cheese whey. Furthermore, what is also stressed is the contribution of the above mentioned technology in the improvement of the quality of milk and cheese production, especially at a time when products' high quality standards should be ensured.

Understanding the Greek situation is a prerequisite for the drawing of well founded results. Trikala - a typical agricultural and pastoral provincial Greek town - became the starting point of such an evaluation. The determining criteria for choosing this specific town were: First, the fact that cheese manufacturing is a representative sample of domestic production. Second, the fact the variation during cheese-making has common elements with other Greek towns characteristics of cheese production. Finally, after communicating with inhabitants and the cheese-makers of the model area, what became evident was need for dealing immediately with the environmental pollution problem and the resulting degradation of quality of life.

METHODS

Membrane technology is a proven separation method used on the molecular and ionic levels. Most of its development has started in the dairy industry. Historically it left the laboratory at the end of the 1960s, after the fundamental discovery of asymmetrical membranes. These membranes had a permeability to water 100 times higher than the symmetrical ones. The separation and concentration methods using membranes, when applied in dairy industries, present considerable economic and mainly technological advantages in comparison with conventional methods. The most important of them concern the low-temperature membrane function which does not alter the products' nutritious value, the low consumption of power, and the facility to design units in stages, something which is related with their ability to be extended and flexible as well.

In the dairy industry, membrane technology is principally associated with Reverse Osmosis (RO), Nanofiltration (NF), Ultrafiltration (UF), Microfiltration (MF). All the above techniques feature crossflow membrane filtration, in which the feed solution is forced through the membrane under pressure. There is a wide range of membrane configurations available: Ceramic for MF, spiral wound of hollow fibre for UF and spiral wound for NF and RO. Maubois (1991) indicated that membrane equipment is now in dairy factories around the world - mainly in Europe, North America and New Zealand. Nowadays, ultrafiltration is the most used technology with more than 150,000 m^2. Most of these surfaces are devoted to whey treatment, but the share of the membrane surface for milk treatment has considerably increased since 1980. The surface area for reverse osmosis seems to have settled at 50-55,000 m^2 and is only used for whey treatment. Some microfiltration equipment has been set up during the last years. The installed membrane area is still very low but the potential of this new technology is so high that one can expect a spectacular increase by the end of the decade.

RESULTS AND DISCUSSION

Peculiarities of model area

From the evaluation elements the following conclusions have been derived:

1. The lack of building controls and recognised industrial areas in urban planning, a prevailing phenomenon in Greece, contributed to the dispersed distribution of the sixteen cheese dairies in the region. Consequently these industries cannot be controlled and are placed around the city in a radius of 12-15 km.

2. The available amount of cheese whey is 21,000 t per year, i.e. 4.2% of domestic production, if we consider the fact that the annual production in Greece reaches 500,000 t.

3. Cheese whey production presents great time variations; its main upwards trend appearing from March till May, being considerable during the six months of cheese making (from January till June), while being low during the rest of the year (Figure 1).

4. Cows milk is used in 30% of cheese production while sheep and goats milk usage reached 70%, in contrast with rest of Europe where cows milk is mainly used.

5. The variation observed as far as changing seasons and milk origin are concerned (Figure 2), results in the production of a cheese whey lacking a stable composition (total solids TS, proteins, fat, lactose), a fact that should be taken into account during the application of membrane technology.

6. Almost the entire quantity of cheese whey is partially used in the production of special kinds of cheese, like cream cheese. The BOD_5 in milk sugar has been reduced to 9.5 kg/m^3 milk.

7. Almost one quarter of milk sugar is available for animal foods (pigs). However, this usage cannot be assessed as a recovery method since the lactose serum causes enteric infections to pigs.

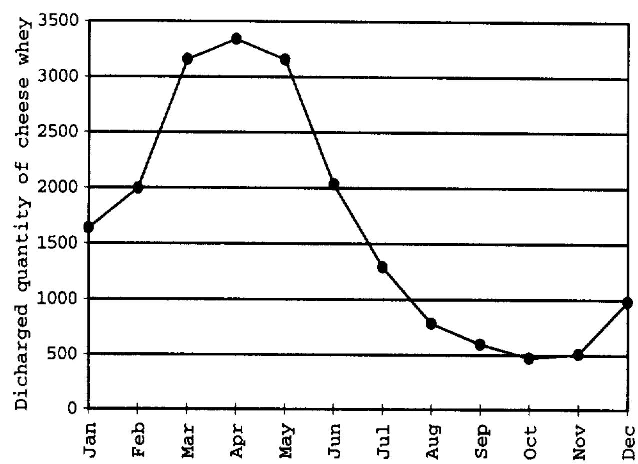

Figure 1. Monthly production of discharged cheese whey.

