Technology Updates — Food

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Product reformulation and *in vitro* testing of low glycaemic breads

Key external stakeholders:
Food ingredients companies, bakeries, millers, food manufacturers, consumers

Practical implications for stakeholders:
Significant findings of the research conducted in this project include detailed information on a range of low GI grains and fibres/flours, and their application in novel low glycaemic index (GI) bread formulations. How these fibres behave under mixing, proofing and baking conditions has been assessed, and their shelf-life (texture) and sensory properties have been established. This project has led to the development of new, high quality, low GI bread formulations.

A large number of new bread recipes containing a range of different low GI ingredients have now been formulated, and information is now available relating to the optimal water addition and mixing characteristics, and expected bread, shelf life and sensory properties of the products. Both quantitative and qualitative sensory trials have shown that low GI flours may be introduced into a wheat bread formulation without significantly negating the sensory properties of the resulting breads.

Main results:
A summary of the main research outcomes is as follows:
- Compositional characterisation of low GI grains.
- Flour blending and baking methods for new low GI bread formulations.
- Sensory properties of new low GI formulations.
- Fundamental rheology, baking and molecular aspects of the new formulations.
- An *in vitro* method for calculating the glycaemic index of the formulations.
- Scientific and technical publications describing the research methods and how the results and formulations may be utilised by an end-user.

Opportunity / Benefit:
Advice, consultancy work and/or technical services, relating to the methods and/or formulations developed during this project can be provided at the Teagasc Food Research Centre, Ashtown, in particular in the areas of cereal chemistry, dough rheology and baking processes.

Collaborating Institutions:
UCC/Teagasc Alliance

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1. Project background:

The regular consumption of foods exhibiting a high glycaemic index (GI) is associated with the development of diseases such as type 2 diabetes, certain forms of cancer and an increased risk of cardiovascular diseases and obesity. Therefore the intake of low GI foods will benefit weight regulation and be favourable in the treatment of obesity.

Bread is one of the most popular dietary carbohydrate sources. It is consumed worldwide by people of all ages, and can be eaten at numerous times during the day. However, the starch present in most breads is rapidly digested and absorbed in the small intestine producing undesirably high blood-glucose and insulin levels after a meal. Current diet concerns and health trends have seen continually rising demands by consumers for lower glycaemic impact foods.

The rationale for this research was to formulate bread which will achieve a nutritious, slowly-digestible status, rich in dietary fibre/resistant starch and functional ingredients, to diversify the range of available foods with a low glycaemic response to meet the rising demands of consumers.

2. Questions addressed by the project:

- Can a low GI bread be formulated to the same baking standard to that of wheat bread?
- What are the most appropriate ingredients to use for low GI breads?

3. The experimental studies:

The methodologies which were used in this project may be classified into different sections; milling, flour and dough analysis, bread and baking analysis, sensory analysis, compositional analysis and finally in vitro glycaemic analysis. Where the techniques for milling, flour, bread and sensory analysis may not have been novel, they were applied in a novel way in this project to determine the effects of new milled fractions and new blends of flours on the different flour and baking characteristics.

- **Milling**

The Bühler mill was used to fractionate grains into their different constituents (endosperm flour, bran, germ and middlings), and the Cemotec mill was used to mill the grains into wholegrain flour. Grains which were milled during the project include oats, buckwheat, amaranth, quinoa and barley.

- **Flour and dough analysis**

The Farinograph was used to assess the optimum water absorption capacity of the different blends of flours. Other properties of the flours which were analysed include optimal mixing time, dough development time, dough stability. The Extensograph was used for large scale extensional rheology of the resulting doughs from the flour blends, i.e. to assess extensibility, resistance to extension. The Rheofermentometer assessed a number of different proofing/fermentation properties of the yeasted doughs, in particular the total volume of dough, carbon dioxide produced from the dough and retained within the dough, retention coefficients of the doughs. The Rheometer measured fundamental rheological deformation of all of the doughs, i.e. how the viscoelastic and flow properties of the doughs behaved when subjected to oscillation, stresses and strains. Scanning electron microscopy and confocal microscopy were used to assess the microstructure of the low GI flours, doughs and breads.

