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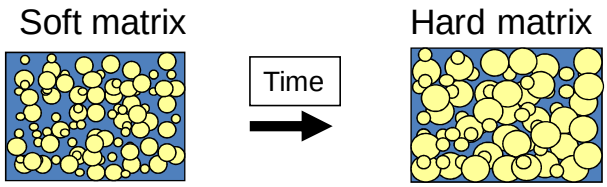
Water activity control and texture stabilisation of high protein snack bars



Key external stakeholders:

Dairy industry manufacturers of milk powders and dairy ingredients; formulators of nutritional snack products

Practical implications for stakeholders:

High protein snack are particularly susceptible to hardening during storage. As a critically important market outlet for functional milk protein ingredients, it is imperative to have an improved understanding of the ingredient interactions that may be contributing to this product defect.

- The outcomes of this research study now reveals a complex science occurring in a matrix of highly concentrated ingredients dispersed in an intermediate moisture environment
- A database of information resulting from this research enables better choices of ingredients to be made in order to ensure improved shelf-life, and which can be utilised by ingredient manufacturers' support teams during engagement with their respective food formulator clients
- Use of specialised analytical tools provide insights into changes at the macro- and micro-structural level

Main results:

- The relative susceptibility to hardening of bar formulations featuring a range of dairy proteins was established under standardised conditions.
- Minimising water activity differences between liquid and solid components provides a means of controlling or delaying textural change.
- When appropriately directed, moderate levels of whey protein hydrolysis was highly effective in retarding bar hardening with time. Though not always the case e.g. hydrolysed casein, it appears that proteolytic effects at molecular or mesostructural levels may not be sufficient to significantly affect macrostructure especially when molecular jamming has yielded a highly confined, protein continuum.

Opportunity / Benefit:

A platform for testing ingredients, particularly proteins, in model protein bars is available. Expert knowledge and specialised analytical services are available to characterise performance and diagnose changes during the course of shelf life tests.

Collaborating Institutions:

University College Cork

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Teagasc project team: Dr. Phil Kelly
Dr. Sean Hogan
External collaborators: Prof. Yrjo Roos (UCC)
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1. Project background:

The combined market for bars (sports/nutrition/snacks) in the USA is valued at $2 billion plus, having increased by a total of 169% since 1999, and is continuing to grow at the rate of 1-2% on an annual basis (Reed, 2007). With the advent of protein fortification, these healthy bars appeal to consumers engaged in sport, dieting and as meal replacements. It is estimated that over 10,000 tonnes protein ingredients are used in bar formulations to supply the US market alone, most of it supplied as milk protein by dairy companies.

A relatively simple process is involved in bar production. However, in the relatively low moisture environment of bars, the proteins present attract moisture and may exert considerable influence over bar texture. The result is that over time the bars may become progressively harder with increasing shelf life. Furthermore, marketing personnel emphasise that a high degree of innovation is required to help sustain future annual growth rates in bar consumption, and also to step up to even healthier standards through compositional improvements.

2. Questions addressed by the project:

The project was singularly focussed on addressing a key scientific issue e.g. what are the factors underlying textural changes in high protein bars during storage that ultimately result in hardness. Hence, the experimental studies were aimed at generating an improved understanding of the intermolecular interactions taking place in the concentrated intermediate moisture environment that constitutes the matrix of such high protein bars.

3. The experimental studies:

Methodologies were developed for the preparation of high protein bars, and protocols for accelerated storage trials were adopted in order to assess the effects of ingredient mixing, moulding and extrusion on the development of hardness in bars.

In depth analysis of formulated bars was undertaken using the analytical capability e.g. DVS analyser and NFIC equipment for food structure imaging. Ingredient composition and powder property manipulation was accomplished using Moorepark's scale-up facilities available i.e. BFE and MTL to prepare experimentally-dried ingredients for incorporation into bars.

