Molecular insights in lactose refining

Low molecular weight compounds in lactose refining streams from whey - a potential new source for value added products.

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During the production of cheese, whey is generated, which contains 95% water, lactose, proteins, minerals and LMWs. Whey is processed into new products and ingredients, usually by isolating proteins. These practices lead to the generation of whey permeate, a protein-free yellow liquid that contains numerous LMWs including NPNs. Whey permeate is primarily used to produce lactose during which various underutilized side-streams are generated.

It is clear that despite the optimized production yield and efficiency in the dairy industry, the increased and diversified processing capacities of the dairy industry result in the generation of large amounts of side-streams. Exploring their molecular composition is necessary to monitor their quality and classify compounds that can be used to produce novel ingredients and products. One notable example is whey permeate, which is primarily used to produce lactose leading to the generation of underutilized side-streams. Research shows that whey permeate contains bioactive peptides and oligosaccharides, indicating that the NPNs fraction of whey permeate might be a source of functional compounds for novel products and/or ingredients. This discovery shows the need for the detailed analysis of the LMWs and NPNs of whey permeate and the processing side-streams thereof.

The methods and standard operating procedures developed in this project were validated by analyzing samples from trial lactose productions at Arla Foods Ingredients, allowing for the investigation of the low-molecular weight, including the NPN, fraction of whey permeate.

Towards molecular characterization of lactose production streams

In total, 110 low-molecular weight compounds were identified out of which 49 were quantified, providing unique compositional information for whey permeate, lactose powder and lactose process streams. A particular emphasis was given on identifying and quantifying NPN compounds. In total, 37 NPN compounds were identified and quantified including 13 amino acids, seven amino acid derivatives, four amino alcohols, two organic acids, three methylamines, two nucleobases, one nucleotide, one nucleoside, one amino sugar, one vitamin, urea and ammonia. Of these compounds, 19 were detected in

ABSTRACT

Whey is the largest volume co-product of the dairy industry, and while its major components are known, the content of low-molecular weight components (LMWs) has been overlooked. With low-molecular weight components in whey remaining largely unknown, their potential valorization for the production of new value-added products remains limited. In this project we developed high-throughput methods to screen more than 100 metabolites, including nearly 40 non-protein nitrogen compounds (NPNs), in whey permeate and lactose production streams. The results show how processing affects the composition of production streams giving insights on how the dairy industry can optimize lactose crystallization and valorize side-streams by extracting functional compounds for novel and high-value food ingredients.

