Project number: 5412
Funding source: DAFF (04/R&D/TN/249)
Date: June, 2011
Project dates: Jul 2005 – Jan 2009

New and rapid methods for evaluating the baking characteristics of Irish grown wheat varieties

Key external stakeholders:
Millers, bakeries, food ingredients companies, food manufacturers

Practical implications for stakeholders:
Based on the results of this project, it is now possible for Teagasc to recommend rapid, scientific, accurate tests on grains, flours, doughs and baked products to the industry. Furthermore, these researchers have the expertise to work with relevant industry to increase their capabilities in these areas, or to engage in confidential industry-led research, using these newly developed methodologies.

As some traditional methods are not deeply scientific, it is possible that some vital information relating to dough and baked properties had not previously been uncovered. Therefore, the methods which have been developed should be of significant advantage to the milling, baking industry and food industry for a complete analysis and better characterisation of their raw materials and end products, while complementing the more traditional cereal methods.

The new suite of modern and novel methods developed for use along the complete chain from the grain to the finished products include spectroscopy, rapid flour protein fractionation, laser imaging and digital mage analysis.

Main results:
Novel methods have been developed in the following areas:

- Near infra-red spectroscopy of grain, flour, dough and bread.
- Flour protein fractionation.
- Native starch and protein properties of flours.
- Imaging of confectionary batter and cookie dough during baking.
- Laser imaging of bread dough fermentation and density properties.
- Digital image analysis of bread crumbs.

Opportunity / Benefit:
Advice, consultancy work and/or technical services, relating to the novel and/or traditional methods, in the areas of wheat chemistry, dough rheology and baking processes, can be provided through the Teagasc Food Research Centre, Ashtown.

Collaborating Institutions:
University College Dublin.

Contact Eimear Gallagher Email: Eimear.gallagher@teagasc.ie.

Teagasc project team: Dr. Eimear Gallagher (PI)
Dr. Anastasia Ktenioudaki
Prof. Gerard Downey
External collaborators: Prof. Francis Butler, University College Dublin.

1. Project background:

Each year at Ashtown, wheat varieties are received from field trials conducted by the Department of Agriculture, Fisheries and Food. These varieties undergo a routine testing programme. All samples are initially subjected to preliminary grain tests (e.g. moisture content, protein content, Falling Number). Depending on these results (certain thresholds need to be passed), the baking properties of the selected milled flours are analysed (e.g. flour colour, gluten content, water absorption), and the resulting baked breads are also assessed (loaf volume, crumb softness, crust/crumb colour).

This research was undertaken for a number of reasons; the most important of these was to inject appropriate, modern scientific techniques into this routine work. Another significant purpose for the project was to try and develop novel methods for cereal analysis, particularly in the area of dough rheology and bread structure, as there was good scope for improving/updating older rheological methods. It was envisaged that the new tests developed would be of significant help to the milling and baking industry, and that the methods would also be available for the industry to adopt. The rationale behind the research as a whole was quite unique; it dealt with wheat grains being delivered to Ashtown directly from the farmer's fields, monitoring these grains as they went through the milling process, analysing the flours, the doughs and finally the baked products.

2. Questions addressed by the project:

- Could modern, rapid methods for the comprehensive analysis of Irish and international wheat varieties, milled wheat flour and dough be developed? And could the baked products be characterized?
- Could the original properties of the wheats and flours be linked to the final characteristics of the baked products?

3. The experimental studies:

The rationale behind the project was to introduce modern methods to complement traditional methods in cereal analysis along the complete chain from the grain to the finished products. Below is a brief description of the main novel techniques, materials and technologies that evolved over the course of the project.

- **Near infra-red spectroscopy (NIR) of grain, flour, dough and bread**

NIR was applied in a novel way to trace the molecular aspects of 194 samples of wheat grain, through to the milled flour, the dough and the baked bread, and the results obtained from the baked products were linked with the original wheat grain. Results were then correlated with those obtained using the more traditional methods of analysis for as moisture, protein (for flour), volume and texture (for bread).

- **Rapid flour protein fractionation**

Using an Agilent Bioanalyzer, the procedure for extracting and analysing flour proteins was optimised, giving precise information as to the quantity and quality of the type of protein subunits present in a large variety of wheat flours. An extensive library of information relating to the protein properties of Irish wheats has been built, and as the project progressed, the application of the method was extended to also study a range of international wheat varieties.

- **Native starch and protein properties of flours:**

Methods have now been optimised for analysing the native starch in flour, and in particular how the starch behaves during mixing and increasing temperature. This method has also been optimised to study how alcohol-soluble proteins in the flour behave during mixing, and whether they denature at higher temperatures.

- **Imaging of confectionery batter and cookie dough during baking**

Using a novel digital imaging technique, a dynamic height profiling method has been established for monitoring the changes in cake volume during baking, when different types of flour are used in the cake

Contact Eimear Gallagher Email: Eimear.gallagher@teagasc.ie.

formulation. The method gives a time-related visualisation of the actual expansion of cake batter during baking. A similar method has been developed to compare the rheological and baking properties of biscuit flours by monitoring cookie dough expansion. Both methods are simple, low cost and extremely effective in ascertaining information as to the baking properties of weak wheat flours.

- **Laser imaging of bread dough fermentation and density properties**

A new technique using strips of laser lights has been set up to follow yeasted (bread) dough development during fermentation, and relate results back to the density of the dough. Five laser lines are set up along the fermenting dough, and images are captured as the dough ferments and expands within the proofing cabinet.

- **Digital image analysis of bread crumb**

A C-Cell digital imaging system was proved to be an excellent indicator of the mixing capacities of different flour types, and also yielded extensive information as to the structural properties of bread crumb.

