Optical analysis of membrane fouling in green beer filtration using confocal laser scanning microscopy

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Highlights:

- Identification of membrane-blocking beer ingredients during beer membrane filtration via confocal laser scanning microscopy
- Quantification of adsorbed biopolymers and correlation with filter performance
- Investigation of the local distribution of biopolymers on the fouled membrane, classification into substance group-specific internal and external fouling

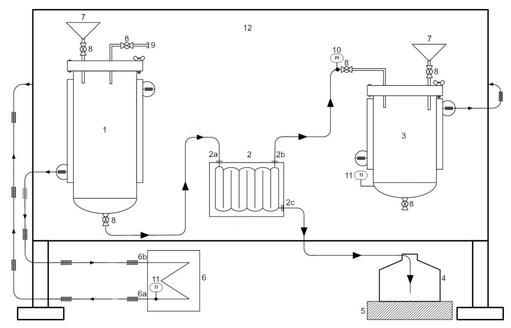


Figure 1: Experimental setup of the laboratory crossflow membrane filter. The filter consists of three vessels with cooling jackets which are connected to a cooling unit. Sensors are used to record the variables relevant to filtration. The temperature sensor (11), the pressure sensor (10) and the scale (5) are connected to a computer for logging.

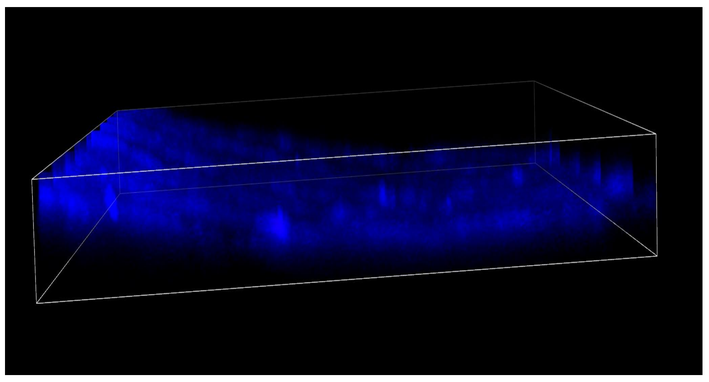


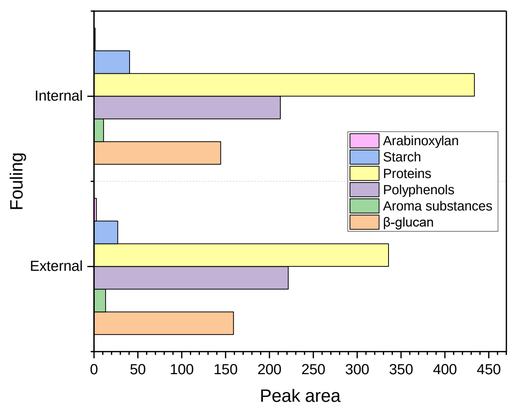
Figure 2: Section of a hollow fiber membrane stained with Calcofluor to visualize β-glucan (laser 488 nm)

Material and methods:

- Crossflow filtration trials were performed on an automated laboratory filter system (see Fig. 1) by using 0.45 µm flat sheet PES membranes
- After filtration, the membranes were removed from the filter and prepared for microscopy
- After dying the membrane cutouts with substance group specific fluorescent dyes, confocal laser scanning microscopy was used to create a 3D image of the membrane (see Fig. 2)
- The created 3D image is decomposed into the individual planes, which are then post-processed and evaluated
- For each z-value, the percentage of the area occupied by the specific fluorescent object is obtained

Substance group-specific breakdown of internal and external fouling

Figure 3: Plot of the mean values of the peak areas of the individual fouling components β-glucan, aroma compounds, polyphenols, proteins, starch and arabinoxylan, divided into internal and external fouling (n=15 per membrane, n=3 membranes per beer tested; membrane manufacturer Sartorius, 16 different unfiltered beer from seven different breweries)



- In beer samples, the substance groups β-glucan, polyphenols and proteins could be identified as the main causes of fouling
- Characterization of the fouling of the individual substance groups:
  - β-glucan predominantly causes external fouling
  - Aroma substances show fouling only in case of strong external fouling by β-glucan
  - Protein as single substance only causes internal fouling; through interaction with other substance groups also strong external fouling occurs
  - Polyphenols cause fouling mainly through interactions with other substance groups
  - Starch shows very low fouling
  - Arabinoxylan shows low fouling in the samples tested; but predominantly external fouling

Correlation of the absorbed biopolymers with filtration performence

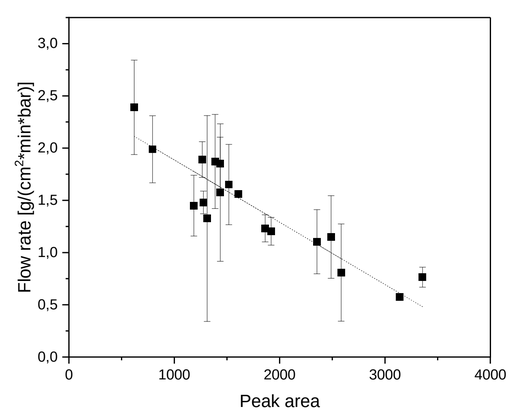


Figure 4: Plot of mean flow rate (n=3, with standard deviation as error bar) against total peak area of fouling of PES membranes (n=15 per membrane, n=3 membranes per beer tested; membrane manufacturer Sartorius, 16 different unfiltrates from seven different breweries, R^2 = 0.96).

- Direct correlation between the filter performance and the occurred fouling of all substance groups summed up (**R^2 = 0.96**)
- Direct correlation between filter performance and fouling occurred by β-glucan (**R^2 = 0,97**)
- Also direct correlation between filter performance and fouling occurred by polyphenols (**R^2 = 0,89**)
- Other substance groups showed no good correlation

Conclusion and outlook:

- The results show good correlation between the optical method and filtration performance, making it a great tool to troubleshoot filtration problems in industrial scale filtration
- In beer samples, β-glucan was identified as the main cause of fouling
- Optimization of membrane clarification processes by investigating chemical and enzymatic membrane cleaning processes for the retention of specific beer polymers as well as the type of membrane blockage will be possible in the future

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