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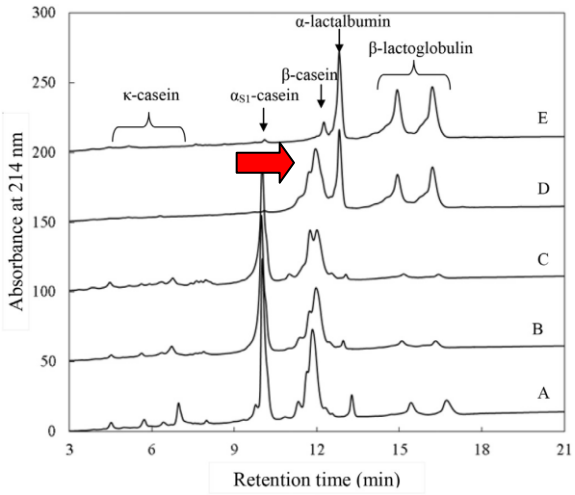
Concept Protein Ingredient for Next-Generation Infant Formula



Key external stakeholders:

Dairy ingredient manufacturers, Infant formula manufacturers, Dairy ingredient end-users

Practical implications for stakeholders:

The project adopts a new approach to manufacturing infant formula by using a membrane-based integrated system to produce a new concept protein base ingredient from which a finished product can be made. This base ingredient can be used as a nutritional base to build a 1st stage infant formula from. The new process has potential beneifits for the manufacturer and environment as it is less energy intensive when compared to more traditional processes.

- The objective of the work was to modify the protein composition of bovine skim milk using pilot-plant membrane filtration to produce a whey protein-dominant ingredient with a protein profile closer to human milk.
- The new process can be used to produce either a base ingredient or a finished Infant formulation. It can be implemented at commercial scale, has a low thermal load during processing, and has good reconstitution and nutritional properties.

Main results:

- Membrane process:
  - Filtration was carried out at 50 or <10°C, using ceramic microfiltration (MF) membranes, followed by concentration of the permeate stream using polyethersulfone ultrafiltration (UF) membranes (10 kDa). Permeate from the cold microfiltration (<10 °C) process contained a casein:whey protein ratio of ~35:65, eniched in β-casein, with no α_s- or κ-casein present, compared to a casein:whey protein ratio of ~10:90 at 50°C.
  - Processing parameters including pre-treatments, membrane operating parameters and holding times were identified, making the process ready for large scale manufacturing.

Opportunity / Benefit:

- The study has demonstrated the application of membrane fractionation to produce a β-casein enriched whey ingredient suitable for manufacture of infant milk formula. The concept 'protein base' ingredient, made using an integrated membrane system, allows for manufacture of infant formula directly from milk at a single location, changing the current philosophy of how infant formula is manufactured.

Collaborating Institutions:

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1. Project background:

The global market for infant milk formula (IMF) is consistently growing, with Ireland producing in the region of 10-12% of global exports. Ireland is host to some of the worlds leading infant formula manufacturers who have large scale processing facilities within the country. As a consequence, Ireland is strategically committed to the infant formula sector which indirectly provides a vital channel for ulitisation of locally produced dairy ingredients. This project, through the UCC/Teagasc alliance, aimed to research and develop a new concept ingredient for use in 1st stage infant formulations, with minimal processing and reduced carbon footprint. Current manufacturing practices are energy intense and require transport of ingredients from different locations for formulation, e.g., use of skim milk powder, whey protein ingredients and lactose. The aim was to develop technology to provide a 'one fits all' humanised dairy protein base with optimal thermal stability and functionality, for use in infant formulae. This concept base ingredient can facilitate the addition of nutrients (fat, carbohydrate, minerals and vitamins) to the required solids content to enable a direct feed to the spray dryer (i.e., no evaporator), thus reducing the complexity of manufacture. The concept 'protein base' ingredient was made using an integrated membrane system, coupled with mineral selectivity to confer broad spectrum stability during processing.

2. Questions addressed by the project:

- What is the correct protein chemistry and membrane separation technology required to create a protein ingredient with composition closer to human milk.
- Can the use of a membrane-based integrated manufacturing system produce a concept protein base ingredient which is stable during concentration, emulsion formation and subsequent drying.
- Can the concept ingredient facilitate manufacture of infant formula directly from milk at a single location.

3. The experimental studies:

The protein composition of bovine skim milk was modified using both laboratory and pilot scale membrane filtration to produce a whey protein-dominant ingredient with a casein profile closer to human milk. A series of laboratory trials were carried out to investigate the processing and protein-fractionation characteristics of different polymeric membranes during filtration of skim milk at refrigeration temperatures. These were followed by scale-up pilot plant trials whereby milk was first separated into skim and fat, then microfiltered into a retentate stream and a whey / β-casein enriched permeate stream, for evaluation in a 1st stage infant formulation. Skim milk was processed at low (8.9°C) or high (50°C) temperature using ceramic microfiltration (MF) membranes (0.1 μm mean pore diameter). The permeate stream was enriched in β-casein by the cold filtration under different experimental conditions of pH etc., and concentrated using polyethersulfone ultrafiltration (UF) membranes (10 kDa cut-off). The protein profile of MF and UF retentate streams were determined using reversed phase-high performance liquid chromatography and polyacrylamide gel electrophoresis. The functionality (thermal and emulsion stability) of the casein components (micellar and free β-casein) in the enriched UF permeate streams was evaluated using chemical and rheological methodologies. Additional studies were performed to understand the thermal stability of the protein system during concentration, in both dispersed and emulsified systems, to simulate high solids processing practices. Finally, a finished model infant formula was manufactured using the new protein base produced.

