EFFECT OF INSERTED STATIC MIXER ON CROSSFLOW MICROFILTRATION OF ROUGH BEER

Running title: Static mixer for beer filtration

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Abstract

According to *Codex Alimentarius Hungaricus,* beer should be mashed with water from malt and adjuncts, flavoured with hops, fermented with brewer's yeast, carbonated, usually alcoholic beverage. The clarification of rough beer is important, because of improving product quality, efficiency, environmental regulations and sustainability. A standardized lager beer was brewed for the filtration investigations. We used 2P type full factorial experimental design, the three factors were the following: Static Mixer, Transmembrane Pressure and Recirculation Flow Rate. Flux was considered as a response. A membrane cleaning method was developed and analytical measurements were performed. It is shown that operating parameters have an effect on Flux and results of analytical measurements.

Keywords

beer, crossflow membrane filtration, static mixer

Introduction

Brewing is making beer with the following process steps: water treatment, grinding the malt (limited germination and drying of cereal grains or *Pseudocereals*, the aim of malting is to produce enzymes in the germinating kernel and to cause certain changes in its chemical components, this germination process is interrupted by the above-mentioned drying procedure,

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known as kilning) and adjuncts (unmalted cereals and carbohydrates), mashing (a gradual increase in temperature is applied to the mash to activate enzymes for the malt, promoting the breakdown of complex and insoluble carbohydrates into other smaller, simpler molecules), lautering (the liquid phase called wort is separated from the solids), wort boiling with hop (*Humulus Lupulus*) products, whirlpool (hot trub is separated from the wort), wort cooling to the temperature of the fermentation, fermentation (convert sugars into alcohol usually with *Saccharomyces cerevisiae*), conditioning (settling of proteins and polyphenols at low temperatures), clarifying, stabilization and packaging (rough beer may be filtered or/and pasteurized to remove all microbial contamination and packaged into bottles or kegs).

The membrane can be defined essentially as a barrier which separates two phases and restricts transport of various compounds in a selective manner. In the following paragraph importance and applications of Membrane Separation Processes in the Brewing Industry are explained.

Membrane Separation Processes are more and more important in the Brewing Industry because of improving product quality, efficiency, environmental regulations and sustainability. Currently the different Membrane Separation Processes are investigated in the following fields in the brewing industry: Reverse Osmosis for water treatment and dealcoholisation of beer; Microfiltration for recovery of beer and yeast, clarification and cold sterilization of beer; Dialysis for dealcoholisation of beer; Membrane Contactors for gasification and degasification. New possibilities and hottest topics are extract recovery from hot and cold trub with Microfiltration, recovery of carbon dioxide from fermentation with Membrane Contactors, dealcoholisation of beer with Osmotic Distillation, dealcoholisation of beer and aroma recovery with Pervaporation.

In Crossflow Microfiltration, the fluid to be filtered flows parallel to the membrane surface and permeates through the membrane by mean of a pressure drop (*Figure 1.*).

