Whey2Food Publishable Summary

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Summary description of project context and objectives

The goal of the Whey2Food project is to develop and establish a highly efficient, selective, gentle and economically attractive electro-membrane filtration (EMF) technology to enhance separation and concentration of proteins and protein peptides from whey. The EMF technology combines the ultrafiltration technique with the migration of charged species in an electric field that enables the separation of molecules with similar molecular weight but different electric charge. Compared to state-of-the-art ultrafiltration, EMF significantly increases filtration yields and reduces membrane fouling, therefore reducing cleaning efforts and membrane replacement costs. Whey is a by-product of the manufacture of cheese or casein and is considered a promising raw material for various commercial applications due to its high-value components like proteins. The separated protein fractions are of high interest in food (infants or sports), medical, and personal care applications. However, most of the produced whey is currently disposed and not used for further processing.

The efficient recovery of functional protein fractions through EMF technology will provide an important source of high-value natural food emulsifiers and protein supplements for various food formulations and nutritional applications, while providing an economic alternative to whey disposal and reducing the environmental impact of European SME dairies. The key innovations of the Whey2Food project are:

- A novel large scale EMF technology to process whey
- A process that can be tailored to adjust and control the output protein fractions. This can be reached due to the fact that EMF separates not only by the molecular weight, but also by the electric charge of the proteins under interest.
- An electro-membrane filtration unit with automated function and minimal maintenance requirements. Membrane cleaning can be performed not only by applying a backpressure, but also byreversing the cell voltage.
- A method to produce proteins of specific functionality or to enrich specific proteins
- A cost effective, flexible in production and easy to operate system for small-scale cheesemakers

- A process with a wide range of potential applications in biotechnological downstream processes

Scientific objectives of the Whey2Food project are:

- Understanding of the electric field distribution in the Whey2Food reactor and its effect on the transport of the proteins across the filtration membrane
- Understanding the effect of key operation parameters on the separation yield and efficiency
- Characterization of the functional properties of protein and peptide fractions in model and food application

The Whey2Food project therefore combines scientific research with industry-relevant applications. The work performed in the project covers the physical modelling of the EMF process and cell, the development and fabrication of a novel cell with improved performance, the integration of this cell into an industrial relevant process concept for the separation of proteins from whey, the analysis of the proteins, the demonstration of the running system in real-time applications and the analysis of promising markets and applications of our technology.

Based on these project targets and work, the consortium of the Whey2Food project has been formed: The consortium consists of experts on electro-physical separation processes, dairy technology and analysis, design and fabrication of reactor cells and its components, automation, and application in the whey and milk product industry. The partners therefore form a complete supply chain from the system development to demonstration and application.

Description of work performed and main results

During this project, A technical-economic analysis of different protein fractions in the whey and their market potential was conducted. Specific target proteins were identified and a corresponding separation concept based on the EMF technique was developed.

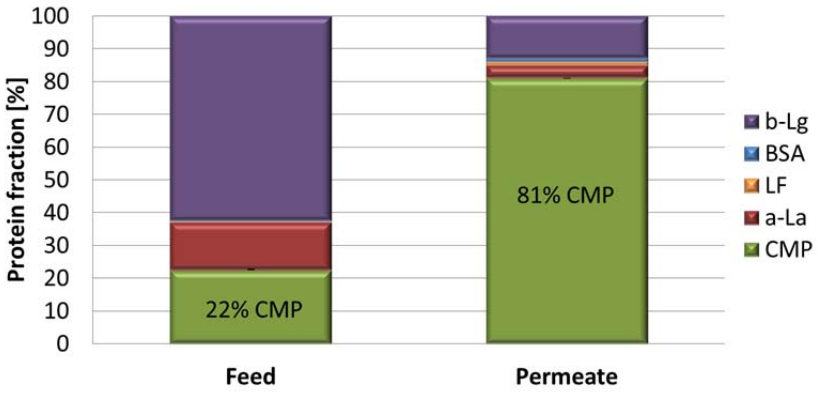
Enriched whey protein fractions were obtained by selecting appropriate electrode material and cell configuration parameters, including placement of filtration membranes and electrode shielding membranes, electric field strength, pH, fluid temperature, fluid pressure gradient and membrane cut off (pore size). The aim was to obtain a full understanding of the EMF process and its interferences with whey and the contained compounds to create a knowledge base that supports the development of an optimal system configuration at laboratory level and enables the scale up of the process and into a demonstration prototype suitable for use at an industrial relevant environment.

The project focused on the enrichment of a whey protein fraction containing Casein Macro Peptide (CMP). CMP is the hydrophilic fraction of κ-Casein that remains in the whey after the Lab-induced formation of curd during the cheese-making process. Its concentration in whey is around 1.5 g/l. This peptide has proven immunomodulatory, health promoting properties and is currently being commercialized for clinical foods and infant nutrition formulas. CMP has also extraordinary foaming and emulsifying properties that widens its area of application in foods. Commercial benchmarks report a CMP concentration of 75 to 85% of total protein. Accordingly, research activities focused on a strategy to obtain a similar concentration of CMP in the enriched fraction.

