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The pressure membrane techniques as BAT in dairy industry

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A B S T R A C T

Progress of industrial development since years has been causing problems with increasing amount of environmental pollution as well as the levels of sources and energy consumption. Finally the environmental problems where considered as the prior value in the European Union (EU) law regulations.

In 1996, common rules for permitting and controlling industrial installations were adopted by the European Council as the Integrated pollution Prevention and Control (IPPC) Directive. In essence, the IPPC Directive is about minimizing pollution from various industrial sources. According to the Annex I of the IPPC Directive operators of industrial installations are required to obtain an environmental permit. The conditions of the authorisation are mainly based on Best Available Techniques (BAT), the second principle of the IPPC Directive.

The main environmental impacts related to the dairy industry are: the high consumption of water and energy, the discharge of effluent with a high organic load like whey in the wastewater.

The high level of environmental protection is offered by membrane processes. The practical employment of membranes is one of the methods leading to rationalization of industrial technologies what is the aim of the main European law regulations such as the IPPC Directive.

Keywords: Pressure membrane processes; Microfiltration; Ultrafiltration; Nanofiltration; Reverse osmosis; Dairy industry; BAT

1. Introduction

In the beginning of 1990s the idea of sustainable development took place in the European countries and gave the foundations of the EMAS and ISO 14001 certifications. The participation in those structures was free to choose for the operators of different industrial sectors in European Union (EU).

In 1996 common rules for permitting and controlling industrial installations were adopted by the European Council as the Integrated Pollution Prevention and Control (IPPC) Directive which is one of the most important law regulations in EU. The idea of integrated approach focused on to a high level of environmental protection taken as a whole was introduced as one of the IPPC Directive principles.

According to the Annex I of the IPPC Directive operators of industrial installations are required to obtain an authorisation (environmental permit) from the authorities in the EU countries. The conditions of the authorisation are mainly based on Best Available Techniques (BAT), the second principle of the IPPC Directive.

The BAT definition is consists of three main points given below:

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''best'' means most effective techniques in achieving a high environment protection level treated as a whole; ''available'' means techniques developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator; ''techniques'' includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned [1].

In the European structures The European Integration Pollution Prevention and Control Bureau (EIPPCB) has been formed with the task of producing BAT Reference Documents (BREFs) for each industrial activity area listed in Annex I of Directive 96/61/EC [1]. Each BREF should serve as an indication book aimed at the improvement of environmental performance across the EU. The BREFs are not the obligatory law regulations, but give information what may be technically and economically available to industry in order to improve their environmental performance and consequently improve the whole environment. The governments of EU countries has been created structures such as The Environment Agency producing Sector Guidance Documents addressed to BAT implementation and make it commonly available for industrial operators.

2. Applications of the pressure membrane processes (PMP) in the dairy industry

Increasing demand for the processed food technology related to the high level of environmental protection is offered by membrane processes.

Development of technology allows use the membrane techniques practically in all branches of industry where there is a need of separation, clarification, fractionation and concentration of both organic and inorganic matters. The membrane techniques were attractive to the food processing mainly owing the moderate operating temperatures, lack of phase transitions and low energy consumptions. Membrane processes are also offered multiple porosity levels which could replace several traditional processes in a single operation. It is also possible an integration membrane techniques and traditional operations as well as combination of different membrane processes [2–5].

The dairy industry has been one of the industrial sectors with wild range of pressure membrane techniques applications.

Generally, possibilities of employing pressure membrane techniques in the dairy industry could be divided into three areas presented below as:

1. technologies of dairy products such as milk, cheese, butter, yogurt, ice-cream, etc.
2. processes use in the utilization of wastes, mainly whey;
3. possibilities of solutions recovery with the integrated cleaning-in-place (CIP) systems.

2.1. PMP in the technologies of dairy industry products

There are various possibilities of PMP applications in the dairy industry technologies (Fig. 1.).

In the milk production microfiltration (MF) is mainly used in the purification processes [3–5].

Traditionally, the removal of microorganisms from dairy fluids has been based on heat treatment. The reduction of bacterial load could be achieved by employing MF but it requires fat separation as the first step of the milk processing with the centrifugal separator usage. The application of MF in milk purification has already found employment in France (milk named ''Marguerite'') and in Poland (''Cold milk'').

The process combining high temperature (130°C) treatment or pasteurization and MF for the removal of bacteria from raw milk has been implemented in Canada, Scandinavian counties and France in industrial scale. Such solution guarantees no changes in the physicochemical characteristic of milk constituents [4,5].

MF is also one of the methods used in the casein separation [4].

