APPLICATION OF CROSS-FLOW MICROFILTRATION TO SEMI-HARD CHEESE PRODUCTION FROM MILK RETENTATES

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Keywords: Microfiltration; Cassette module; Semi-hard cheese; High viscous protein concentrates

1 Introduction

Membrane separation technology is already employed in many different applications in the food industry. In the dairy industry, cross flow filtration is used mainly for whey concentration, the reduction of bacteria and spores in skim milk, processed milk standardization, the selective fractionation of value-added milk compounds and for the regeneration of brine baths [1]. The concentration of milk using ultrafiltration (UF) for continuous cheese production is standard technology in the cheese industry when manufacturing soft and fresh cheeses. Unlike UF, in microfiltration (MF) the milk fat and caseins are concentrated, whereas the whey proteins are generally able to pass through the membrane. This yields a milk retentate of similar composition to traditional semi-hard cheese curd [2, 3].

The aim of the present study was to produce a semi-hard cheese, from highly concentrated MF milk retentate, of the quality and composition comparable to that of traditionally made cheese. Therefore, a part of the study was to check whether a retentate with the dry matter necessary for the manufacture of semi-hard cheese could be produced in batch mode with conventional ceramic modules in which the milk was concentrated at temperatures of 55 °C to 75 °C. Comparative trials were also conducted in continuous mode with new cassette modules at a filtration temperature of 50 °C to 55 °C.

2 Experiments

Non silage milk from a local Emmental cheese factory, with different fat contents (< 0.1, 2.0 and 3.2% fat), was pasteurized at 72 °C for 18 seconds (pasteurizer and milk cooler, Gebrüder Ott AG Maschinenfabrik, Switzerland), cooled and concentrated by microfiltration before being processed into semi-hard cheese the following day. Alternatively, instead of cheese milk pasteurization, treatment by microfiltration (1.4 µm) at a temperature of 50 °C was used to reduce the bacterial content of the skim milk and the fat content was adjusted with heattreated cream (tube heater, JAG Jakob Prozesstechnik AG, Switzerland). The manufacturing process of cheese made from MF retentate is shown in Figure 1.

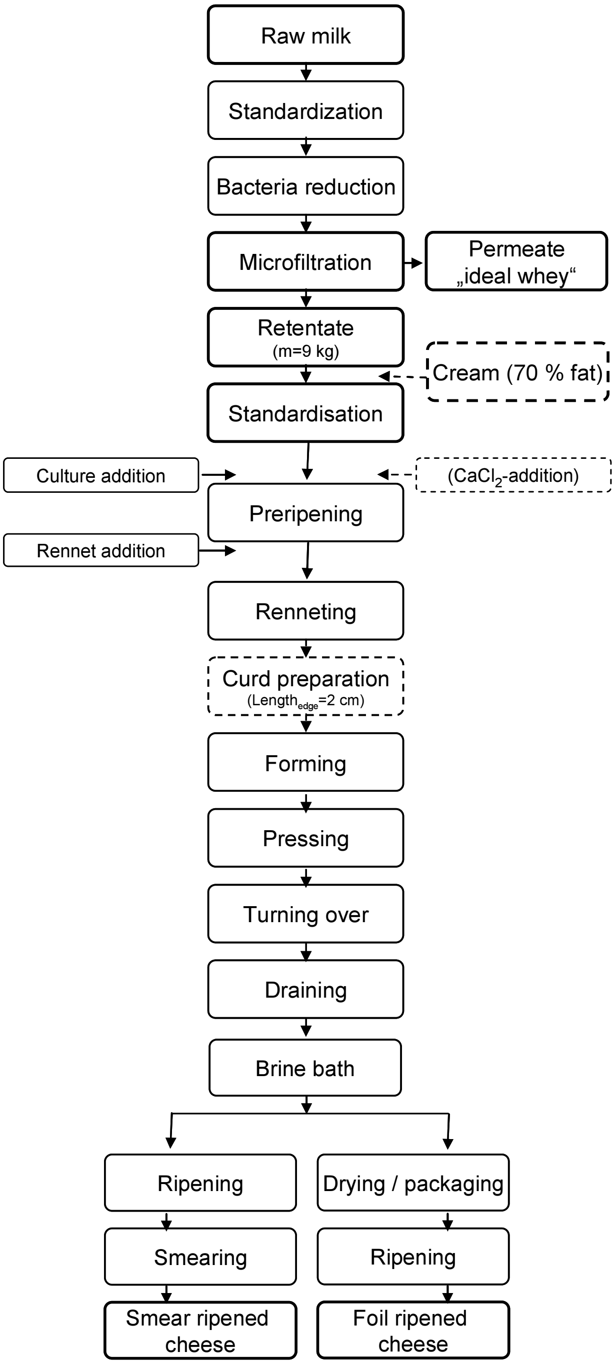

Figure 1: MF-cheese production process

Two different membrane systems were tested (Table 1). Firstly, a single-stage MF plant (Alcross M, Type 7, Tetra Pak Switzerland AG) was equipped with a Membralox ceramic membrane (P19-40 GP, Pall-Exekia, France) for batch concentration of 300 litres milk at filtration temperatures of up to 75 °C.