The main challenge is to separate CMP from α-Lactalbumin (α-La) and β-Lactoglobulin (β-Lg), whose isoelectric points are found within a very narrow range. Therefore, a fine adjustment and monitoring of pH, transmembrane pressure, crossflow and the conductivity is necessary. Because the molecular weight of α-La and β-Lg at least double that of CMP, the electric field applied was able to retain them at the retentate side while CMP was rather transmitted to the permeate under the influence of the transmembrane pressure applied. During laboratory trials CMP was successfully enriched in the

permeate to a concentration of up to 81% with respect to the sum of all protein fractions transmitted (Figure 1). With this process the CMP/ β-Lg ratio from the feed solution was shifted to ca. 6.2 in the enriched permeate, increasing over 10-fold.

Figure1: Distribution of Protein fractions in feed and in permeate after EMF treatment



After process optimization at laboratory level, a pilot unit was developed. The core of this unit is an optimized EMF cell, which takes into account an optimum distribution of electric field, minimizes pH-shifts and ensures the adjustment of the crossflow and transmembrane pressure to the required range. The unit operates in semi-batch mode (feed and bleed) with feed flow of 1000 L/h at optimum transmembrane pressure conditions (Figure 2).

Figure 2: EMF pilot unit

A life cycle assessment (LCA) study conducted to verify the economic-ecological significance of the Whey2Food concept as an efficient and ecologically friendly process technology for the recovery of protein fractions from whey. In this LCA study, the concept of EMF was compared with conventional ultrafiltration as the competing state-of-the-art technology. The analysis of the different scenarios is

then based on the LCIA-CML 2001 methodology, using the four impact categories "Global Warming Potential", "Abiotic depletion of elementary resources", "Abiotic depletion of fossil resources" and "Marine Aquatic Eco Toxicity Potential".This analysis and the comparison of results show that the Whey2Food process at this stage is at a similar level with the state of the art process already. However, the Whey2Food technology has a clear potential to surpass the standard ultrafiltration. Beyond the ecological aspects the electro membrane filtration has already clear benefits over the state of the art, especially when it comes to the required effort in maintenance and the connected production downtimes, which have to be avoided by any means in an environment of industrial production.

Expected final results and potential impacts

Consumers are increasing their awareness towards health and wellness, thus driving market growth of food protein ingredients worldwide. Accordingly, whey proteins have gained major attention for applications in infant formula, sports and clinical nutrition due to their health and nutritional benefits, large availability as a by-product from cheese-making and low raw material cost. Moreover, whey proteins fractions have the potential to replace chemical additives in formulations due to their extraordinary techno-functional properties, including foaming, emulsifying, gelling and water-binding potential.

Whey is a by-product of the manufacture of cheese or casein and is considered a promising raw material for various commercial applications due to its high-value components (e.g. proteins) and its large availability. Around 81 million tons of liquid whey was produced by the approximately 150,000 European cheese makers in EU-27 in 2011. However, according to the European Whey Products Association (EWPA), only 40% of the liquid whey in Europe is being processed for its utilization in food and human nutrition or in feed applications, while the rest is still being dumped into municipal sewages, mainly by SME dairies. This is neither ecologically nor economically reasonable.

Current technologies for protein fractionation and concentration are still laborious and require several processing steps, the use of chemicals, large amounts of eluents or buffers or need huge cleaning efforts due to membrane fouling and have high membrane replacement costs (e.g. ultrafiltration). In addition, acids, alkalis and high temperatures are often needed to achieve separation, causing protein denaturation and diminishing product quality. In general, these technologies are difficult to up-scale and are associated with additional environmental problems due to disposal of chemicals and the large amounts of waste water generated. Therefore, an economic and sustainable solution for the valorization of whey is urgently needed.

The Whey2Food project resulted in a novel large scale EMF technology to process whey. For this purpose, an EMF cell reactor including suitable electrodes and membranes were specified, developed, fabricated, and tested with model and real whey solutions. The effect of process parameters like cell voltage, transmembrane pressure and cross flow velocity was analyzed in order to optimize the process performance. The Whey2Food project also provided detailed information on different market applications which can be targeted using the developed technology.

The system developed in the Whey2Food project is able to meet these requirements: Compared to state-of-the-art ultrafiltration technology, the EMF is expected to reach higher separation yields with low energy consumption and reduced electrode and membrane fouling, resulting in less cleaning efforts and therefore reduced operation costs.

The results of the project will therefore have a significant technical, economic and ecological impact. The technology developed in this project will provide a cost-effective method to separate protein fractions from whey, which will in the end increase the competitiveness of European SME cheese makers.

Project Partners

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MALTHE WINJE AUTOMASJON AS, Norway
INTERNATIONAL FOOD NETWORK, United Kingdom
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