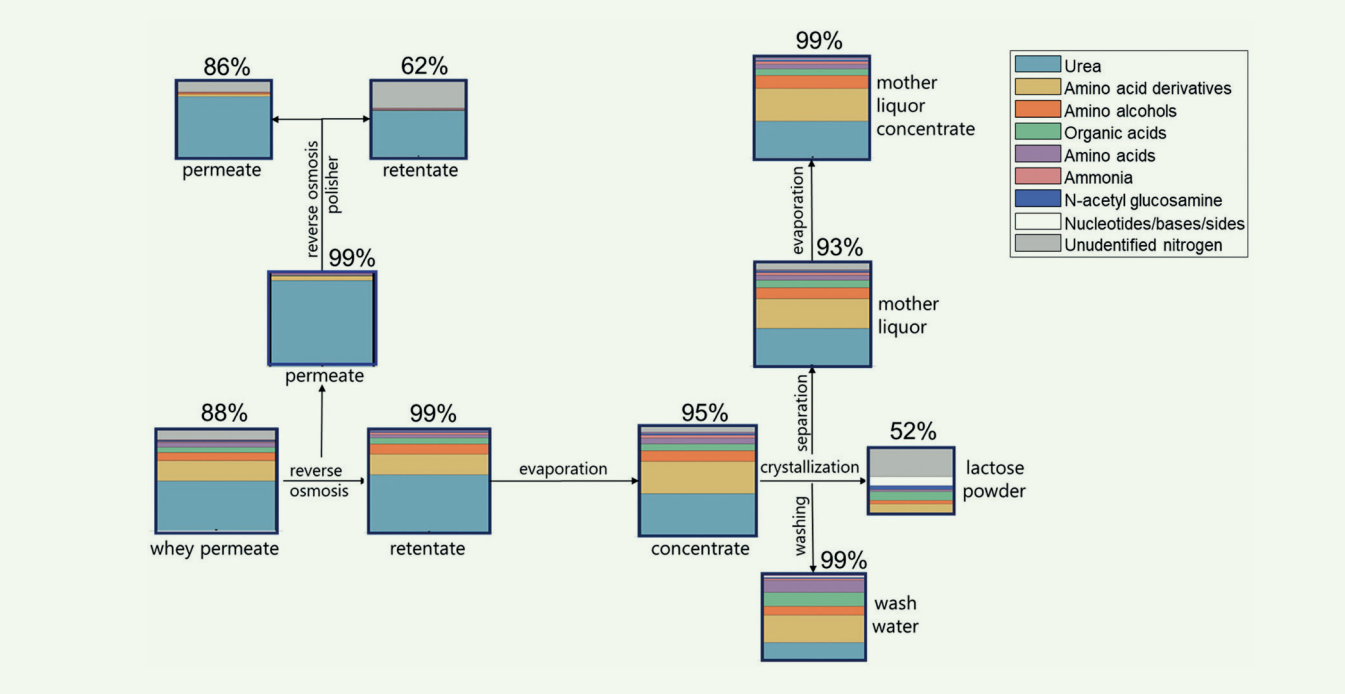

Figure 1. Nitrogen recovery (%, w/w) for each analyzed process stream from a trial lactose production process together with the nitrogen contribution of the identified and quantified NPN compounds.

whey permeate for the first time, while two compounds, i.e. norvaline and pyruglutamic acid were detected for the first time in dairy matrices.

The quantitative data were used to investigate how unit operations affect low-molecular weight compounds during lactose production. In total, 23 compounds found in lactose powder, including 11 NPNs, showing affinity to lactose and/or lactose crystals. Thirty-eight compounds, including large molecules, like fatty acids, permeate reverse osmosis membranes; with urea consisting the main organic compound in reverse osmosis permeates. Heating during evaporation was found to affect volatile compounds and urea, as well as other substances like citric acid, which precipitates and contributes to evaporator fouling. Additionally, heating leads to a reduction in creatine, with a concomitant increase in creatinine. Most of the compounds were concentrated in the de-lactosed whey permeate and water used for the lactose crystals washing. Finally, the percentage of nitrogen recovered in the present work was ranging from ~57 to 99%, with streams containing higher levels of nitrogen showing better recovery.

How can the industry benefit from this research?

The dairy industry can utilize information about the molecular composition of specific lactose process streams to further control lactose crystallization and secure increased yield of crystals with minimum loss in mother liquor and during washing. The detailed composition of underutilized side-streams, such as mother liquor concentrate, may help their valorization and the development of new ingredients/products. In particular, valorization of side-streams can be achieved through extraction of beneficial NPN compounds for the production of high-value food ingredients and ensure documented quality in dairy food production. ●

PROJECT OVERVIEW

Title: Low molecular weight compounds in milk and dairy streams - a potential new source for value added products.

Project leader: Professor Søren Balling Engelsen, Department of Food Science, KU.

Participants: University of Copenhagen, Arla Foods Ingredients

Project period: March 2020 – February 2023.

Objective: Milk and whey products contain minor components which remain largely unknown, posing a barrier to the manufacture of more high-quality, value-added products. This project aims to extend current knowledge on the unknown substances of milk products and establish analytical methodologies for detailed analysis of minor components of milk and whey products.

PROJECTS RELATED TO THE DANISH DAIRY RESEARCH FOUNDATION