The study commenced with an appraisal of a range of commercial high protein bars sourced in the USA according to their gross composition and ingredient classification. Analytical test protocols established to determine physico-chemical changes in bars with time included determination of moisture sorption isotherms (Teagasc and UCC), time-dependent changes in bar hardness by texture analyser (Teagasc and UCC), water activity (UCC), confocal laser scanning microscopy (CLSM) (Teagasc), differential scanning calorimetry (UCC) and changes in protein by reversed-phase HPLC (Teagasc). Time-dependent, protein-induced hardening was assessed as a function of composition during the course of elevated temperature storage.

The relationships between length scales and macrostructure in model, protein bars were investigated through in situ proteolysis of whey and caseinate proteins. Texture analysis, small angle oscillatory rheology, electrophoresis, gel permeation chromatography and infra-red spectroscopy were used to examine structural hierarchies via enzymatic deconstruction.

4. Main results:

The relative susceptibility to hardening of bar formulations featuring a range of dairy proteins was established under standardised conditions. However, it is cautioned that such comparisons are highly system dependent. Co-solvents were examined in both simple, binary systems and in model bar systems in order to elucidate this system dependency. When comparing the effects of a wide range of milk protein

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powders on textural change in model, high protein bars, solidification behaviour of powders was dependent on concentration (or volume) in a type-dependent manner and that protein powders have different windows of concentrations over which jamming and subsequent hardening occurs.

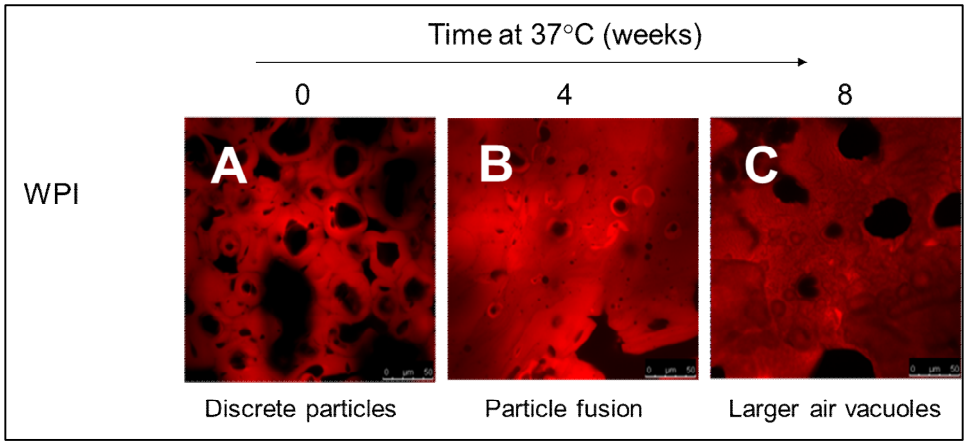

Figure 1. Microstructural changes occurring during accelerated storage testing at 37°C of bar formulations containing whey protein isolate (WPI)

- A wide range of protein powder physicochemical characteristics were correlated against textural changes in bars over time.
- Minimising water activity differences between liquid and solid components provides a means of controlling or delaying textural change.
- FT-IR measurements showed that water or solvent-induced plasticisation of protein powders in bar matrices was sufficient for protein-ingredient interactions to occur at a molecular level.
- Hardening in mixed protein bars resulted in a broadly linear response to ratio inclusion.
- Confocal scanning laser microscopy (CSLM) techniques were developed that allowed good quality imaging of physical changes in protein bars during storage. This led to a significant improvement on the fundamental understanding of the behaviour of dairy proteins and their interactions in highly-concentrated systems.
- Functionality differences in protein bars incorporating co-dried (CD) and dry-blended (DB) protein powders reflected structural and surface area effects attributable to the co-drying process. Physical interactions occurring between protein types during spray drying also impact on the functional characteristics of the resultant powders.

Effect of protein hydrolysis on hardening

The extent and effects of enzymatic hydrolysis differed between protein types. Only limited proteolysis was required to slow the extent of hardening in whey protein containing bars. In contrast, more extensive cleavage of calcium caseinate proteins caused greater hardening. It is possible that cleavage of high molecular weight calcium caseinate proteins produced altered functionalities, similar, in effect, to sodium caseinate, which contributes to extensive bar hardening. The findings suggest that proteolytic effects at molecular or mesostructural levels may not be sufficient to significantly affect macrostructure, particularly where the extent of jamming has yielded a highly confined, protein continuum.

