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Engineering of high quality gluten-free breads

Key external stakeholders:

Food manufacturers, bakeries, food ingredients companies.

Practical implications for stakeholders:

- Pseudocereal flours are feasible ingredients in the formulation of good quality gluten-free breads.
- Pseudocereals are important energy sources, due to their starch content, and contain good quality protein, dietary fibres and lipids rich in unsaturated fats.
- Pseudocereals have adequate levels of important minerals such as calcium and iron.

A number of recent studies highlighted the poor nutritional quality of gluten-free cereal-based products available on the market. This project evaluated the baking and nutritive properties of the pseudocereals amaranth, quinoa and buckwheat, and their applications as functional ingredients in a gluten-free bread formulation.

The pseudocereal flours proved to be extremely viable and should play an important part in enhancing the nutritional properties of gluten-free breads. This gluten-free project has further improved the knowledge and expertise of the cereal group at Ashtown in this significant and ever-growing area.

Main results:

- Buckwheat and quinoa breads had increased bread volume.
- Pseudocereal containing breads had a softer texture than the control bread.
- Higher levels of protein, fat, fibre and minerals were found in the pseudocereal breads.
- Buckwheat breads had the highest total phenol content.
- Quinoa and buckwheat grains are rich sources of polyphenols.
- Amaranth, quinoa and buckwheat breads are excellent sources of vitamin E.

Opportunity / Benefit:

The opportunity exists to produce a range of nutritionally enhanced gluten free breads providing interested companies with a competitive advantage. Teagasc can provide the knowledge and technical services required to develop these products successfully.

Collaborating Institutions:

University College Cork

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1. Project background:

Coeliac disease is one of the most common life long disorders worldwide with an estimated mean prevalence of 1 % of the general population. The only acceptable treatment to date for coeliac disease is the strict lifelong elimination of gluten from the diet. For the majority of coeliac disease patients, adherence to a strict gluten-free diet will lead to progressive clinical improvements in parallel with the healing of the intestinal mucosa.

Many staples worldwide such as bread and pasta are made using gluten-containing grains such as wheat, and must be avoided by the coeliac patient. Although gluten-free alternatives are readily available in the market, these products are often perceived as being of inferior quality compared with the gluten-containing products they are intended to replace. Thus, finding other ingredients that can mimic gluten functionality and replace gluten in gluten-free cereal-based products has been the focus of a significant amount of research in recent years. Some of the approaches developed to date to improve quality attributes of gluten-free products such as texture, mouth-feel acceptability and shelf-life include the use starches, hydrocolloids, protein-based powders and enzymes.

In addition to quality defects, gluten-free foods are also characterized by an inferior nutritional quality. They have been reported to contain lower levels of essential nutrients such as B-vitamins, iron and fibre, than wheat-based products. This is not surprising, as gluten-free cereal-based products are generally formulated with starches and refined flours, and are not generally fortified.

Results from a number of studies have indicated that the intake of certain essential nutrients is limited in coeliac patients, a fact that the authors have attributed to the poor nutrient content of gluten-free products available. Also, it appears that the intake of carbohydrates in coeliac patients is unbalanced, with a higher percentage of energy coming from fats and carbohydrates, possibly a reflection of the poor quality of the gluten-free food products available in the market.

A need exists, therefore, to provide the coeliac patient with palatable, healthy gluten-free foods. Several gluten-free grains exist, such as the pseudocereals amaranth, quinoa and buckwheat. These grains are also rich in nutrients and thus, their incorporation in the gluten-free diet could add not only variety but also improve the nutritional quality. Many beneficial attributes characteristic of these grains, such as their high protein, fibre and mineral content as well as the presence of many bioactive components, make them attractive alternatives to traditional gluten-free ingredients in the production of high quality, healthy gluten-free products. This project focussed on the application of these pseudocereal grains in gluten-free bread formulations and their ability to produce high quality products with enhanced nutritional aspects.

2. Questions addressed by the project:

- Could Teagasc enhance the overall baking properties (texture, sensory and shelf-life) of gluten-free breads?
- Could the introduction of gluten-free pseudocereal grains enhance the nutritional value of gluten-free breads?

3. The experimental studies:

A gluten-free bread recipe that is similar to commercial formulations based on rice flour and potato starch was used as a control. One of the pseudocereals amaranth, quinoa and buckwheat replaced the potato starch in each of the experimental formulations. The following analyses were undertaken:

Starch properties of the flours:

The pasting properties of the flours and starches were evaluated using a Rapid Visco Analyzer.

Bread evaluation

Loaf specific volume was measured using a bread volume measurer. Moisture was assessed following an oven-drying procedure. Crust and crumb colour were measured using a tristimulus Minolta Chromameter.