Ultrafiltration (UF) is commonly used in cheese production to pre-concentrate milk before cheese making process (Fig. 1) and as the operation for protein standardization (Fig. 2).

Applications of UF in cheesemaking offer technological as well as economical advantages such as saving of rennet and skim milk (in quarg production to 14% compared with the traditional processes) or better consistent quality. The low concentrated retentate (LCR) allows the use of conventional cheese making equipment and gives a more consistent quality in the final product. The medium concentrated UF retentates (MCR) bring as a result 6–8% increase in cheese yield. The liquid pre-cheese (LPC) concept enables cheesemaking at the next step without a need for a cheese vat and with minimal whey drainage [4].

In the dairy industry it has been common practice to standardize the fat content of milk. Unlike fat standardization in EU a minimum protein content for cow's milk is defined in some jurisdictions indicate that

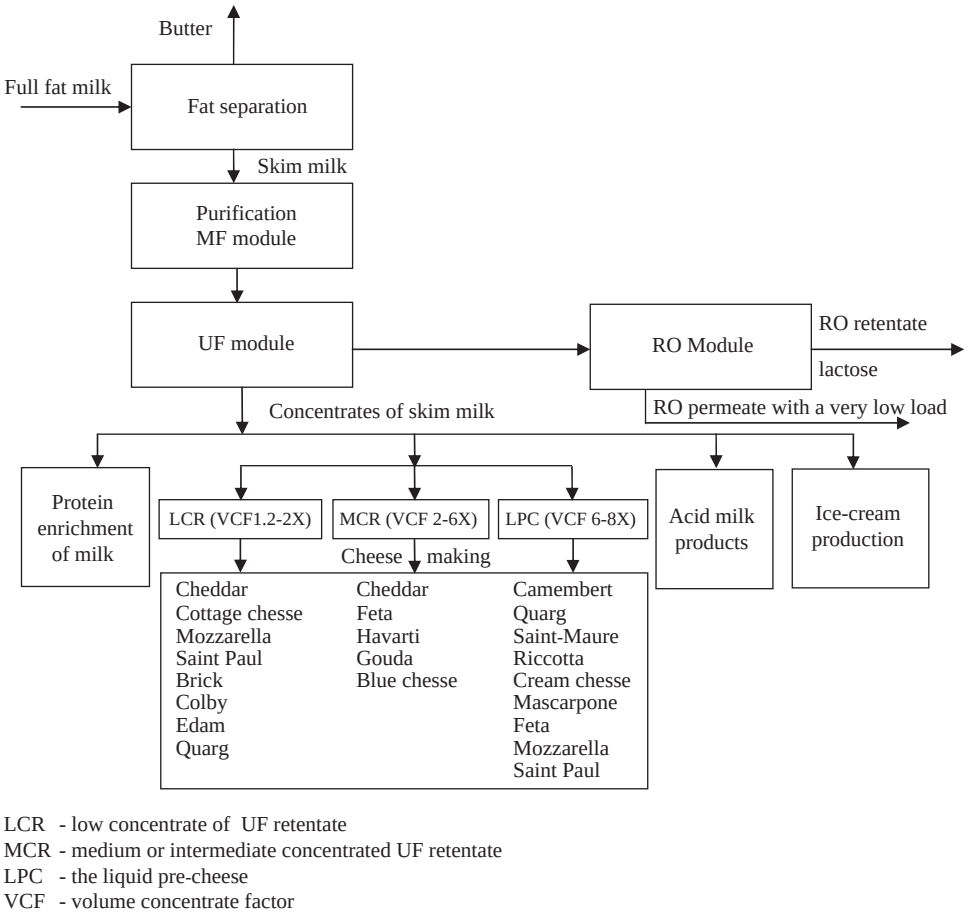

Fig. 1. Scheme of milk processing with pressure membrane processes applications [3–5].

''down'' standardization as well as ''up'' standardization of fluid milk content is necessary. UF used in protein standardization ensures the reduction of energy consumption. Employing UF in standardization of condensed milk and milk powder production has been improved at the 1995 Annual Sessions of the International Dairy Federation (Brussels) [6].

Reverse osmosis (RO) applications in the dairy industry allow the milk or whey concentration by removal of water and ionized minerals with a very low load to environment.

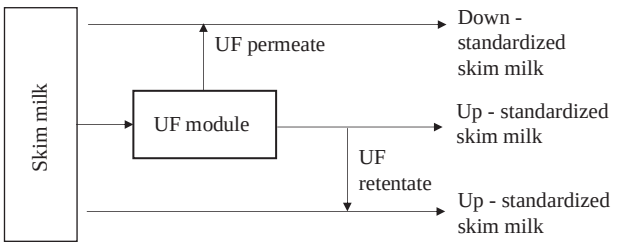

Fig. 2. Scheme of UF usage in the up-standardized or down standardized skim milk production [6].

