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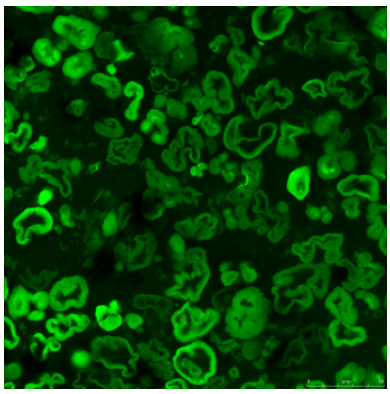
In-situ starch modification in food formulations using protein



Key external stakeholders:

Dairy ingredients and Starch Industry
Prepared foods and Nutritional beverage manufacturers
Academic and Research Institutions

Practical implications for stakeholders:

The objective was to study the behaviour of mixed protein-starch systems with a view to understanding protein starch interactions as a possible mechanism for in-situ alternation to starch functionality.

- Structure of the starch pastes can be altered by the presence of the proteins (intact or hydrolysed).
- Gelatinisation temperature of starch and denaturation temperature of proteins can be synergistically used to create new food structures.
- A novel rheological reactor cell can be used for simultaneous measurement of viscosity and in-vitro digestion of protein-starch mixtures.

Main results:

- The gelatinisation temperature of potato starch is lower than the temperature for whey protein denaturation / aggregation; thus in mixtures of potato starch and whey proteins, starch granules swell before denaturation / aggregation of the protein occurs, resulting in a reduction in viscosity and change in functionality.
- Hydrolysed whey protein resulted in a reduction in potato starch granule swelling during heating.
- Different blends of dairy proteins were evaluated in the presence of pre-gelatinised starch for changes in viscosity during in-vitro digestion using a newly designed rheological reactor cell. The study found that a blend of casein and α-lactalbumin may provide viscosity increase and release of peptides / amino acids for use in commercial applications, e.g., anti-reflux infant formula.

Opportunity / Benefit:

New knowledge on the effect of intact and hydrolysed dairy proteins on the pasting properties of waxy maize and potato starch can be utilised for development of structure in beverage and prepared food applications. The methodologies developed in this study can be used to evaluate ingredients under simulated (in-vitro) gastrointestinal digestion for use in development of functional, medical or therapeutic beverages.

Collaborating Institutions:

University College Cork, UCC

Contact Mark Fenelon Email: mark.fenelon@teagasc.ie

Teagasc project team: Dr. Mark Fenelon (PI)
Brid Treacy
Dr. Valérie Chaurin
Dr. Joseph Kehoe

External collaborators: Prof Edwin Morris
Prof Alan Kelly
Dr Seamus O Mahony

1. Project background:

Experimental investigations at Teagasc (FIRM project 06RDTMFRC445) have shown that the individual caseins (β-casein and α-casein) have the ability to alter pasting behavior of waxy maize starch, however, the exact mechanism for this altered behavior has not been fully elucidated. While research has been carried out independently on both protein and starch the effect of protein and in particular, high value added protein ingredients on the physicochemical properties of starch have not been extensively studied. This project describes findings from model systems to investigate dairy protein - starch interactions for use in the development of new ingredients with application in formulated foods, imitation cheese and nutritional beverages.

2. Questions addressed by the project:

In many food applications starch is gelatinised in the presence of proteins and other non-starch carbohydrates. Consequently, there is a need for mechanistic studies on starch – dairy protein interaction to support the extensive use of these ingredients in food products. The project addresses this gap in knowledge and has resulted in the establishment of new rheological, thermal and microscopic methodologies for the investigation of protein-starch mixtures including a novel rheological reactor cell developed during the FIRM funded project for simultaneous measurement of viscosity and digestion.

3. The experimental studies:

The project comprised these key tasks:

- Investigation of the effect of dairy proteins on the gelatinisation behavior of starch (waxy maize and potato).
- Evaluation of the microscopic, rheological, thermal and dynamic behavior of selected protein/starch mixtures with the aim of understanding the effect that dairy proteins have on starch functionality
- The effect of various conditions of pH, salt and protein concentration on starch functionality was investigated.
- In-Vitro characterisation of viscosity development and digestion kinetics of protein-starch mixtures using a novel rheological reactor cell simulating the effect of viscosity on digestion kinetics
- Effect of hydrolysed whey proteins on starch pasting properties
- Microscopic investigations using imaging techniques that involve shear and stationary measurements.