4. Main results:

- **Infrared spectroscopic analysis of grain, flour, dough and bread**

Chemometric procedures were applied to the spectroscopic data and NIRS was shown to accurately separate a wide range of wheats according to type and location of harvest. Also, for the grain and flour, moisture and protein contents were successfully predicted. Analysis of dough proofing using NIR showed that again, doughs could be separated according to their gluten strength / the type of flour used in the formulation. NIR has the ability to extract new molecular information about the properties of grains, flours and doughs. Results from the dough studies may form the basis for remote control of the proofing process.

- **New and rapid techniques to analyse the individual components of the different wheat varieties**

Techniques were developed to provide a better understanding of the fundamental components of wheat flour varieties.

1. Flour protein isolation and fractionation (ability to distinguish wheat flours for end use and as a discriminatory tool for variety identification based on protein molecular weight).
2. Analysis of native starch pasting properties while undergoing mixing.
3. Analysis of alcohol soluble proteins plus starch components while undergoing mixing and increasing temperatures.
4. Ability to define the molecular make-up of a very broad range of wheat varieties.

Results obtained from the protein fractionation method highlighted the importance of high molecular weight flours for breadmaking, whereas biscuits and sweet baked goods such as cakes could be formulated with flours of a lower protein content, and containing lower molecular weight protein. An extraction method using the Bioanalyzer was optimised to fractionate flour proteins into their individual subunits. The method was developed to initially study a wide range of Irish wheat varieties, but its scope has now been expanded to cover international wheat varieties of any quality, and other non-wheat flours such as barley, buckwheat, amaranth and quinoa.

- **Fundamental rheological properties of doughs**

A number of innovative methods have been developed and successfully utilized to characterize the properties of fermenting bread doughs, cake batters and cookie doughs. A laser imaging technique has been set up to monitor the proofing capacity of bread doughs within the proofing cabinet. Results from the trials were highly correlated with other proofing tests and also with the baked properties of the breads, e.g. loaf volume, crumb hardness, crumb imaging characteristics. A biaxial extensional test was developed on the Texture Analyser, to measure the stretching properties of doughs. Results from this test were found to be an accurate reflection of the type of mixing action (e.g. high/low electrical energy) previously used on the doughs. This test was used in conjunction with the Alveograph so that an all round indication of the uni-axial (stretching the dough in one direction) and bi-axial (stretching the dough in more than one direction) properties of the doughs could be obtained.

- **Baking characteristics and shelf life studies**

Breads and biscuits from Irish flours over three harvest years (2005, 2006, 2007) and a variety of Irish locations were assessed. The crust/crumb colour and texture of the products was analysed but new dimensions were also added to this work. The C-Cell image analysis system was used to measure the characteristics of sliced baked products. The software measures many aspects of the size and shape of the sample, its cell structure and features. The use of this system proved invaluable for studying the effects of

Contact Eimear Gallagher Email: Eimear.gallagher@teagasc.ie.

mixing, for evaluating the quality of flours and other ingredients and also for providing objective data which can be linked with other properties such as texture and volume. Another important method was texture profiling for bread crumb, giving information relating to the hardness, springiness, cohesiveness, resilience etc. A final method for precise bread evaluation has been the use of a new computerized method for measuring loaf volume and loaf specific volume. This method has proven to be quick and accurate, and results are highly correlated with texture profiling trials.

- **Amalgamation of instrumental results and to uncover optimum sets of variables for prediction of wheat and flour end-use properties**

When the lab work in this project was completed, all of the information was gathered and merged, and results were linked from the very beginning of the trials, to those obtained post-milling and post-baking. Datasets revealed correlations between NIR spectra, grain moisture, flour moisture and flour protein. From the mixing and rheology trials, it was found that the electrical work input of the mixer used significantly effects fermented dough height, biaxial extensional dough viscosity, loaf volume and bread slice height. Multiple regression analysis was carried out relating loaf volume to all of the measured flour characteristics and rheological parameters. The loaf volume correlated most accurately with dough extensional parameters. Extensibility at rupture and biaxial extensional viscosity were two parameters that gave consistent high correlation with baking volume. Proofing tests on the dough were also closely linked with final bread volume.

5. Opportunity / Benefit:

Following the development of methods from this project, advice, consultancy work and/or technical services can now be provided at Ashtown in the area of wheat 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 Whole Grain Global Summit (Newcastle, UK); Trends in Cereal Science and Technology (Thessaloniki, Greece) and "A Baker's Dozen" (Dublin, Ireland). Technical reports relating to this work can be downloaded at www.relayresearch.ie

Main publications:

- Ktenioudaki, A., Butler, F. and Gallagher, E. (2011). Studying the dough characteristics of Irish wheat varieties I. Rheological properties and prediction of baking volume. LWT – Food Science and Technology, 44 (3): 594-601.
- Ktenioudaki, A., Butler, F. and Gallagher, E. (2011). Studying the dough characteristics of Irish wheat varieties II. Aeration profile and baking quality. LWT – Food Science and Technology, 44 (3): 602-610.
- Ktenioudaki, A., Butler, F. and Gallagher, E. (2010) Rheological properties and baking quality of wheat varieties from various geographical regions. Journal of Cereal Science, 51 (3): 402-408.

Popular publications:

- Gallagher, E. and Ktenioudaki, A. (2009). Wheat discrimination according to the fermentation capacity of doughs. Chopin Tribune, 26: 2.
- Gallagher, E. (2009). Testing times. British Baker, April, 31.

7. Compiled by: Dr. Eimear Gallagher