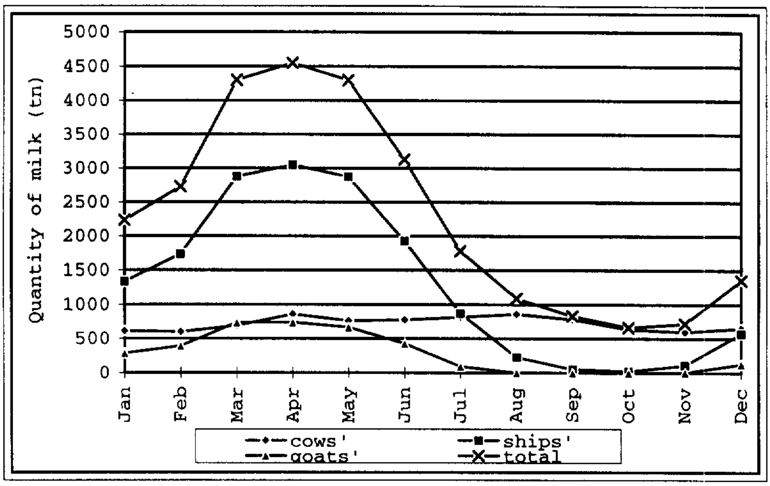

Figure 2. Monthly consumption and milk origin for cheese production.

Cheese whey recovery

In all the sixteen cheese dairies in the area only the two largest industries are equipped with one- or two-stage biological process units treating wastewaters, except from cheese whey. Furthermore, after estimating the load equivalent, what becomes evident is the fact that direct treatment of milk sugar in the municipal conventional biological unit is impossible. Installing inplant cheese whey treatment units in every cheese dairy is not financially attainable. Taking into consideration the above mentioned factors, the construction of a modern central station of cheese whey recovery applying membrane technology becomes necessary. The selection of the station's location will be based on the minimum cost of transportation of the cheese whey from the industries to the station (the most financially profitable method). The block diagram in Figure 3 summarises various processes which are proposed for the treatment of whey and its end products.

Firstly, cheese whey is transported to the central processing station after it has been cooled down to about 5°C in order for the bacterial growth to be temporarily stopped. After this the whey is preheated and separated to recover as much fat as possible in the form of 25-30% cream. This cream can be reused for fat standardisation of cheese milk. The separation stage also removes fines. Then the whey, for further treatment, is transferred to a MF plant. Merin and Daufin (1990) highlighted the potential of MF in retaining Ca ions, fat residues, casein fines and bacteria in order to improve RO and UF flux and also the quality of the whey powder and the concentrated whey.

Production of Whey Protein Concentrates (WPC) and Lactose: The permeate from microfiltration treatment is pumped to the ultrafiltration plant. In concentration most of the true protein, typically > 99% is retained. For 85% protein concentrate to be obtained, the liquid whey is first concentrated by direct ultrafiltration to a solids content of approximately 25%; this is regarded as the maximum for economic operation. WPC result from the retantate after it has bee spray-dried to reduce the moisture content to a maximum of 4%, before bagging. The permeate derived from ultrafiltration contains most of the lactose (about 85%). In order to achieve a satisfactory lactose recovery, this permeate is processed by crystallisation.