4. Main Results:

The gelatinisation temperature of potato starch is lower than the temperature for whey protein denaturation / aggregation. As a result, the starch can swell before the whey protein has denatured / aggregated; the net effect is a reduction in peak viscosity and change in functionality. The aggregation of the intact whey proteins during the starch gelatinisation process has a significant effect on the viscosity of the pastes formed. However, when the starch is gelatinised before the whey protein aggregation occurs, as is the case with potato starch, the pasting curve is significantly modified when compared to waxy maize where its gelatinization temperature is similar to the denaturation temperature of the whey proteins. The study demonstrates a mechanism whereby the functionality of food systems can be altered by selection of starches with gelatinsation temperatures differing from the denaturation temperature of the protein system used.

The addition of casein increased the onset temperature of starch gelatinsation; this was observed in rheological and differential scanning callorimetry studies. The addition of whey protein isolate to potato starch reduced peak viscosity. The peak viscosity of the waxy maize starch increased when the casein was added. The final viscosity of the waxy maize starch pastes was not altered by the presence of the hydrolysates but whey protein isolate and pre-aggregated WPI increased the final viscosity significantly.

Contact Mark Fenelon Email: mark.fenelon@teagasc.ie

The functionality of starch was studied using a prototype rheological reactor cell. This cell was attached to a controlled-stress rheometer to measure rheological properties of model infant formula emulsions containing pre-gelatinised starch under simulated gastro-intestinal digestion in-vitro. The cell can evaluate viscosity changes in complex multi-phase food systems under different physiological conditions (i.e., ionic strength, shear, pH and hydrolysis by peptic or amylolytic enzymes). It was demonstrated that, while starch was a critical component, protein type also affected viscosity development during acidification. The highest viscosity was achieved with a phosphocasein / starch mixture, followed by β-lactoglobulin / starch and then α-lactalbumin / starch mixture. Of the protein mixtures analysed, a combination of casein and α-lactalbumin provided viscosity increase and digestion kinetics, i.e., release of peptides / amino acids that may have application in special purpose beverages, e.g., anti-reflux infant formulae. The study also highlighted the importance of pH and protein buffering during digestion, as it influences the activity of pepsin and thus breakdown of the casein matrix, with subsequently influences the ability of starch to contribute to viscosity development.

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5. Opportunity/Benefit:

New techniques / methodologies have been developed at Teagasc and UCC, including rheological, microstructural and thermal, for elucidating the role of protein in modulation of starch paste functionality. These techniques can be applied to any combination of starch and protein for development of prototype food structures for industry. The findings from the study demonstrate the role of protein in modulating viscosity in the presence of starch on acidification during simulated digestion for application in nutritional, medical and therapeutic foods.

6. Dissemination:

Presentations

Abstract / Poster presented at International Symposium on Food Rheology and Structure - ISFRS 2009. Latest research on microstructure of hydrocolloids and starch. Influence of α- and β-casein on the gelatinisation and subsequent amylolytic digestion of waxy maize starch. Valérie Chaurin & Mark A. Fenelon

Abstract / poster presented at XVIII INTERNATIONAL STARCH CONVENTION CRACOW-MOSCOW, Cracow, Poland June 21-25, 2010; Measurement of viscosity of an anti-reflux infant formula in-vitro using a rheological reactor cell, Brid Treacy, Anthony P. Kett, Valérie Chaurin, Alan L. Kelly, Mark A. Fenelon

Presentation at the 4th working group / conference: Improving health properties of food by sharing our knowledge on the digestive process (INFOGEST) 2014. Presentation Title: 'A mass spectrometry study of the peptides produced during the in vivo digestion of α-Lactalbumin' - presented in conjunction with project FIRM 08/RD/TMFRC/650 BioA-Lac, finished 28 February 2013. The work involved the study of peptides produced from whey proteins (as produced in the current study) during digestion. Joseph Kehoe

Relay Update: RU –FI014-1-DT: Modifying starch functionality in food formulations using proteins

Relay Update: RU –FI014-2-DT: Starch / protein interactions influence digestion in the stomach

Main publications:

Influence of milk proteins on the pasting behavior and microstructural characteristics of waxy maize starch. 2013. Anthony P. Kett, Valérie Chaurin, Sinead M. Fitzsimons, Edwin R. Morris, James A. O'Mahony, Mark A. Fenelon. Food Hydrocolloids 30: 661-67

MSc Thesis (Brid Treacy) entitled: Starch and Dairy Protein Interactions in Anti-Reflux Infant Formula

7. Compiled by: Mark Fenelon

Contact Mark Fenelon Email: mark.fenelon@teagasc.ie