- **Bread and baking analysis**

The following methods/techniques were used to assess the baking and bread properties of the novel formulations: CIE Colour (L*, a* and b*) of the crust and crumb, loaf specific volume, % bake loss, texture profile analysis/staling of the crumb.

- **Bioprocessing**

A wide range of lactic acid bacteria (starter cultures), as well as mixed strain starter culture were screened in model bread systems. Their growth in sourdough, as well as their effects on dough pH, acid production, sourdough fermentation time, dough proofing and yeast addition was monitored. Their effect on the preferment on the baked breads was also analysed using some of the methods described above. Response surface methodology was used to optimise the processing parameters.

- **Sensory analysis**

Two distinct methods of sensory analysis were performed during this project; quantitative sensory analysis (taste panels) and qualitative sensory analysis (focus groups).

- **Compositional analysis**

The following properties of the milled grains were assessed: Protein, fat, starch, dietary fibre and ash.

- **Glycaemic analysis**

Methods for starch hydrolysis analysis and glycaemic were set up to assess breads of different GI ranges. The bread samples were subjected to an in vitro enzymatic starch digestion over a 3 hr period and dialysates were analysed for total dialysable sugars (fructose, glucose, maltose and sucrose) with a reversed-phase high-performance liquid chromatographic (HPLC) method. The separation was carried out on carbohydrate column using refractive index detection. A non-linear model was applied to describe the kinetics of starch hydrolysis and estimate the area under the curve for bread samples. Through a series of calculations, the estimated GI of the samples could be determined.

4. Main results:

- **Milling and partial starch replacement of wheat flour with alternative high fibre milled cereal fractions in bread.**

Milled pseudocereal flours were assessed in dough and breads on a substitution basis with wheat flour. Initial empirical rheological tests showed that these doughs required longer mixing times and had increased dough development times (most likely due to the higher fibre present), once the optimal hydration was calculated and added. Doughs containing amaranth and quinoa revealed properties which were most similar to those of wheat dough. All pseudocereal-containing breads were characterised with darker crusts (due to the presence of the wholegrain fractions). Additions of 40% were found to be above optimal, as the staling rate for these breads was significantly more rapid than the control bread. At 10% inclusion levels, however (which would still represent a significant decrease in GI), breads containing amaranth flour showed similar baking properties to the wheat control (texture, staling, crumb grain etc.). Those with buckwheat and quinoa were not as high in baking quality, which was a reflection of the high fibre content in each of these flours.

A range of other low GI commercially milled factions were also studied: oat bran, inulin, oat beta glucan (OBG) and apple fibre. Additionally, other low GI commercially available ingredients, including rice bran, chickpea flour, maize bran, pea fibre, inulin, low lactose dairy flours and resistant starch were also assessed. As expected, the inclusion of these fibres in a wheat dough formulation resulted in a significant increase in the water absorption of the doughs, and even with the adjusted hydration levels, all breads, apart from those containing oat bran had lower volumes than the wheat control. Texture profiling of the breads also showed that the oat bran breads (10%, 20%), and inulin (10%, 20%) staled at a comparable rate to the control. Oscillation and complex viscosity analyses (i.e. small deformation rheological tests) were undertaken for each of the doughs. An increased elastic modulus (G') was observed for all doughs containing the low GI fibres, and results correlated well with the large deformation tests which were also carried out on the doughs. Despite the correction for optimal dough hydration levels, less viscous doughs were found for those containing the beta glucan and apple fibres. Fermentation trials on these dough showed slightly different proofing patterns over the 3 hour test, where the dough development progressed to a similar end point to the control dough. Doughs containing the low GI ingredients did show a loss of carbon dioxide, due to the network being interfered with by the fibre fragments, therefore decreasing the capacity of the doughs to retain gases while fermenting. In general, breads containing oat flours showed excellent baking properties, and high sensory scores also reflected this.

