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Re-engineering process technology for the manufacture of infant formula

Key external stakeholders:

Dairy Ingredients and Infant Formula Sector
Dairy Processing Equipment Manufactures
Academic and Research Institutions

Practical implications for stakeholders:

The study aimed to re-engineer process technology for the manufacture of infant milk formula (IMF) by modification of formulation dynamics and use of steam shockwave injector (Maklad-Fluid GmbH) technology:

- A greater understanding of the impact of macronutrient interaction (upon heating) on viscosity during IMF manufacture has been achieved and can be utilised for new formulation development
- High solids infant formulations can be processed using a shockwave steam injector
- IMF concentrate manufactured with a selectivity hydrolysed whey protein ingredient has application in high dry matter processes for reduced energy costs and more sustainable processing

Main results:

The study demonstrated that heat-induced changes in infant formula associated with whey protein (denaturation, viscosity) are not only a function of concentration but are also dependent on interactions between macronutrients. Selectively hydrolysed proteins were shown to be an effective way of reducing viscosity, while maintaining good emulsification capacity, in heat-treated high solids concentrates of 1st age (0 – 6 months) infant formula. A new energy efficient high solids process for manufacture of infant formula with lower viscosity was developed using a shockwave steam injector.

Opportunity / Benefit:

The research provided a platform for understanding the heat-induced changes associated with macro-nutrient interactions in IMF for development of new formulations. In addition, technology has been developed for processing formulations at high solids using novel energy efficient approaches based on new ingredients and processing techniques. The new knowledge / process can be exploited by end users i.e., ingredient manufactures and infant, adult and medical nutritional beverage sectors.

Collaborating Institutions:

University College Cork, UCC

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External collaborators: Prof Yrjo Roos, University College Cork.

1. Project background:

Infant formula (IMF) manufacture plays a significant role in the Irish dairy industry as a large consumer of milk and high quality dairy ingredients. The scale of operation is such that multinational IMF companies involved provide a vital channel to market across large geographical regions for Irish dairy processors and their ingredients. The current project provides latest research in ingredient and process innovation to support and build research capability for both the ingredient and infant formula sector.

2. Questions addressed by the project:

The project aims to address the need to manufacture ingredients / infant formula in a more sustainable and energy efficient way. The project provides new knowledge and mapping techniques on how protein ingredients interact with other nutrients within an infant formula process. The new process is based on a high solids approach whereby manufacturers bypass processing steps such as the evaporator to reduce operation costs.

3. The experimental studies:

The project consisted of three distinct experimental phases:

(i) Studies to understand the consequences of the interactive effects of macro-nutrients (protein, fat and carbohydrate) on hydration of ingredients, lactose solubility, and the subsequent colloidal stability during processing and spray drying

(ii) Investigation of new technological approaches (high shear shockwave injector) for manufacture of infant formula at high total solids content (> 55% solids)

(iii) Development of innovative intermediate protein ingredients to support the process re-engineering objectives of (i) and (ii) above

4. Main results:

- Thermal behaviour of macronutrients (casein, whey, lactose, fat) was studied, in isolation and combination, over a range of concentrations. Addition of phosphocasein to whey protein solutions elevated the denaturation temperature of β-lactoglobulin. Secondary structural changes in whey proteins occurred at higher temperatures in dispersions containing phosphocasein, however, the final extent of viscosity increase was similar to that of whey protein alone. Addition of lactose to whey protein solutions delayed secondary structural changes, increased denaturation and reduced viscosity post-heat treatment.
- A new energy efficient high solids process for manufacture of infant formula was developed using a shockwave steam injector. This study evaluated the use of an inline rotor-stator mixer (Ytron^{TM}) followed by direct steam injection to disperse and heat-treat (110 °C, 3 s) high-solids (60% w/w) formulations, for the production of powdered infant milk formula. Formulations subjected to the steam injection process had significantly ($P<0.05$) lower viscosity compared to control formulations, made using indirect heat treatment, at equivalent solids contents (55% w/w); this was partly attributed to lower levels of whey protein denaturation. Prior to spray drying, volume mean particle size of high-solids steam injection processes was not significantly different ($P>0.05$), 2.04±0.22 than the control, 1.82±0.04 µm. Powders produced using the new process had statistically similar surface free fat content, wettability and dispersibility to the control powder. The study showed that it is possible to produce quality model infant milk formula powders from a high-solids concentrates while considerably reducing process complexity.
- Selectively hydrolysed proteins were shown to be an effective way of reducing viscosity during concentration / heating, while maintaining good emulsification capacity, in heat-treated high solids wet-mixes of a 1st age infant formulations. Heat-treated and homogenised wet-mixes containing hydrolysed ingredients had significantly ($P < 0.05$) lower viscosities than formulations containing non-hydrolysed ingredients. Ingredients in which β-Lactoglobulin was selectivity hydrolysed resulted

