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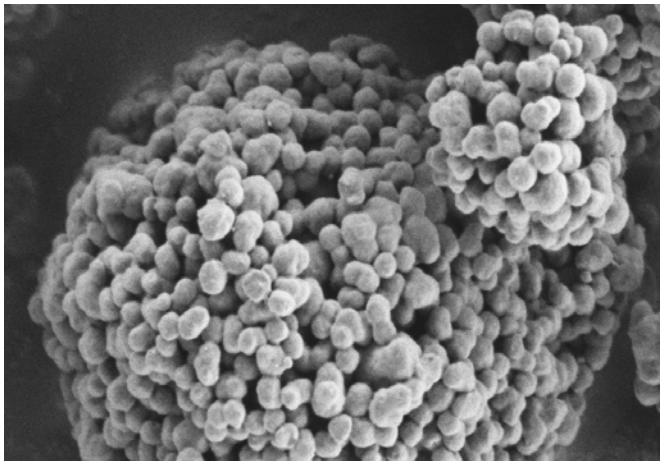
Kinetic trapping: a novel, energy-efficient approach to designing protein-based fat replacers



Scanning electron micrograph of spray dried protein particles

Key external stakeholders:

Dairy & food industry, ingredient manufacturers

Practical implications for stakeholders:

Kinetic trapping is a novel low-energy process for producing nano- and micro-sized protein particles. The technology relies on precise process control of standard food ingredient mixtures using readily available food manufacturing equipment. The kinetic trapping process represents a **new platform technology** for producing size-controlled protein particles in the nano- and micro-size range which was developed and used in this project to produce novel fat replacer ingredients. The benefits of such ingredients when compared to other fat replacers include reduction in capital costs, lower energy demand, enhanced nutrition & functionality and improved sensory quality. Also the use of non-chemically modified ie natural ingredients is significant.

Because of health concerns relating to Olestra, a chemically modified oil-based fat replacer, the demand for protein and polysaccharide based fat replacers is increasing. With the market for fat-replacers globally expected to be **280,100 metric tons** with a compound annual growth rate of **6.03%** between 2011 and 2015 (Global Industry Analysts), the availability of such a novel fat replacer ingredient has significant implications for the dairy and food industry and specifically ingredient manufacturers.

Main results:

- A new whey protein-based fat replacer ingredient was produced using kinetic trapping
- The novel fat replacer ingredient was produced in dried form with and without konjac gum (soluble dietary fibre) and had creamy texture when added to ice cream. It was whey protein particles size-optimised (100 nm – 10 μm) and calcium enriched (~100mM Ca+)
- Conditions for production were optimized and ingredients produced in spray dried form

Opportunity / Benefit:

This novel platform technology represents a significant advancement in production of fat replacer ingredients and a patent application is currently being filed to protect the novel process and resulting unique products. Teagasc is keen to engage with dairy and food industry and ingredient manufacturers to consider collaborative opportunities as a means of optimizing, validating and ultimately commercialising this technology.

Collaborating Institutions:

N/A

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External collaborators: N/A

1. Project background:

Energy costs are rising and proposed carbon taxes will place a further burden on all energy-intensive food processing operations. Commercial ingredient products that fall into this category are fat replacers such as Simplesse® and Dairy-Lo® which are based on microparticulated whey protein (MWP). These ingredients are widely used in a variety of food products marketed as "low fat", a market worth an estimated at $30bn. The current technology for producing MWP is very energy intensive with high capital equipment costs. The unique feature of this project is that we can form a calcium-rich fat replacer, similar to commercial MWP but with a much reduced energy and equipment cost. We propose to create novel whey-based structures in the nano- and micro- size range (100 nm – 10 um) by exploiting the natural tendency of certain protein-polysaccharide mixtures to phase-separate. In doing so, we will develop a ***process*** that is effectively a new platform technology AND a ***product*** with potential as a fat replacer, which is calcium-fortified and fibre-enhanced. Phase separation occurs when two incompatible solutions such as proteins and certain polysaccharides are mixed together. By adjusting the relative concentrations of two ingredients, we can confine one phase into a progressively smaller volume, a process called "kinetic trapping". Whilst this phenomenon has been studied scientifically, kinetic trapping has yet to be commercially exploited. Controlling phase separation to produce defined structures at a commercial scale and with consistent quality requires a highly specific set of conditions and significant technology development. Our solution is to *reduce energy costs by eliminating certain processing steps such high pressure homogenization and high shear*. We will also *eliminate high capital costs* as we will be exploiting the natural tendency of gums and proteins to separate by carefully controlling the temperature and balancing the concentration of raw materials by employing readily available basic dairy processing equipment. The new ingredient will have a specified particle size and shape and contain soluble fibre and bio-absorbable calcium, thus giving it a competitive edge over existing fat replacers.

2. Questions addressed by the project:

The kinetic trapping concept matches the following food industry drivers:

- Can Teagasc develop a new platform technology based on kinetic trapping?
- Can kinetic trapping be used to create a new protein-based fat replacer in liquid or dried form?

