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NutriCerealIreland: Exploring the properties of Irish-grown cereals as functional bakery ingredients

Key external stakeholders:

Cereal/milling industry
Bakeries
Food manufacturers
Food ingredients companies

Practical implications for stakeholders:

This project has shown that once the correct characterisation tests are undertaken, and appropriate processing aids applied, Irish-grown barley and oat varieties can serve as feasible ingredients in novel bakery and snack formulations.

- Currently, the use of Irish-grown barley and oat varieties is predominantly limited to livestock feed and minor food applications. This project investigated the potential of these cereals as ingredients for bakery and snackfood applications; also their nutritive properties, soluble fibre, phenolics and essential amino acids were studied.
- Through science-based innovation, the researchers involved in this project have shown how new, innovative and healthy cereal-based ingredients and food products, when used in conjunction with appropriate processing aids, may be developed from Irish-grown barley and oats.

Main results:

- Irish-grown oat and barley varieties, over three successive harvests were collected, milled (wholegrain and fractionated) and utilized as ingredients in novel bakery and snack formulations.
- A bread formulation containing wholegrain barley, a biscuit formulation containing milled oat fractions, a cracker product containing milled barley fractions and an extruded/puffed snack containing a blend of corn and barley were formulated and assessed.
- Ingredient interactions, nutritive value, chemical composition and structural properties of the new products were evaluated.
- A process for beta glucan extraction was optimized, yielding a very pure form of the polysaccharide.
- A series of bioactive peptides with ACE-inhibitory activities were identified from barley proteins.

Opportunity / Benefit:

End-users can exploit the outputs from this project, which include a significant amount of new information in relation to the milling, functional properties, utilization and nutritional benefits of utilizing oat and barley milled fractions, thus adding value to Irish-grown cereals.

Collaborating Institutions:

UCC, UCD

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1. Project background:

Over the last decade, Ireland has had the second highest average oats and barley yields in the world. As well as having high yields, these cereal crops contain significant levels of soluble fibre (beta glucan), phenolics and essential amino acids. However, their use in Ireland is predominantly limited to livestock feed and minor food applications. The research targets of the overall project were twofold: 1) to provide knowledge and tools for the processing of foods and beverages of high nutritional quality which contain Irish-grown oats and barley, and 2) to assist with the production of disease-free crops.

2. Questions addressed by the project:

- What properties do oats and barley have that may highlight their potential as ingredients in new bakery and snack formulations?
- How can they be incorporated in new formulations, and what are their effects (both functional and nutritive)?

3. The experimental studies:

Grain fractionation:

Barley and oat varieties from 3 successive harvests were treated and fractionated to produce milling fractions of different composition and particle size.

- A CD1 mill was purchased for the project. This was used to mill the de-hulled oats and barley and the process generated three milling fractions: bran, semolina, endosperm flour.
- The wholegrains were also milled on a Perten mill. This generated wholegrain flours.
- Varieties of barley were also selected for the pearling process, which removes the outer layers of the kernel and generates two fractions: pearlings and the pearled kernel.

Composition analysis of the milled fractions:

- Moisture, fat, protein, ash, minerals, total starch, total/soluble/insoluble fibre, fatty acids, yeast/mould and alpha-amylase activity of the milling fractions were analysed.

Hydration capacity and starch functionality of the milled fractions:

- Water holding capacity, water binding capacity and swelling capacity were determined.
- Starch pasting properties of the fractions were established.

Microstructure of the milled fractions:

- Scanning electron microscopy was completed on all of the grain milled fractions (wholegrains, brans, middlings, endosperm flour).

Bioactive and anti-hypertensive characterisation of the milled fractions:

- Assessment of oat proteins as a source of PAF-AH, ACE, renin, DPP-IV inhibitory activities was completed.
- In silico analysis of oat peptides was also undertaken.
- The phenolic content and antioxidant capacity of all samples, including milled barley and snacks, were measured.

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- Microwave assisted methyl-ester derivatisation of fatty acids, which is a novel automated technique, was adapted for barley fatty acids.

Developing novel baked and extruded snacks containing the milled barley and oat fractions:

- Novel biscuit formulations were developed, containing oat fractions at 10% and 15% inclusion levels.
- Novel saltine cracker formulations were developed, containing barley milled fractions.
- Novel bread formulations containing 30% barley plus baking enzymes were developed.
- A novel extruded snack formulation was developed, which contained 20% pearled barley.
- Quality tests on the novel formulations: Dough rheology, mixing optimisation, texture/shelf-life/staling/acoustic assessment, specific volume and bake loss, expansion properties, 2D image analysis of crumb grain, crumb microstructure, sensory analysis, flavour chemistry/volatile analysis, phenolic, and antioxidant analysis.

Characterisation of the composition and nutritional properties of the novel products:

- Moisture, fat, protein, ash, starch, fibre, minerals, beta blucan, polyphenols, antioxidant potential, flavonoid content and lipophilic components of the novel baked and extruded snacks were assessed and quantified.

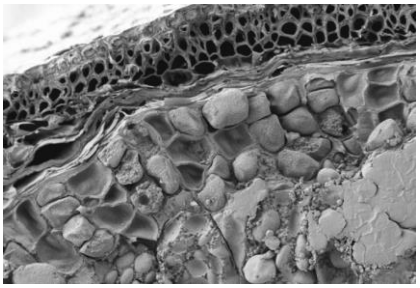
4. Main results:

Generation of milled fractions:

- Pre-conditioned barley and oat varieties from three harvests were milled, resulting in a number of different milling fractions being generated. These were wholegrain flour, bran, semolina and endosperm flour.