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in wet-mixes with lowest viscosity. The reconstitution properties of powders made from selectively hydrolysed wet-mixes were comparable or better than those powders made using intact, non-hydrolysed wet-mixes. Production of low viscosity wet-mixes, using selectively hydrolysed whey proteins, provides a potential mechanism for drying IMF at high dry matter content while maintaining good concentrate atomisation and ensuing powder functionality (flowability, wettability)

- Process mapping techniques have been developed to monitor the behaviour of dairy ingredients in different product formulations. These techniques have been used for troubleshooting in commercial applications.

5. Opportunity/Benefit:

The project provides new understanding and scientific methodologies related to the re-engineering of processes for manufacture of infant formula and also the incorporation of novel protein ingredients into infant formulations. The new knowledge should help ingredients and infant formula companies to continue to develop research capabilities, placing them at the forefront of international research in these areas. A parallel objective is to support development of functional ingredients by Irish ingredient manufacturers for use in infant and adult formulated beverages. Opportunities for the ingredients and infant formula sector include a new process for high solids processing and detailed information on incorporation of new protein ingredients into nutritional beverages. The new process developed in this project is highly exploitable as it can provide companies with the ability to manufacture food/beverage formulations in an energy efficient and sustainable way. In addition, the project has generated many research tools such as predicative models and methodologies for ingredient suppliers to incorporate ingredients into nutritional beverage formulations.

6. Dissemination:

Presentations

- Scientific workshop 19th April 2011: Opportunities to grow the infant milk formula sector, the technical capability within Teagasc and UCC: Title of presentation: Re-Engineering Process Technology for the Manufacture of Infant Formula. Presented by M. A. Fenelon.
- The effect of high velocity steam injection on the colloidal stability of concentrated emulsions for the manufacture of infant formulations. Abstract at 11th International Congress on Engineering and Food, May 22-26 2011, Athens - Greece. Presented by Eoin G. Murphy.
- Invited speaker at International Conference on Functional Dairy Foods (ICFDF 2011). 'New High Solids Process for Infant Formula Manufacture'. Held in Karnal, India 16th to 19th November 2011. Presented by M. A. Fenelon.
- Teagasc Walsh Fellow Seminar, Re-Engineering Infant Formula Manufacture. 2011. Presented by E. G. Murphy.
- Invited speaker at 5th IDF/INRA International Symposium on SDDP. Title of presentation "High solids processing of infant formula using a shockwave steam injector". Venue: St. Malo, France 19th to 21st June 2012. Presented by M. A. Fenelon.
- Lactose solubility in concentrated protein systems measured by refractometry. Poster at Sustainable Dairy Technology Conference, UCC, September 2012. Presented by Eoin G. Murphy.
- Murphy, E.G., and M.A. Fenelon. Relay Research Update: New process technology aimed at nutritional beverage manufacturers, project code FQ013.

Main publications:

1. Murphy, E.G., J.T. Tobin, Y.H. Roos and M.A. Fenelon. 2011. The effect of high velocity steam injection on the colloidal stability of concentrated emulsions for the manufacture of infant formulations. Procedia Food Science 1; 1309-1315
2. Murphy, E.G., J.T. Tobin, Y.H. Roos and M.A. Fenelon. 2013. A high-solids steam injection process for the manufacture of powdered infant milk formula. Dairy Science & Technology Vol 93; Issue 4-5 pp 463-475
3. Murphy, E.G., M.A. Fenelon, Y.H. Roos and S. A. Hogan. 2014. Decoupling Macronutrient Interactions during Heating of Model Infant Milk Formulas. Journal Agricultural & Food Chemistry 62, 10585−10593
4. Murphy, E.G., Y. H. Roos, S. A. Hogan, P. G. Maher, C. G. Flynn, and M. A. Fenelon. 2015. Physical stability of infant milk formula made with selectively hydrolysed whey proteins. International Dairy Journal 40; 39-46

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Popular publications:

T-Research Article - The infant formula sector in Ireland. M Fenelon and Phil Kelly. Volume 5: Number 4. Winter 2010

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