Secondly, a three-stage MF/UF/UF plant (HF-Finnatec GmbH, Switzerland) with new cassette modules (Consep® 11000, NCSRT, USA) was used for continuous concentration of milk batches of 1000 litres each. The first loop was fitted with a MF membrane, and the second and third loop with an UF membrane. The filtration temperature was between 50 and 55 °C. Diafiltration was carried out in the second loop of the plant to reduce the lactose content of the milk retentate.

Table 1: Specifications for the membrane modules used.

Plant	MF	MF/UF/UF
Filter type	Pall-Exekia P19-40 GP	NCSRT Consep® 11000
Module	tubular	cassette
Material	Al_2O_3	PS/PES/PES
Pore size	0.1 µm	0.12 µm/10 kDa/10 kDa
Total filter area	1.68 m^2	10/10/5 m^2

Both systems operating in cross flow mode are shown in Figure 2. The permeate flux at the start of the batchwise filtration of vat milk with 3.2% fat running via the MF pilot plant was 81.5 L/hm² at a transmembrane pressure of 1.1 bar and a feed inlet pressure of 4.35 bar. The viscosity of the retentate rose as the concentration of the vat milk increased [4]. To maintain a pumpable consistency of the highly concentrated retentate, the temperature was raised from TS 14% to 58 °C and from TS 27% to 75 °C until the end of filtration. With increasing concentration of the vat milk, the transmembrane pressure rose to 3 bar until a minimum permeate flux of approx. 12 L/hm² was achieved and filtration could be completed. In the MF/UF/UF pilot plant the milk was continuously concentrated to high dry matter contents at a moderate temperature of 50-55 °C. The retentate flow for pasteurized vat milk with a fat content of 3.2% was 47.73 L/h and had a diafiltration factor (DF) of 0.28. The DF is defined as the ratio of output quantity to wash water quantity. The filtration temperature was kept between 50-55 °C to avoid protein denaturation and to guarantee optimum suitability for cheese production.

Filters at the end of each filtration run were cleaned with step-by-step procedure: an alkaline solution and water rinse, and an acidic step or additional oxidative step. The acidic solution remained in the plant until the next filtration. Finally, the microbiological quality of the clean water flows were checked. The values for the total count of bacteria (aerobe mesophilic bacteria) and the enterobacteriaceae were < 50 cfu/g and < 1 cfu/g, respectively.

Figure 2: Membrane filtration plants for semi-hard cheese production process.

3 Results and Discussion

3.1 Composition of retentates

For milk containing 3.2% fat and skim milk, a concentration factor (i) of 6.6 and 9.1 respectively was obtained using the MF/UF/UF pilot plant fitted with cassette modules. Milk containing 3.2% fat was concentrated in batches by a factor of 5.7 in the pilot plant using the ceramic membrane. The concentration factor (i) of MF was calculated as the ratio of fat content of the retentate to the fat content of the milk. The casein retention of both plants was very high (> 98.5%). The composition of the milk used for filtration and the corresponding retentates are shown in Table 2 and 3.

Table 2: Composition of milk.

	MF from milk 3.2% fat	**MF/UF/UF** from milk < 0.1% fat	**MF/UF/UF** from milk 3.2% fat
Milk			
DM [g/kg]	117.2	91.2	119.4
Fat [g/kg]	31.5	0.7	32.0
Raw protein [g/kg]	33.2	34.0	32.5
Casein [g/kg]	25.7	26.9	25.8

Table 3: Composition of the corresponding retentates.