Resistant starch, when used at a 5% replacement level, resulted in a crumb structure that had an increased number of cells/mm^2 when compared with the wheat control, indicating a fine crumb structure. Sensory panellists rated all of the test breads as being acceptable for crumb visual appearance, flavour, texture and overall assessment on a 5cm hedonic scale. Lowest scores were generally given for those formulations containing rice bran. The low GI breads were extremely positively accepted by focus group participants, in particular those containing 20% resistant starch and 10% resistant starch+15% maize flour. Hydrolysis and glycaemic testing showed that of all the breads tested, formulations containing 10% rice+5% maize, 10%

chickpea and 20% maize decreased the GI from 71.12 for the wheat control to 64.07, 63.66 and 59.35 respectively.

- **Impact of Bio-processing on the GI of cereal products.**

A wide range of lactic acid starters, single strain and mixed strain were assessed for their suitability in high fibre/low GI breads. Strains which showed the ability to produce extra cellular enzymes and antimicrobial properties were selected for more in depth study. The presence of LAB increased the water absorptions of the low GI bread formulations, and once the optimal was calculated and executed, the inclusion of LAB stains served to significantly improve the loaf volume and staling characteristics of the breads.

The impact of these lactic acid bacteria on the ultrastructure of low GI bread formulations was investigated. The laser scanning microscope was used and the staining procedure optimised. The pre-ferments (sourdough), dough containing 20 % sourdough and sourdough bread were analysed and compared to a control which contained no LAB. It was shown that the addition of LAB significantly changed the ultrastructure of the protein to a coarser and somewhat amorphous structure. These changes were detected in the preferment and the dough (containing 20 % sourdough), but to a lesser extent in the bread. Rheological studies which were carried out on these doughs revealed that the low GI bread which contained sourdough had lower complex modulus values than both the high GI and medium GI bread, most likely due to increased proteolytic activity of indigenous wheat enzymes caused as a result of a drop in the ph during sourdough fermentation. Significant improvements in the staling characteristics of low GI breads containing sourdough were observed.

- **Development of an in vitro test.**

Hydrolysis curves were generated from a 3hr starch digestion which mimicked that of an in-vivo digestion. The area under the resulting hydrolysis curves, along with the total available carbohydrate, which were calculated from the sum of total starch and free sugars (determined using a total starch assay and HPLC analysis using refractive index detection, respectively), were used to determine the hydrolysis index (HI) of the breads. Equations were developed and used to convert the HI value into estimated glycemic indices (eGI).

5. Opportunity / Benefit:

Advice, consultancy work and/or technical services can now be provided at Ashtown in the area of milling, cereal chemistry, dough rheology and baking processes through Teagasc's fee-paying service. Following the completion of this project, confidential commercial trials are currently ongoing with a number of bakeries.

6. Dissemination:

Oral presentations communicating the results of this project have been made at a number of conferences and workshops, including the American Association of Cereal Chemists International conference. Technical reports relating to this work can be downloaded at www.relayresearch.ie

Main publications:

- Burton P., Monro J.Aa, Alvarez-Jubete L., and Gallagher E. (2011). Glycemic impact and health: new horizons in white bread formulations. *Critical Reviews in Food Science and Nutrition*, 51(10):965-82.
- Patras, A. Oomah, D. and Gallagher, E. (2011). High fibre by-product utilization. Chapter 12. In: *Pulse Foods: Quality, Technology and Nutritional Applications*. Published by Elsevier. ISBN 13:978-0-12-382018-1
- Nunes HB, Moore M, Ryan LAM and Arendt EK (2010). Impact of low lactose dairy powders on the quality and rheological properties of breads and batters. *European Journal of Food Research and Technology*, 229: 31-41

Popular publications:

- Gallagher, E. (2009). Better breads for better health. Ashtown Food Innovator, (5): 3.
- Gallagher, E. (2007). Some new projects to be added to the mix! Presentation at a cereal workshop ("A Bakers Dozen") hosted at Ashtown.

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