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Milk whey treatment with recovery of valuable products

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Abstract

This paper deals with the environmentally acceptable disposal of the polluting water solutions resulting from the manufacturing of cheese and other similar milk derived products. The proposed treatment, which allows one to recover the most valuable compounds of the milk whey, is based on the integration of a simple purification process with various independent manufacturing processes at different levels. The purification process was obtained by a proper connection of ultrafiltration (UF) treatment with a reverse osmosis (RO) treatment. As a consequence, it is characterized by a significant lower energy consumption in comparison to traditional evaporative processes which allow to produce a much less valuable mixture of both whey proteins and lactose. The process was tested at pilot plant scale by using a previously described multipurpose pilot plant (MPP) equipped with all the automatically controlled units required for this study.

Keywords: Waste disposal; Ultrafiltration; RO; Multipurpose pilot plant

1. Introduction

The treatment of agro-industrial waste waters in order to meet all the recent environmental regulations is a very important problem due to the overall huge amount of this extremely polluting streams usually coming from many small and or medium manufacturing plants. On the other hand, the solution of this problem is a quite interesting challenge for process engineers who, taking into account the above mentioned conditions, have to combine both economical and environmental acceptability of the purification process. An interesting way is represented by the integration of the treatment process with the manufacturing process at different levels. In a previous paper [1], we applied this approach to the treatment of vegetation waters resulting from the production of olive oil. In that case, a thermochemical treatment process was also developed and suggested as an optimal alternative to other possible treatment processes. In this paper, we show how a similar general approach may be useful for the cheese whey purification, which, like the

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vegetation waters, is a traditional very polluting stream coming in a overall huge amount, from many small and from some medium or large cheese manufacturing plants. Furthermore, a new simple purification process is developed which, in addition, can produce valuable materials for feeding different manufacturing processes.

All the results reported in this study were obtained by using milk whey resulting from the production of "scamorza", a kind of cheese from the Abruzzi region of Italy. The amount of this raw material which could be reasonably collected to a single treatment plant is around 1,000 tons/d and its BOD ranges from 30,000 to 40,000 ppm [2]. Until now most of this whey is used without any further treatment by large pig farm which are located far from the whey production area. In addition, lactose is difficult to metabolize by these and other animals, and consequently, other inexpensive available carbohydrates are preferred unless the cost of the whey is extremely small or negative.

For these and other good reasons related to the predictable changes of the agro-industrial structure in the near future, a new whey purification plant was recently built in the above mentioned area which aims to recover both capital investments and process costs by producing a marketable whey powder containing all the nonvolatile components of the whey. However, it was found that the operation of this 300 tons/d purification plant was not convenient. On the other hand, there are other practical experience which show that the operation of whey purification plants is convenient provided that it is possible to recover separately both proteins and lactose, preferably of food grade quality. The major problem in this case is related to the large capital investment required and to the low flexibility of such a plant in relation to the evolution of the market.

2. Process integration strategy

A possible useful way for the integration of a whey purification process with other manufacturing processes at different levels is shown in Fig. 1.

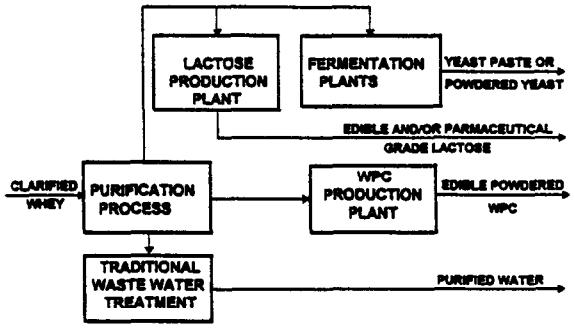

Fig. 1. Block diagram of a whey purification process integrated with other manufacturing processes at different levels.

The block diagram represented in Fig. 1 is based on the following considerations:

a) the most valuable components of cheese whey are the whey proteins (about 7 kg/ton of whey) and the lactose (about 40 kg/ton of whey), provided that the final products derived from both of them can be obtained at high level of purity and quality;
b) the production of these high value and sophisticated final products can be achieved only by very costly and advanced plants and processes;
c) all the plants mentioned under point b) are already existing, independently from the whey disposal problem. In addition, the potential of each such plant may be quite different and is usually determined by the nature of the product instead of the feed which usually comes from different sources;
d) the only purpose of the purification process is to solve the whey disposal problem while avoiding any kind of complication in the cheese manufacturing process and giving some easily obtainable valuable by-products to recover the process costs;
e) the value of the intermediate by-products

coming from the purification process is directly related to the possibility of using this streams as alternative and/or in addition to conventional feeds for the production of high value marketable products.

