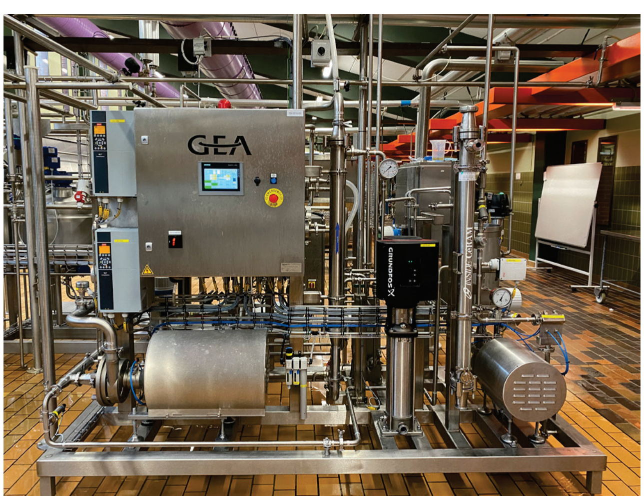
Caseins in focus

Filtration techniques can change the ingredient landscape – from raw material to functional ingredient.

Membrane filtration has for many years given the dairy industry a toolbox to separate and concentrate milk components based on size and composition. By carefully choosing the right tools – microfiltration, ultrafiltration with or without diafiltration – manufacturers can tailor this to create products with unique functionalities. Ultrafiltration and microfiltration refer to filtration at different membrane pore sizes, which allows for the design of processes for targeted separation of different components. This can be combined with diafiltration to enhance this separation. Diafiltration is, in principle, a "washing" process, performed by adding a solvent, in most cases water, to the feed during filtration, either continuously or in batch mode.

Milk protein concentrates and micellar casein concentrates are two examples of specialized concentrated milk protein products obtained by ultra- and microfiltration, respectively, which are in high demand for applications like infant formula, high-protein drinks, and baked goods. A challenge, which is often overlooked, is that the properties of the final casein-containing concentrates can be strongly impacted by the processing history, i.e., the conditions applied during the filtration process. In some cases, even small differences in processing can have a major impact on their behavior. This relates to the importance of the structure of the casein micelle, which is subjected to changes depending on the filtration conditions.

Figure 1. Pilot trials



As casein micelles are spherical aggregates of casein proteins and calcium phosphate clusters, stabilized by κ-casein on the surface, they are highly sensitive to changes in the environment. For example, filtration at low temperatures can lead to greater release and separation of β-casein, one of the proteins in the casein micelle, and the level of diafiltration can impact the amount of calcium phosphate nanoclusters "washed out" during the process. Furthermore, as the filtration occurs and the casein micelles are pushed closer together, there can be changes in their interactions and rearrangements. All these changes can potentially impact the properties of the final concentrate, for instance, its gelation (as in yogurt or cheese) and heat stability (as in sterilized products).

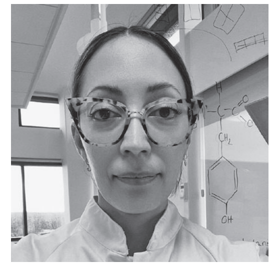
How changes in processing translate into changes in functionality is however not well understood. By exploring how fractionation, concentration, and diafiltration impact casein micelles, this research aims to help the dairy industry better understand and fine-tune its processes.

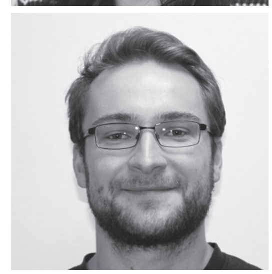
Microfiltration enhances gel strength and heat resistance

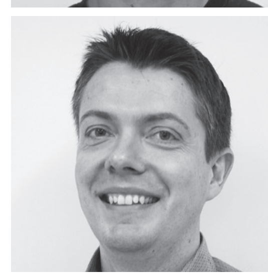
This research explored the impact of ultrafiltration and microfiltration, combined with varying diafiltration levels, on the chemical composition and properties of milk protein concentrates compared to regular skim milk, to see the impact of the different processing steps. Filtration was performed both in lab-scale but also at pilot scale (Figure 1). Since the behavior of skim milk is very well understood, any differences compared to this helped identifying where potential changes come from.

Using this systematic approach, it was shown that there are significant differences between the concentrates depending on the pore size used i.e. ultrafiltration vs. microfiltration. In microfiltration, the whey proteins passed through the membrane, resulting in milk with fewer dissolved proteins as well as less calcium compared to ultrafiltration where the skim milk is retained (Figure 2).