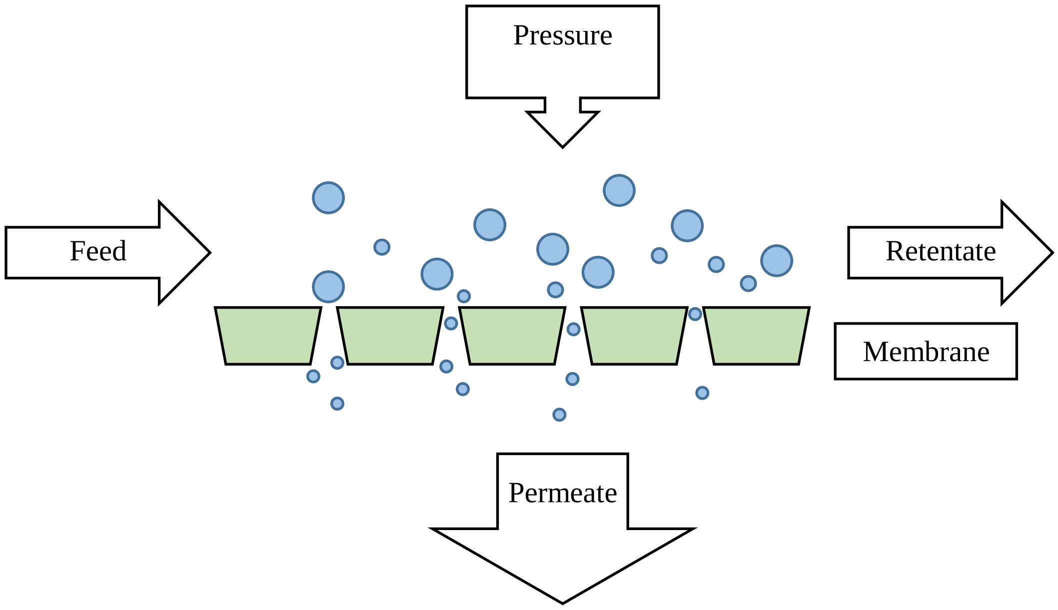

Figure 1.: Principle of crossflow microfiltration

The liquid amount that passes through the membrane is called permeate while the retained molecules and solvent constitute the retentate which is concentrated progressively during filtration process. The major problem in practical applications of membrane separation processes is reduction of the permeate flux with time due to membrane fouling (cake layer is built), but the use of static mixer (turbulence promoter) can effectively enhance the permeate flux in crossflow membrane filtration of particulate suspensions.

The scope of this paper is effect of inserted static mixer on Crossflow Microfiltration of rough beer, because static mixer isn't used throughout the above mentioned beer filtration process nowadays in laboratory and industrial scale.

Materials and Methods

Standardized lager beer (2A. International Pale Lager from BEER JUDGE CERTIFICATION PROGRAM 2015 STYLE GUIDELINES) was brewed for the filtration investigations at the Department of Brewing and Distilling in pilot scale. A filtration equipment (*Figure 2.*) was built for the special task. The rough beer that is in the cooled feed tank is transferred to the membrane module with the pump. Flow rate is controlled with a frequency inverter indirectly and the transmembrane pressure with one of the valves directly. Permeate is collected into a measuring cylinder and retentate is recirculated.

We used 2P type full factorial experimental design. The three factors with the values of levels and center points were the following: Static Mixer (-1 = NSM = No Static Mixer, +1 = SM = Static Mixer), TMP = Transmembrane Pressure (-1 = 0.4 bar, C = 0.8 bar, +1 = 1.2 bar; 1 bar = 10^5 Pa) and Q = Recirculation Flow Rate (-1 = 50 l/h, C = 125 l/h, +1 = 250 l/h; 1 l/h = $2.77*10^{-6}$ m^3/s). J = Flux was the response (l/m^2h = $2.77*10^{-6}$ m^3/s). An effective membrane cleaning method was developed for the special filtration investigations. Analytical measurements such as extract, alcohol content, viscosity, pH, colour were performed. For evaluation of the measurements of the viscosity a decent model was tested and chosen.