	MF from milk 3.2% fat	**MF/UF/UF** from milk < 0.1% fat	**MF/UF/UF** from milk 3.2% fat
Retentate			
DM [g/kg]	393.0	333.7	448.1
Fat [g/kg]	178.9	6.7	212.1
Raw protein [g/kg]	162.6	277.0	197.7
Casein [g/kg]	n.d.[1]	250.8	185.9

[1]n.d. = not determined

When processing retentates of high viscosity to cheeses the following points must be considered:

- At 5 °C the microfiltration retentate is in gel form and solid; with increasing temperature the viscosity decreases and only at 40 °C it becomes pumpable. This will have an effect on the mixing process when adding cultures, rennet and possibly other additives to the retentate.
- Because of its high viscosity, special cutting tools are also required.
- The use of retentates for cheese making requires the use of adapted cultures. In preliminary tests various cultures were checked for their usability in highly concentrated milk retentates.
- Poor heat transfer: Heating and cooling of retentates need more time than milk.
- Good quality milk is necessary since microorganisms are concentrated by microfiltration.
- Cleaning of the microfiltration plant must be monitored very carefully. Increased fouling of equipment and plant needs special cleaning.
- Interim storage is not recommended since skin formation on the retentate surface will occur during cooling and is difficult to homogenize when re-heating the retentate.

3.2 Composition of raw cheeses

Using minimal curd separation, a semi-hard cheese with a dry matter (DM) of 533 g/kg, moisture on a fat-free basis (MFFB) of 626 g/kg and fat on a dry basis (FDB) value of 478 g/kg (determined in cheese aged 1 day) was made from the milk retentate produced with the ceramic module (Table 4). The ripened cheese fulfilled the legal requirements of a traditionally produced semi-hard cheese as well as the required sensory quality. Using the MF/UF/UF plant, a DM of 495 g/kg (MFFB 669 g/kg, FDB 493 g/kg) was achieved in a semi-hard cheese made from skim milk. Using a larger spacer distance in the last loop of the MF/UF/UF plant, cheese production from full concentrate starts to become a real possibility.

Table 4: Composition of semi-hard cheeses (one day old).

Component	**MF** from milk 3.2% fat	**MF/UF/UF** from milk < 0.1% fat	**Traditional production**
Cheese (one day)			
DM [g/kg]	533.0	494.5	543.5
FDB [g/kg]	477.5	493.4	475.0
MFFB [g/kg]	626.4	669.3	615.4
Fat [g/kg]	254.5	244.0	258.2
Raw protein [g/kg]	228.2	217.4	211.8
Calcium [mg/kg]	7182	6383	4809

3. 2 Impact of MF-retentates on cheese making

In comparison to traditionally made cheeses, only a minimal curd treatment is required when retentates are used for cheese making. The foil ripened MF cheeses had a good cohesion of curd grains and an elastic and compact body. In contrast, the body of the smear-ripened cheeses showed mechanical openness (occurrence of irregularly shaped holes). This defect could be prevented by vacuumizing the MF cheeses (dried after brining) in foil before smear-ripening (Figure 3). In general, all MF cheeses had a tendency to tear. During the first few days after production the MF cheeses had to be handled with care.

Figure 3: MF cheese with (left) and without (right) mechanical openness. MF cheese (left) was produced from pasteurised milk with 3.2% fat and was foil-ripened for 68 days. MF cheese (right) was made from 1.4 µm microfiltrated milk with 3.2% fat. After brining it was first vacuumized for two days in foil before smear-ripening for 90 days.

The casein-bound calcium was concentrated with the proteins during microfiltration. At an average of 6.9 g/kg the calcium content was 1.4 times that of a traditional semi-hard cheese and impaired the melting properties of the semi-hard cheeses made from MF-retentates.

The addition of $CaCl_2$ is not advisable since it had a detrimental effect on the melting qualities as well as slightly increasing the bitterness of the cheese. On the other hand, the use of 1.4 µm microfiltration for the reduction of bacteria and spores in industrial milk and a two day vacuum foil treatment prior to smear-ripening had a positive effect on the cheese quality.

The souring behaviour of the cultures in cheese made from MF-retentate was distinctly slower in the initial phase compared to traditional cheese making. However, after 24 hours the pH value of cheese made from retentate was between 5.08 - 5.18 and comparable to that of traditionally made cheeses. The slow initial acidification rate of MF cheese could be improved in further experiments by adding a cheddaring step in the manufacturing.

4 Conclusion

The use of MF plants makes it possible to produce viscous milk retentates with high dry matter content. Semi-hard cheese of good sensory quality was produced from the MF retentates with minimal curd treatment. The limiting factor during concentration is the protein content since it plays a key role in retentate viscosity. Therefore, for continuous semi-hard cheese production without whey separation further procedural steps must be introduced in order to increase dry matter, to reduce calcium and to obtain a composition similar to traditionally produced semi-hard cheese.

References

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