3. The experimental studies:

Figure 1 summarizes the kinetic trapping process:

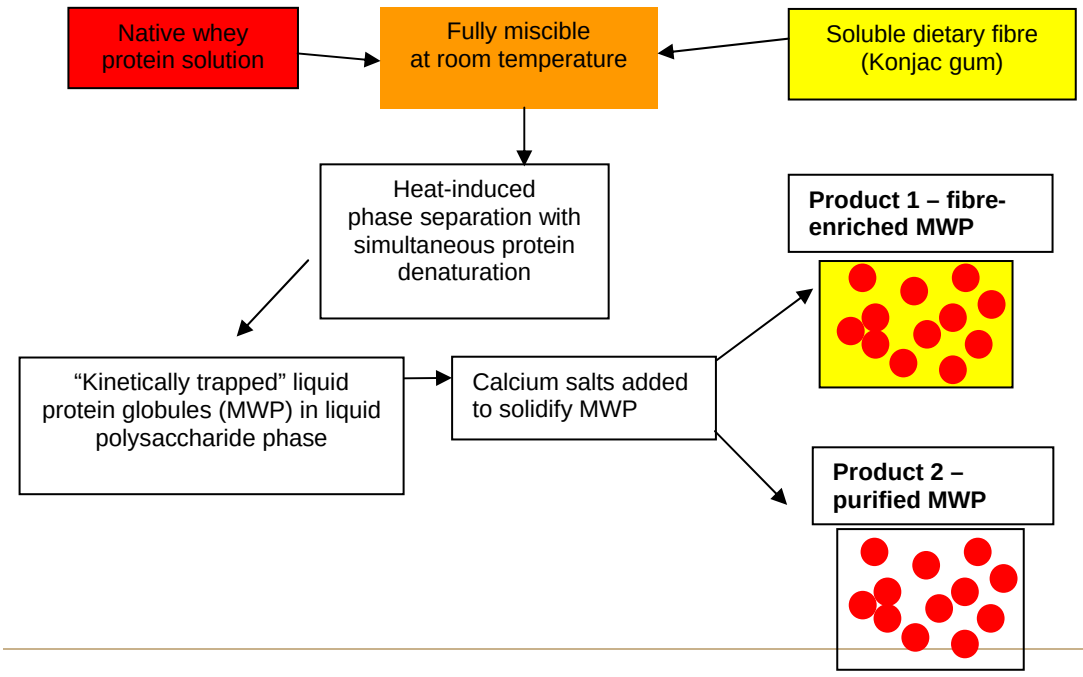

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Figure 1 – Schematic of the kinetic trapping process. The size of particles can be controlled by adjusting relative concentrations of protein and polysaccharide.

- Establish the major parameters affecting particle size by creating phase diagrams of the protein-polysaccharide mixtures. Phase separation will be monitored in real time by light and confocal microscopy and will be used together with visual assessment of bulk phase separation Both whey protein isolate (>98% protein) and whey protein concentrates (WPC, 40% protein, a lactose-rich but cheaper ingredient) will be evaluated as the source of particles.
- Optimize formulations and conditions to produce larger volumes (up to ~5 litres) of stable particles with defined size ranges. Size distributions will be monitored by laser scattering and light and confocal microscopy.
- Separate particles from the Konjac polysaccharide phase using a combination of dilution, sedimentation and mild centrifugation.
- Both purified and Konjac-rich products will be dried by freeze- and spray-drying to form a crude powdered ingredient.
- Informal sensory evaluation of test products including yoghurt, mayonnaise low fat spreads and ice cream.

4. Main results:

- Conditions were optimised for size-controlled production of kinetically trapped whey particles
- Particles produced were spherical, stable and in the size range 100 nanometers to 3 microns (Fig 2).
- Pilot-scale quantities (5l liquid/1Kg freeze- or spray-dried) were sucessfully produced.
- Test products (low fat spread, mayonnaise, yoghurt, ice cream) were produced containing the new fat replacer
- The new fat replacer ingredient was particularly effective when added to ice cream and produced a **creamier** product than that containing similar levels of fat.
- The process produced more controlled and regularly-shaped particles compared to existing high-shear technology.
- Dried ingredients contained ~ 100mM calcium

5. Opportunity/Benefit:

The kinetic trapping process has geat potential as a new platform technology for producing size controlled protein particles in the nano- and micro-size range using basic food processing equipment and with lower energy costs. The fat replacer product produced was very effective when added to ice cream and actually produced a creamier product than that containing similar levels of fat. This fat replacer ingredient had the further advantage of being calcium enriched. Pilot-scale quantities (5l as liquid or 1Kg dried) were sucessfully produced and further scale-up is necessary for full commercialisation. This work employed a batch process technique sucessfully on a pilot scale although further work to develop a continuous process would further improve efficiencies. Further work is also required to produce a more heat stable product. This study concentrated on producing protein particles from purified whey protein isolate as a fat replacer; however, the kinetic trapping process could be used to encapsulate a wide range of bioactive compounds including trace elements, antioxidants and vitamins in addition to food colours/flavours. Costs could be further reduced by using whey concentrate or even liquid sweet/acid whey as the protein source.

6. Dissemination:

An invention disclosure report has been sent to a patent attorney for evaluation as a patent. Discussions with potential industry stakeholders are ongoing.

7. Compiled by: Dr Mark A.E. Auty

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