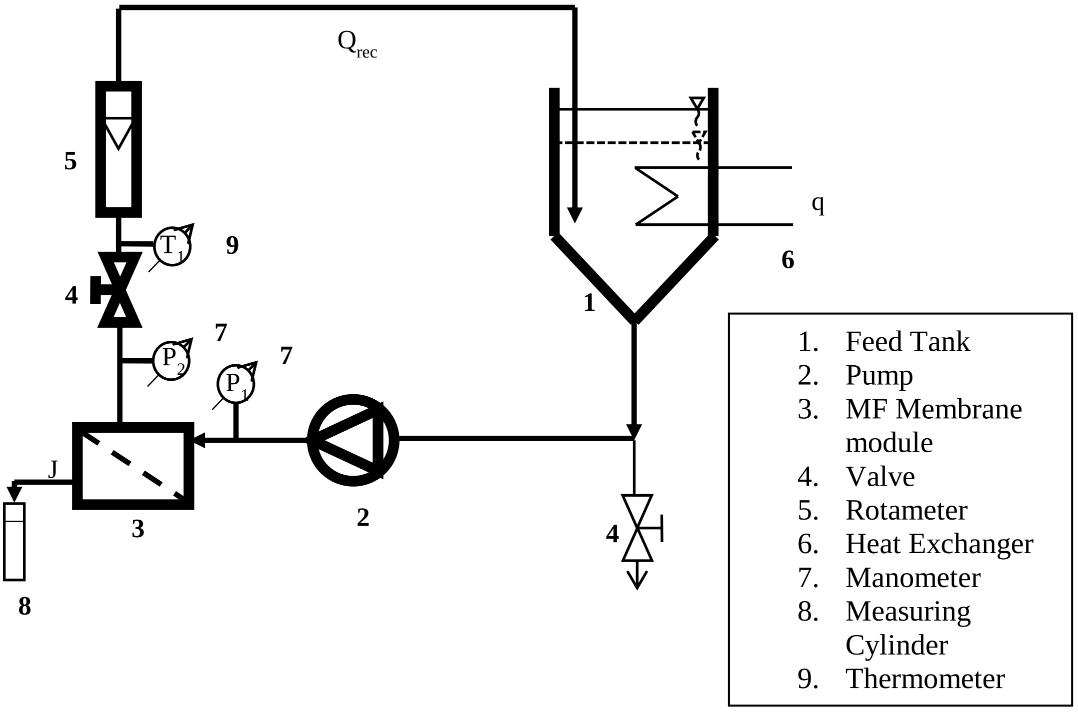

Figure 2.: Schematic flow diagram of beer membrane filtration

Results

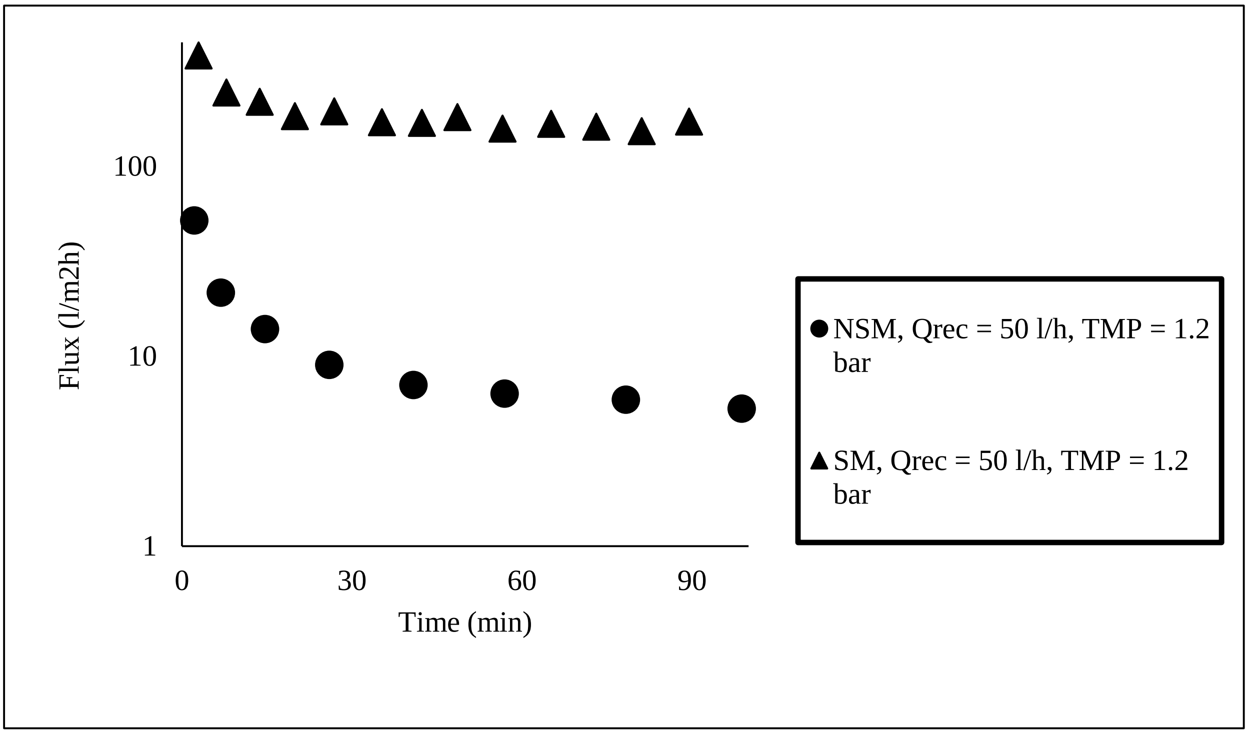

Figure 3.: Time - Flux relationships of two different filtrations

Table 1.: Results of analytical measurements of rough beer and two different filtrations

Parameters	**Rough Beer**	**Filtered Beer (NSM, Qrec = 50 l/h, TMP = 1.2 bar)**	**Filtered Beer (SM, Qrec = 50 l/h, TMP = 1.2 bar)**
Extract (m/m %)	4.48	3.24	3.89
Alcohol (V/V %)	4.6	3.4	4.3
Viscosity (10^{-3} Pas)	5.12±0.14	4.31±0.10	4.25±0.38
pH	4.547±0.110	4.651±0.007	4.645±0.003
Colour (EBC)	6.53	4.23	5.70

Discussion

As shown in the *Figure 3.*, the usage of Static Mixer influences the initial and the steady state Flux values, in the case of usage of Static Mixer these values are higher than the values of conventional filtration, but the deviation of values are also higher.

As it can be seen in the *Table 1.*Table the values of extract, alcohol content and colour decreased in both cases compared to the values of rough beer, however the pH values increased.

Conclusions

According to the some of the experimental results, it is shown that Static Mixer may have positive effect on important Flux (initial and the steady state) values and results of analytical measurements. Based on the current measurement data and results a mathematical model for membrane filtration process of rough beer will be developed. Much more attention is needed to be place for data analysis.

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