4. Main results:

The protein composition of bovine skim milk was modified using membrane filtration (at both laboratory and pilot scale) to produce a whey protein-dominant ingredient with a casein profile closer to human milk. Bovine skim milk was processed at low (8.9°C) or high (50°C) temperature using ceramic microfiltration (MF)

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membranes and the permeate stream was concentrated using polyethersulfone ultrafiltration (UF) membranes. Permeate from the cold MF process (8.9°C) had a casein:whey protein ratio of ~35:65 with no α- or κ-casein present, compared with a casein:whey protein ratio of ~10:90 at 50°C. The study has demonstrated that application of cold membrane filtration (8.9°C) can produce a dairy ingredient with a protein profile closer to that of human milk.

5. Opportunity/Benefit:

Traditionally skim milk and whey protein based powders from different sources are used in combination for formulation of 1st stage infant formula. The formulator has little control over the thermal history, functionality and/or behaviour of this protein system in the presence of mineral salts during concentration and subsequent rehydration post drying. The study has demonstrated that it is possible to produce a protein base combining both whey and casein components, targeting the protein profile of human milk, from an integrated membrane system. The concept protein base has potential to be used as a single protein ingredient from which infant formulations can be made in a more efficient and sustainable way.

6. Dissemination:

Main (peer reviewed) publications:

1. McCarthy, N.A., P.M. Kelly, P.G. Maher and M.A. Fenelon. 2014. Dissolution of milk protein concentrate (MPC) powders by ultrasonication. Journal of Food Engineering 126:142-148.
2. Crowley, S. V., Desautel, B., Gazi, I., Kelly, A. L., Huppertz, T., and O'Mahony, J. A. (2015). Rehydration characteristics of milk protein concentrate powders. Journal of Food Engineering, 149, 105-113.
3. Crowley, S. V., Caldeo, V., McCarthy, N. A., Fenelon, M. A., Kelly, A. L., and O'Mahony, J. A. (2015). Processing and protein-fractionation characteristics of different polymeric membranes during filtration of skim milk at refrigeration temperatures. International Dairy Journal, 48, 23-30.
4. Crowley S.V., Kelly, A.L. and O'Mahony, J.A. (2014). Fortification of reconstituted skim milk powder with different calcium salts: Impact of physicochemical changes on stability to processing. International Journal of Dairy Technology Vol 67, No. 4 November 2014, 474-482.
5. Crowley, S. V., O'Callaghan, T. F., Kelly, A. L. Fenelon, M. A., and O'Mahony, J. A. (2015). Use of ultrafiltration to prepare a novel permeate for application in the functionality testing of infant formula ingredients. Separation and Purification Technology, 141, 294-300.
6. Crowley, S. V., Jeantet, R., Schuck, P., Kelly, A. L., and O'Mahony, J. A. (2016). Rehydration and solubility characteristics of high-protein dairy powders, in, Advanced Dairy Chemistry: Volume 1: Proteins, Part B, Applied Aspects, 4th edn., P. L. H. McSweeney and J. A. O'Mahony (eds.), New York: Springer, pp. 99-131.
7. Crowley, S. V., Dowling, A. P., Caldeo, V., Kelly, A. L., and O'Mahony, J. A. (2016). Impact of α-lactalbumin:β-lactoglobulin ratio on the heat stability of model infant milk formula protein systems. Food Chemistry, 194, 184-190.
8. Crowley, S. V., Kelly, A. L., Lucey, J. A., and O'Mahony, J. A. (2017). Potential applications of non-bovine mammalian milk in infant nutrition, in, Handbook of Milk of Non-Bovine Mammals, 2nd ed., Y. W. Park, G. F.W. Haenlein and W. L. Wendorff (eds.). John Wiley & Sons, Ltd, Oxford, UK.
9. Crowley, S. V., O'Mahony, J. A., and Fox, P. F., (2017). The proteins of milk, in, Achieving Sustainable Production of Cow's Milk, Volume 1: Safety and Quality, N. van Belzen (ed.). Burleigh Dodds Science publishing, Philadelphia, US.
10. McCarthy, N.A., H.B. Wijayanti, S.V. Crowley, J.A. O'Mahony and M.A. Fenelon. 2017. Pilot-scale ceramic membrane filtration of skim milk for the production of a protein base ingredient for use in infant milk formula. International Dairy Journal 73 (2017) 57-62.

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Publications / abstracts including those presented at conferences:

1. Crowley, S. V. (2016). Next generation milk protein ingredient isolation and functionality. IDF Parallel Symposia: Concentrated and Dried Milk Products, Dublin, Ireland, April 11-13th, 2016.
2. Crowley, S. V., Molitor, M., Kalscheuer, R., Lu, Y., Kelly, A. L., O'Mahony, J. A., and Lucey, J. A. (2016). Use of a liquid-solid hydrocyclone in the recovery of milk minerals from acid whey. IDF Parallel Symposia, Dublin, Ireland, April 11-13th, 2016.
3. Fenelon et. al. 2016. Oral Presentation: Lead Speaker: "Next Generation Infant Formula Processing. IDF Parallel Symposia: Concentrated and Dried Milk Products, Dublin, Ireland, April 11-13th, 2016.
4. Fenelon et. al., Invited Speaker. Impact of Protein Aggregation on In-process and Finished Product Stability of Infant Formula. 28/06/2017. ADSA, Pittsburgh, 2017.
5. O'Mahony, J.A., Kelly, A.L., McCarthy, N. M., Fenelon, M.A., 2015. Invited Speaker. Development of Next Generation of Infant Formula Ingredients using Integrated Membrane Filtration. 2nd International Conference on Separation + Drying Technologies for milk and whey. Cologne, March 23-24, Anuga FoodTec.

7. Compiled by: Dr. Mark Fenelon

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