Packing behavior of powder particles

Four whey powders, including three hydrolysates, were evaluated to determine the effects of particle interactions, moisture uptake, glass-transition temperature and deformation on structure formation, in particular the nature of the liquid-solid transition and the development of ‘solidity’. Intact whey protein powder dispersions behaved as normally distributed, non-interacting spheres. By contrast, hydrolysate-based systems behaved as weakly, attractive colloidal particles, with a greater propensity for self-organisation. Frequency dependent approaches to the liquid-solid transition also differed as a function of hydrolysis. The study provides insight, from a fundamental rheological perspective, on the physical causes for lower susceptibility to hardening observed in hydrolysed powders. Such findings have potentially useful implications for the analysis of structure in particulate food systems.

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Long term ambient storage trials

Long term ambient temperature storage studies of model whey protein bars, including whey protein hydrolysates, was carried out over a period of 18 months. Bars, produced at a relatively low volume fraction, did not demonstrate physical destabilisation, such as phase separation and remained stable with respect to hardening. Colour changes, visual appearance and overall sensory quality appeared acceptable. Equivalent samples, prepared at higher volume fraction underwent more extensive hardening but remained within estimated consumer acceptability limits. This work reinforced the need to establish the critical concentration dependence of protein powders in viscous continuous food matrices.

5. Opportunity/Benefit:

The resulting database of information enables better choices of ingredients to be made in order to ensure improved shelf-life, and can be utilised by Irish dairy company technical support teams during engagement with their respective clients. Background expertise in applying food microstructure imaging and other specialised analytical tools for this type of application can be made available.

6. Dissemination:

Informal communication and verbal updates were provided during the course of engagement with technical representatives of the dairy companies with specific ingredient manufacturing interest for this application

A presentation entitled 'Optimising the shelf-life of high protein snack bars' was given by Sean Hogan Teagasc, Moorepark at RELAY Workshop 'Commercial opportunities for aggregate cereals and snack companies', 16th November 2010, UCC.

An in-house presentation was made to research staff and students at TRFC, Moorepark, by Sean Hogan entitled 'Influence of Co-dried Protein Powders on Textural Change in High-protein Bars', 14th March, 2012.

An in-house presentation was made to research staff and students at TRFC, Moorepark, by Sean Hogan entitled 'Soft matter characterisation of whey-based protein bars', 16th April, 2013.

Main publications:

Hogan, S.A., Chaurin, V., O'Kennedy, B.T. and Kelly, P.M. (2012). 'Influence of dairy proteins on textural change in high-protein bars'. *International Dairy Journal*, 26, 58 - 65.

Popular publications:

Kelly, P.M & Hogan, S. A. (2012) Technological adaptation of functional ingredients to improve texture of dairy-based energy bars. Oral presentation given at the IDF World Dairy Summit – Dairy Science & Technology Conference, 8th Nov 2012. Cape Town, South Africa

Hogan, S.A., O'Kennedy, B.T., Huppertz, T. and Kelly, P.M Influences of co-dried, milk proteins on structural stability of high-protein bars. 5th International Symposium on Spray Dried Dairy Products, 19-21st June 2012, St. Malo. (Oral presentation)

Hogan, S., O'Kennedy, B., and Kelly, P. Influence of dairy proteins on textural change in high-protein snack bars. Flavour and Texture: Innovations in Dairy, 7th NIZO Dairy Conference, Papendal, The Netherlands. 21-23 September, 2011. (Oral presentation).

Kelly, P.M., O'Kennedy, B.T., Hogan, S.A., Chaurin V. and Roos, Y.H. 'Development of model systems to study select microstructure and chemical changes in high protein snack bars'. IDF Symposium on Microstructure of Dairy Products, 9-11th June, 2010, Tromso, Norway. (Poster and Oral presentation).

Hogan, S.A., Chaurin, V., O'Kennedy, B.T. and Kelly, P.M. 'Influence of milk proteins on hardness development in high-protein, solid food matrices'. European Federation of Food Science & Technology (EFFoST), 10-12th November, 2010. Dublin, Ireland. (Poster presentation).

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