In this study, we moved beyond the obvious. By membrane filtration of milk at different pore sizes, it was possible to create two streams, one rich in native whey proteins, and the other depleted of whey proteins. The whey protein-depleted stream







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has some unique features when compared to an ultrafiltered milk protein concentrate. This ingredient is of better value in any process where whey proteins are not important for their technological functionality. However, to really understand the potential, this needed to be tested in more detail.

The functionality of obtained concentrates was tested by evaluating their ability to form acid- and rennet-induced gels - an important property for products like yoghurt and cheese. In this study, simple acid gels were prepared, and the gel formation and strength of the final gel were compared. Results showed that concentrates produced by microfiltration can create stronger gels compared to concentrates produced by ultrafiltration, particularly in the absence of both whey proteins and β-casein, indicating that concentrates produced during microfiltration consist of casein micelles which can more easily interact and form stronger connections.

Heating is also a process whereby whey proteins may be playing a detrimental role. Hence, heat stability of these casein concentrates was also tested. Casein concentrates produced by microfiltration were indeed more stable during heat treatment compared to concentrates obtained by ultrafiltration.

These findings underscore the potential of microfiltration for producing dairy products with improved gel strength and thermal resilience. Overall, this study highlighted how design of microfiltration, ultrafiltration and diafiltration affect casein concentrates differently, showing that the choice in filtering technique is not only a matter of processing but impact the final concentrate, and paving the way for more targeted casein formulations.

How will this help the dairy industry?

Milk protein processing has evolved significantly with advancements in membrane filtration technologies, including ultrafiltration, microfiltration and diafiltration. However, despite widespread adoption, fundamental questions remain about how processing parameters – such as temperature, pore size, and diafiltration mode and media – impact the molecular structure, functional behavior, and stability of protein concentrates. This systematic comparison of milk and casein concentrates with different processing histories in terms of type of filtration (microfiltration vs. ultrafiltration) and diafiltration level provides a more general understanding of how differences in processing translate into changes in the properties of the final concentrates. This can help in the development of more general principles to rely on in the design and understanding of filtration processes in the dairy industry.

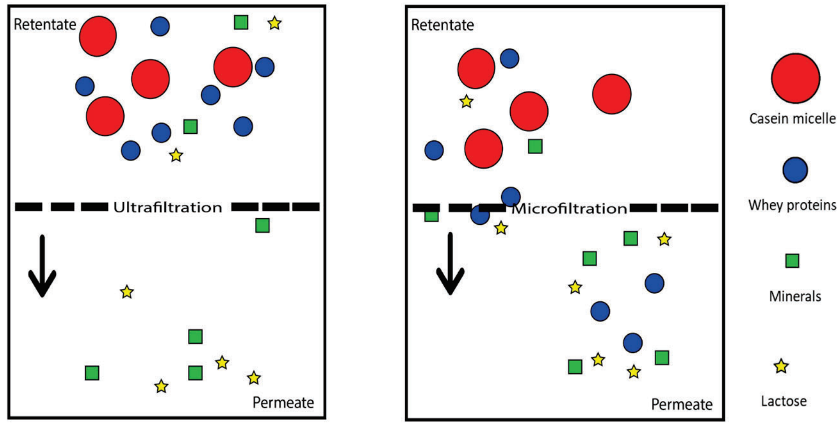

Figure 2. Difference in ultrafiltration and microfiltration

ABSTRACT

In a collaboration between Aarhus University and Arla Foods, and supported by the Danish Dairy Research Foundation, this study details how processing history can have a strong impact on the properties of milk protein concentrates and micellar casein concentrates obtained through membrane filtration technology. It provides a systematic evaluation of the impact of the type of filtration (microfiltration vs. ultrafiltration) and the level of diafiltration on both the structure and functionality of such concentrates. Results highlight the potential of membrane filtration to enhance dairy product quality and functionality and how this can be optimized by controlling processing parameters.

PROJEKT FACTS

Title: Understanding critical processing parameters to design novel improved functional milk protein concentrates (FILTRATE)

Project manager: Milena Corredig

Participants: Aarhus University, Arla Foods amba

Project period: January 2020-December 2022

Objective: The research aimed to determine which processing parameters are critical to cause changes at a supramolecular level to the structure of the casein micelles, and to describe quality parameters able to predict changes in casein micelles functionality. With this aim, the research had the following specific objectives: (1) To understand the state of the soluble protein fraction in the concentrates, (2) Develop a comprehensive understanding of the heat stability and the ability to gel with chymosin of the concentrates, and (3) Evaluate potential utilization of concentrates of interest.

PROJECTS RELATED TO THE DANISH DAIRY RESEARCH FOUNDATION