Fig. 1, along with all the above considerations, show also the advantages of integrating a purification plant with several other independent manufacturing plants at different levels in comparison with a traditional process integration strategy which is based on the integration of the purification plant with dedicated manufacturing plants at the same level. For the sake of clarity some of the most important advantages are:

1) both capital investments and operating costs for a quite simple purification process can be minimized;
2) the overall integrated treatment process is quite flexible with respect to market requirements and product evolution;
3) the potential of the purification plant can be optimized independently from other manufacturing plant;
4) most of the capital investments and of the operating costs required for the overall integrated treatment process can be recovered by the already existing non dedicated manufacturing plants.

Concerning the final destination of the two intermediate streams coming from the purification plant, we discussed the production of both food grade yeast and edible whey protein concentrate (WPC) in a previous paper [3]. However, as shown on Fig. 1, depending on the social and economical environment already existing in the considered area, it may be useful to address one or both of the above mentioned intermediate products to different final destination like pharmaceutical grade lactose and/or a variety of fermentation products. It is worth to point out that, as a general rule, it is impossible to obtain high quality products starting from poor and/or contaminated raw materials.

3. Process description

The purification process of cheese whey consists of an ultrafiltration section (UF) and a reverse osmosis (RO) section. As discussed in the previous sections, it allows the recovery of valuable compounds of whey: lactose and whey proteins.

The flow diagram of the process is shown in Fig. 2. In Table 1 is reported the material balance for a plant for the treatment of 50,000 kg/h of cheese whey. The effluents from the treatment plant are: a concentrated lactose solution (stream 9) with a low protein concentration, a concentrated protein solution (stream 6) with a low lactose concentration, and a low BOD water stream (stream 10) free of lactose and protein. Stream 10 constitutes about 72% of the feed to the plant. The UF section consists of two different stages: the first stage is operated at 45–50°C with a concentration factor up to 20, the second stage is a diafiltration unit operated at 45–50°C with a concentration factor of about 6. The diafiltration unit allows to reduce the concentration of lactose in the concentrated whey protein solution. In order to reduce the fresh water consumption, while obtaining the same lactose concentration in the concentrated whey protein solution, it is possible to use two diafiltration units.

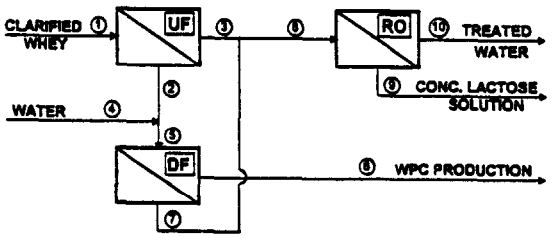

Fig. 2. Flow diagram of the whey treatment process.

The UF section permeate, almost protein free, is fed to the RO section, which is operated at 30°C with a concentration factor of 4.

The process was tested at pilot plant scale multipurpose pilot plant (MPP) available at

Table 1
Material balance for the whey treatment process shown in Fig. 1

Stream	1	2	3	4	5	6	7	8	9	10
Flow rate (kg/h)	50,000	2,500	47,500	12,161	14,661	2,500	12,161	59,661	14,915	44,746
Protein (wt.%)	0.60	11.20	0.04	0	1.91	11.13	0.01	0.04	0.15	0
NPN (wt.%)	0.20	0.20	0.20	0	0.03	0.17	0.01	0.16	0.45	0.07
Lactose (wt.%)	4.60	4.60	4.60	0	0.78	1.00	0.74	3.81	15.25	0
Acid (wt.%)	0.05	0.05	0.05	0	0.01	0.01	0.01	0.04	0.17	0
Ash (wt.%)	0.50	–	–	0	–	0.29	–	0.41	1.57	0.02
Fat (wt.%)	0.05	1.00	0	0	0.17	0.93	0.01	0	0.01	0

CRAB equipped with all the automatically controlled units required for this study. The results of the experimental tests confirm the feasibility of the process and they are in close agreement with the theoretical mass balance reported in Table 1.

4. Conclusions

Several problems related to the disposal of cheese whey have been discussed with particular attention for the recovery of valuable products. To this purpose, it has been found that the integration of a simple process with several independent manufacturing processes at different levels may offer various advantages in comparison to more traditional depuration treatment strategies. In addition, a new UF and RO purification process has been developed which is characterized by simple operation along with low capital investments and operating costs.

References

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