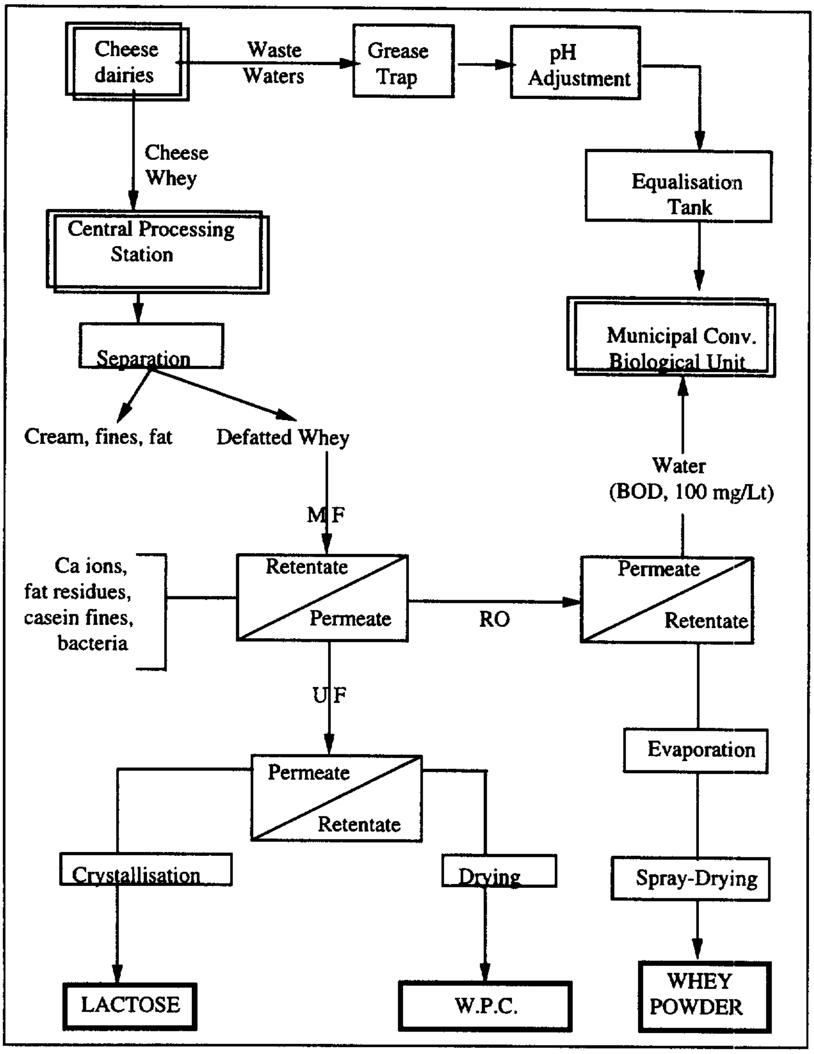

Figure 3. Processing of cheese whey and pretreatment of waste waters.

Whey Powder Production: The permeate from microfiltration is pumped to a reverse osmosis plant. The resulting retentate of this procedure is followed by evaporation and spray drying - the most widely used method at present - for the production of whey powder. The BOD of RO permeate is less than 100 mg/l, so the prospect of discharging it directly to the municipal biological treatment plant appears quite beneficial, as there are no operational problems.

Pretreatment of waste waters

As is shown in the block diagram in Figure 3 a co-treatment of washing and pasteurisation waters with sewage is proposed. In this case a pretreatment is required for the defatting in a grease trap, the adjustment of pH and the equalisation in an appropriate tank.

Microfiltration and ultrafiltration of milk

After microfiltration of the skim milk, the so-called Bactocatch technique - a patent registered by Alfa-Laval Company - a bacteria reduction of about 99.5% is obtained. At the same time all the original milk properties are kept almost intact as less than 5% of the milk is treated. The above mentioned technique can also offer an extended shelf life of 50% over standard pasteurised milk.

Fathy and Marth (1991) proposed ultrafiltration of milk before cheese making claiming advantages in the following areas:

a) Yield: An increase in the yield of cheese from the milk of about 16-20%. This increase results from retention in the cheese of proteins which are not coagulated by rennet.

b) Rennet or Coagulant used: Ultrafiltration can potentially reduce by up to 80% the quantity of coagulant commonly used to prepare a given weight of cheese.

c) Pollution: The ultrafiltrate (new whey or permeate) contains virtually no proteins or milk fat and thus its biological oxygen demand is only 80% of that of traditional whey.

CONCLUSIONS

Whey comprises 80-90% of the total volume of milk entering the process and contains about 50% of the nutrients in the original milk. Despite the chronic protein shortage in large parts of the world, a very considerable proportion of the total whey output is still wasted. Membrane technology can not only introduce an excellent environmental solution but also provides for human consumption one of the biggest reservoirs of food protein. Some examples of the utilisation of whey protein concentrates (WPC), whey powder and lactose are given in the production of:

- Refreshments
- Salad dressings
- Diet food
- Soups
- Whey spread/cheese
- Ice creams
- Baby food
- Bakery products
- Sausages
- Alcohol; as well as
- Pharmaceutical products.

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