The use of membrane processes in the manufacture of fermented dairy products may lead to improvement of quality characteristic control of consistency, post-processing acidification and extend of syneresis [4].

Although many advantages, fouling is the challenge related to development of PMP. Also the control of energy consumption and the increase of membrane productivity with high selectivity is the research topic in the future.

2.3. Utilization of whey with employing PMP

Worldwide an increasing amount of whey, waste from the dairy industry is mainly used directly in liquid animal feeds and is also commercially utilized to more valuable products like whey and lactose powders or protein-rich nutrients.

Whey processing represents one of the first applications of membrane processes in the dairy industry.

MF has been used to reduce bacteria and microorganisms and in deffating of whey.

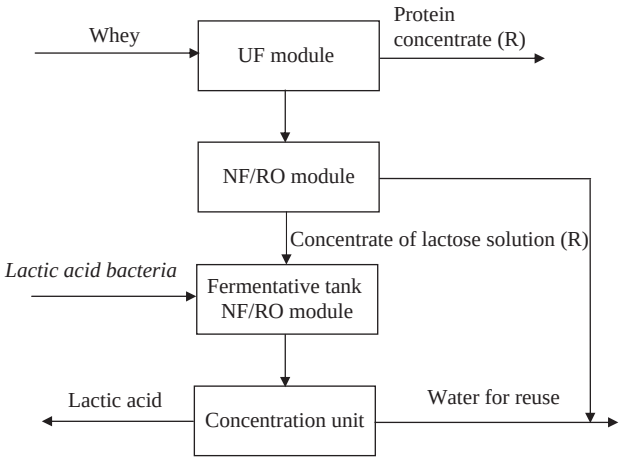

Fig. 3. The conception of lactic acid production from whey with PMP usage.

UF is one of the method of protein concentration and obtained permeate, the source of by products e.g. lactose, could be recover by nanofiltration (NF) or RO [4–8].

Taking into account the industrial scale three lines of whey utilization are proposed by Rektor & Vatai [7]. In all alternatives, the first step is defatting and sterilization of whey by MF. The separated fat can be pasteurized and used as raw material for butter production.

First line is the propose for small and middle sized dairies and requires NF usage for the concentration of the microfiltrated whey.

In the second line after MF two filtration steps were predicted: UF with high rejection of proteins partially combined with diafiltration, which can be used for the production of whey concentrate. The permeate of UF concentrated by NF and combined with crystallization results in lactose right for the pharmaceutical industry. This line is suitable for middle-sized companies.

Third line represents complex separation method, the best solution for small factories. It indicates RO as a process for concentration deffated and sterilized whey. The concentrate can be recycled in cheese making and the filtrate can be discharged to sewers or used for irrigation [7].

Another possibility of utilizing whey is fermentation of lactose to lactic acid. Recently, the bioprocesses are considered the most profitable alternatives for the treatment of whey surplus [8,9]. The fermentative production of lactic acid is made by lactic acid bacteria. The fermentation process can be performed in batch or in continuous mode with better productivity. The lactic acid obtained by fermentation has to be separated from fermentation broth and purified as well as concentrated in order to obtain appropriate product. There are applied neutralization followed by filtration, concentration and acidification, in conventional processes of lactic acid producing.

Nowadays, hybrid technologies employing PMP are the most profitable alternatives for separation, purification and concentration of lactic acid solutions. The membrane approach for production of lactic acid from waste lactose is presented in Fig. 3.

Final product concentration to the commercial level provide RO or NF processes. In practice some conventional units (evaporation, neutralization, filtration, distillation) may be replaced by the above mentioned PMP [8].

2.3. CIP systems with PMP usage

Applications of CIP systems allow food processing plants to be cleaned and sanitized automatically. Recovering used CIP systems in the dairy industry aims to maintain constant cleaning efficiency, minimize pH variations and effluent volume and save water, chemicals and energy. In the dairy industry large amounts of alkaline cleaning solutions are used at high temperatures. Discharge of used chemicals generates environmental problems and need of neutralization [10,11]. The regeneration of alkaline and acid solutions is achieved by usage of following operations: decantation, centrifugation, chemical treatments followed by filtration, PMP (MF, UF, NF). The high reduction of suspended matter is given by UF and MF [10]. The optimal chloride level required for reuse could be achieved by implementation of traditional processes and RO. Such solution is based on technical and economic evaluation of wastewater reuse from industrial region of central Italy [12]. For the regeneration of alkaline solution in the single industrial unit NF is the process with the best efficiency. The most promising solution is the integration of the NF unit into the CIP systems. The integrated CIP systems require investment and exploitation costs, on the other hand give savings of caustic soda, water and energy.