Crumb structure of the loaves was evaluated using the C-Cell Bread Imaging System. Crumb texture and staling properties were assessed by conducting a texture profile analysis (TPA) using a texture analyser. All bread evaluation analysis were conducted 24 h after baking, and moisture and TPA analysis were repeated 72 and 120 h after baking.

Scanning electron microscopy (SEM) and Confocal laser scanning microscopy (CLSM)

Flour samples were examined under a field emission scanning electron microscope.
Bread samples were imaged in confocal scanning laser microscope.

Sensory analysis

Sensory acceptability scoring was conducted by 20 panelists on all bread formulations.

Macronutrient analysis of the grains and baked loaves

The following analyses were undertaken: Protein, moisture, fat, ash, total starch, total dietary fibre, fatty acids.

Other nutritional analyses

The following analyses were also carried out: Mineral content, total phenolic content antioxidant capacity, polyphenol composition, Vitamin E.

4. Main results:

Improved baking characteristics of breads containing pseudocereals

Loaf volumes were increased for breads containing buckwheat and quinoa in comparison with the control. In relation to the crust colour of the baked breads, the pseudocereal-containing gluten-free breads were significantly darker compared to the gluten-free control. The darkening of crust colour brought about by the replacement of potato starch by a pseudocereal flour is desirable as gluten-free breads tend to have a lighter crust colour than white wheat breads and can sometimes appear artificial. In breadmaking, a desirable crumb structure is characterised by a large number of small, thin-walled cells and a soft, spongy texture. In the present study, largest number of cells was found in breads containing buckwheat and quinoa. All pseudocereal-containing gluten-free breads had a softer crumb than the gluten-free control. A similar trend was found for crumb cohesiveness, with all of the pseudocereal-containing breads producing a more cohesive crumb than the control product. In sensory studies, the differences observed in the acceptability of the baked breads were not statistically significant, showing that pseudocereal flours may be introduced into a gluten-free bread formulation to enhance crumb softness and cohesiveness and without adversely affecting the sensory properties of the loaves.

Microstructure of the bread crumb

Starch gelatinisation occurred to a greater degree in the gluten-free control bread compared to the pseudocereal breads. Partial gelatinisation occurred in the pseudocereal-containing gluten-free breads, and as a result, a greater number of starch granules retained their integrity. A more homogenous structure was apparent for the pseudocereal-containing gluten-free breads, with a more even distribution of fat, protein and starch. The images revealed the importance of the fat globules in forming complexes with starch granules and/or stabilizing gas cells.

The baking trials showed that amaranth, buckwheat and quinoa can be used in the production of gluten-free breads with improved texture and structure.

Enhanced nutritive properties

Inclusion of pseudocereal flours produced breads that were characterised by a significantly higher content of protein, fibre, antioxidant capacity and total phenols. The protein content in these breads was, in all cases, at least twice that of the control bread. Dietary fibre content also increased significantly. In particular, fibre content of buckwheat bread, at 23.3 %, was more than three times that of the gluten-free control. Total phenol contents of the pseudocereal breads were also significantly higher than the gluten-free control bread, with highest values found in breads containing buckwheat. Antioxidant capacity was also increased by the presence of the pseudocereals, compared with the control gluten-free bread, with the buckwheat bread again having the highest overall result.

5. Opportunity/Benefit:

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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 gluten-free formulations through Teagasc's fee-paying service. Commercial trials have recently taken place with two bakeries. Further funding has been granted to continue research in this area in the form of a 3 year PhD student.

6. Dissemination:

Main publications:

Alvarez, L.A., Wijngaard, H., Arendt, E.K. and Gallagher, E. (2010). Polyphenol composition and in vitro antioxidant activity of amaranth, quinoa and buckwheat as affected by sprouting and baking. *Food Chemistry*, 119: 770-778.

Alvarez, L.A., Arendt, E.K. and Gallagher, E. (2010). Nutritive value of pseudocereals and their increasing use as functional gluten-free ingredients. *Trends in Food Science & Technology*, 21: 106-113.

Alvarez, L.A., Arendt, E.K. and Gallagher, E. (2009). Nutritive value and chemical composition of pseudocereals as gluten-free ingredients. *International Journal of Food Sciences and Nutrition*, 22:1-18.

Popular publications:

Gallagher, E. (2007). New dimensions in cereal research. TResearch, 15-19.

Gallagher, E. (2009). Better breads for better health. The Ashtown Food Innovator, (2), 3.

Gallagher, E. (2010). Latest developments in gluten-free research. TResearch, 5 (2): 18-19.

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