Nutritive value and chemical composition of the milled fractions:

- A complete breakdown of the composition (composition, functional properties, minerals) of each of the milled fractions and varieties, together with their microstructure was completed (microstructure of wholegrain barley is shown).

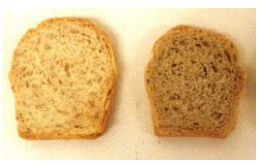


Characterisation and quantification of bioactives in the milled fractions:

- A 75% pure beta-glucan with average molecular weight of 350 kDa from 9 different barley cultivars was obtained.
- The majority of health-beneficial bioactives (beta-glucan, polyphenols, tocols and sterols) in barley were located in the outer layers, indicated by the bran and middling fractions of roller-milled barley. This was also reflected in the barley-derived snacks (crackers) showing significantly higher levels of health promoting bioactives when compared to wheat flour.
- The bioactivity of oat proteins were identified as renin-inhibitory. In addition, novel peptides were identified with Angiotensin-I-converting and renin inhibitory bioactivities.

Development of novel functional 'value-added' baked and extruded snacks containing the milled oat and barley fractions:

The following figures are examples of some of the baked products that were formulated with the Irish barley and oat varieties:



Biscuits (left): Control wheat biscuit (left) and biscuits containing 15% oat flour, 15% wholegrain oat and 15% oat bran (2nd left to right). **Bread** (middle): Control wheat bread (left), bread containing 30% barley + baking enzymes (xylanase/amylase) (right). **Crackers** (right): Control saltine cracker (left) and crackers containing 15% barley bran, 10% barley bran, 35% barley middlings and 15% barley middlings (2nd left to right).

An optimised extruded snack formulation was formulated and characterised. The test samples contained corn, pearled barley, polydextrose, psyllium husk and spirulina; used individually and as a blend. A characterisation of the qualitative and microstructural properties of each of the optimised extruded products

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was completed. Bread formulations containing barley wholegrain flour and natural enzymes were also formulated, along with biscuit formulations containing oat flour, oat bran and wholegrain oat flour inclusions, saltine cracker formulations based on 3 milled barley fractions, and the optimised oat hull-containing scone formulations. The mixing, rheology, baking, shelf-life and microstructural characteristics of the optimised 9

In vitro characterisation and quantification of the nutritional properties of the newly developed products:

- Two products of the roller-milled barley, namely bran and middlings, contained the highest levels of health-salutary bioactives, namely β-glucans, polyphenols and lipophilic organic species.
- Crackers with barley bran or barley flour incorporations had significantly higher β-glucan, polyphenol profile and antioxidant activities than the 100% wheat flour (control cracker).

5. Opportunity/Benefit:

- A number of novel baked and extruded snack formulations were devised and fully characterised (texture, shelf-life, sensory properties), which contained milled fractions of Irish-grown oat and barley varieties.
- A method was optimised for the production of β-glucan from barley, resulting in obtaining a high yield and high molecular weight β-glucan product. These are desirable attributes for manufacturers of healthy food or functional food products. The processes optimised for extraction of β-glucan and proteins from whole grain barley involved food–grade chemicals and solvents and hence can be adopted by industry. The outcomes of this project also encourage food industry to use barley as food ingredients, and not only for beverage production.

6. Dissemination:

Main publications:

Bleakley, S., Hayes, M., O'Shea, N., Gallagher, E., and Lafarga, T. (2018). Predicted release and analysis of novel ACE-I, Renin, and DPP-IV inhibitory peptides from Common Oat (Avena sativa) Protein Hydrolysates Using in silico analysis. Foods, 10.3390/foods6120108

Gangopadhyay, N., Harrison, S., Brunton, N.P., Hidalgo-Ruiz, J.L., Gallagher, E. and Rai, D.K. (2018). Brans of the roller-milled barley fractions rich in polyphenols and health promoting lipophilic molecules. Journal of Cereal Science, 83:213-221.

O'Shea, N., Kilcawley, K. and Gallagher, E. (2017). Aromatic composition and physicochemical characteristics of crackers containing barley fractions. Cereal Chemistry, 94 (3): 611-618.

Gangopadhyay, N., Rai, D.K., Brunton, N.P., Gallagher, E., Harrison, S.M. (2017). Fatty acids, sterols and tocols in Irish barley varieties: Profiling and correlation analysis. European Journal of Lipid Science and Technology: https://doi.org/10.1002/ejlt.201600213.

O'Shea, N., Kilcawley, K. and Gallagher, E. (2016). Influence of α-amylase and xylanase on the chemical, physical and volatile compound properties of wheat bread supplemented with wholegrain barley flour. European Food Research and Technology, 242 (9): 1503–1514.

Gangopadhyay, N., Rai, D. K., Brunton, N. P., Gallagher, E., & Hossain, M. B. (2016). Antioxidant-guided isolation and mass spectrometric identification of the major polyphenols in barley (Hordeum vulgare) grain. Food Chemistry 210, 212-220.

Gangopadhyay, N., Wynne, K., O'Connor, P., Gallagher, E., Brunton, N. P., Rai, D. K., & Hayes, M. (2016). In silico and in vitro analyses of the angiotensin-I converting enzyme inhibitory activity of hydrolysates generated from crude barley (Hordeum vulgare) protein concentrates. Food Chemistry 203, 367-374.

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