Taking into account the balance of expenditures and savings the time of the pay back is about 14 years, but it could be reduced by decrease of investment costs, performance optimization or by cleaning efficiency improvement [10]. Another proposal leading to savings is the reduction of energy consumption by employing appropriate model. The effect of lower energy consumption for the case of RO implementation could be given by using membranes with a higher flow rate factor [13].

Table 1
PMP in the dairy industry – the comparison with the BAT criteria

Numbers of points according to Annex IV	BAT criteria from IPPC Directive [1]	PMP characteristic in dairy industry
1	The use of low-waste technology.	PMP are accepted as a cleaner technologies which is equal to low waste processing.
2	The use of less hazardous substances.	Usage of low amount of chemical substance (e.g. in whey utilization or cheese production).
3	The furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate.	Application in whey utilization (recovery valuable ingredients such as: protein, lactose, lactic acid and producing whey concentrate). Recovery of caustic soda employing NF integrated into CIP systems.
4	Comparable processes, facilities or methods of operation which have been tried with success on an industrial scale.	PMP are considered as more efficiency than traditional techniques and already has found common usage in industrial scale.
5	Technological advances and changes in scientific knowledge and understanding.	PMP are commonly used industrial techniques and has been widely acknowledged as potentially one of the most important production processes in the future. Possibilities of PMP combination of different membrane processes and integration with traditional techniques.
6	The nature, effects and volume of the emissions concerned.	PMP are characterized by the reduction of environmental load and the low amount of wastes.
9	The consumption and nature of raw materials (including water) used in the process and their energy efficiency.	PMP has lower consumption than traditional operations and high operational efficiency. Implementation of PMP gives savings of water and energy.
10	The need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it.	Employing PMP guarantee the reduction of wastes (like whey or caustic soda) and also could minimize an impact of the environmental pollution.

Fortunately, the investment cost of membrane processes are dropping in time with the progress of research directed on optimisation of cleaner technologies usage.

3. The BAT criteria

According to IPPC Directive in determining BAT special consideration should be given to the items listed in Annex IV. The classification of PMP to the BAT criteria is presented in Table 1.

The rest of the BAT criteria from Annex IV are not directly involved with the characteristic of technologies. The other points focused on following subjects:

- the commissioning dates for new or existing installations (point 7);
- the length of time needed to introduce the best available technique (point 8),
- the need to prevent accidents and to minimize the consequences for the environment (point 11);
- the information published by the Commission pursuant to Article 16 (2) or by international organizations (point 12) [1].

Due to the points listed in Annex IV of IPPC Directive the PMP may be considered as the BAT in the dairy industry [14].

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3. Conclusions

According to the IPPC Directive in EU countries operators of industrial installations are required to obtain an environmental permit mainly based on BAT. In this paper PMP are presented as technologies considered as BAT in dairy industry. Pressure membrane techniques are already scaled up for

commercial and industrial purposes and were found applications in the milk processing and as the methods of the wastes utilization such as whey or in the recovery of cleaning solutions.

Due to the BAT criteria from Annex IV of IPPC Directive the most important is the reduction of environmental impact which could be given by implementation of membrane techniques characterized by high efficiency, energy and material savings (for e.g. UF in cheese production and protein standardization usage) and no public nuisance creation.

In the industrial scale the integration of traditional techniques and membrane processes is also a very important factor to achieve an optimisation of production. In dairy industry such solutions have found variety of applications, mainly as the way to get lower consumption of materials and better quality of final products as a result. One of the practical example of the hybrid process implementation in milk processing is combining the pasteurisation and MF in milk production.

The industrial usage of PMP is the way of the practical employment of cleaner technologies with possibility of secondary materials reuse such as whey or alkaline cleaning solutions.

However, the disadvantages of membrane application are: the high cost involved in the investment and the operation equipment (in case of PMP integration with CIP systems), fouling of membranes, a compromise between selectivity and productivity (in case of lactic acid production from waste lactose). The cleaning of membranes is still time and resource consuming problem.

In resume, the pressure membrane techniques has important economic and technical values and they are one of the most promising technology on the market.

The benefits being a result of the membranes techniques go far beyond the direct balance of expenditures and profits – the practical employment of membranes is one of the methods leading to rationalization of industrial technologies which is the aim of the new European law regulations such as the IPPC Directive.

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