Characterization of plant-based protein ingredients for developing nutritionally enhanced baked foods

Key external stakeholders:
Food ingredients suppliers
Food manufacturers
Bakeries

Practical implications for stakeholders:
In recent years, pulses have been highlighted as a key ingredient in food innovation. This is largely due to their significant nutritional and environmental benefits. Pulse flours offer a sustainable source of plant-protein for developing protein-enriched foods. However, their application can also present new challenges, in particular their influence on flavour and textural attributes of the foods into which they are incorporated. This research focused on the processability, nutritive value and sensory properties of pulse flours from dry peas (Pisum sativum) and fava beans (Vicia faba) and their potential application in yeast breads and crackers. During this project, dough rheology, baking properties, internal structure, shelf-life and sensory characteristics of the re-designed protein-enhanced products were studied. Effects of pre-processing of the pulses (germination and toasting) were also examined. A range of novel bread and cracker formulations, containing optimal levels of fava beans, green peas or yellow peas were developed.

Main results:
- Nutritional characterization carried out on fava-bean, green-pea and yellow-pea flours revealed that they have higher nutritional value than wheat flour, particularly with regard to protein, dietary fibre, micronutrients and antioxidant activity.
- A savoury wheat cracker was produced with a reformulated recipe using the pulse flours, at 40% substitution for wheat flour. Wheat-bread was re-formulated with 30% raw, germinated and toasted yellow-pea. Toasting improved dough stability compared with germinated and raw pea flour. The resulting breads had comparable physico-chemical and sensory properties to the wheat-flour control bread.
- Fava-bean and pea flour present exciting opportunities to food product developers for enhancing the nutritional value of bakery products and for increasing the consumption of beneficial plant proteins in the diet.

Opportunity / Benefit:
This research has generated much needed information on the benefits of using underutilized grains and pulses such as fava beans, green peas and yellow peas as a sustainable source of plant protein in cereal product re-formulation. The research has provided the end-user with novel ingredient blends and a suite of techniques for developing baked products with inclusions of these pulse flours. For more information, please contact Eimear Gallagher (Eimear.Gallagher@teagasc.ie).

Collaborating Institutions:
University College Cork.

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

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1. Project background:
Pulse grains were identified as a key resource for food innovation during the International Year of the Pulse (IYP), 2016. Pulse flours offer a sustainable source of plant protein for innovation in protein enriched cereal based foods. As well as being an important source of protein, pulses are rich in a rich source of nutrients and are particularly high in dietary fibre and micronutrients. They are also naturally low in fat and sugar, have a low GI and are gluten-free. Pulses also offer environmental benefits including a high productivity level, soil regeneration and climate tolerance. However pulses are still under consumed in Western diets because of the challenges they present, particularly in relation to texture and flavor when incorporated into a food. This project focussed on the processability, nutritive value and sensory properties of fava bean, green pea and yellow pea flours produced from dry pulses, and their potential application in baked goods.

2. Questions addressed by the project:
What are the technical properties of pulses?
How may they be incorporated into novel bakery formulations?
What is their effect when substituting wheat flour at different levels on baking, shelf-life and sensory properties of baked products?

3. The experimental studies:
   a) **Proximate composition and anti-nutritional characterization of fava beans, green peas and yellow peas:**
   - **Analysis undertaken:** Protein, dietary fibre, minerals, amino acids, phenolic content, antioxidant activity, phytic acid and trypsin inhibitory activity.
   b) **Effects of pulse flour inclusions on the physical and technical properties of breads and crackers:**
   - **Analysis undertaken:** Ingredient blending, baking trials, shelf-life, texture, structure, microstructure, chemical composition.
   c) **Effects of germination and toasting of pea flour on dough rheology and bread baking properties:**
   - **Analysis undertaken:** Soaking and germination trials, toasting trials, microscopy, starch pasting, fundamental dough rheology, bread characterization, proximate composition.
   d) **Sensory properties/consumer acceptability of breads enriched with raw or toasted pea flour:**
   - **Analysis undertaken:** Volatile flavor analysis using SPME, flash profiling descriptive analysis, Check All That Apply (CATA) consumer study.

4. Main results:
   a) **Proximate composition and anti-nutritional characterization of fava beans, green peas and yellow peas:**
   - All pulse flours had higher insoluble dietary fibre compared to wheat flour (P<0.05).
   - Pulse flours were found to contain low levels of methionine and high levels of lysine, offering a complimentary amino acid profile when combined with wheat flour.
   - Fava-bean flour contained high levels of zinc, iron and potassium.
   - Pulse flours had a lower ratio of phytic acid to zinc and iron compared to wheat flour.
   - Pulse flours had higher in vitro antioxidant activity than wheat flour (P<0.05).
b) **Effects of pulse flour inclusions on the physical and technical properties of crackers:**

- Wheat-pulse-flour crackers were produced using broad-bean, yellow-pea and green-pea flours. Substitution of wheat flour with pulse flours (40%) significantly increased the protein and total dietary fibre contents by up to 55%. Phenolic content and antioxidant activity were also significantly increased.
- Addition of pulse flours resulted in a darker and more golden cracker colour, a characteristic which was preferred by the consumers in comparison with the control cracker, which was lighter.
- Consumer preference studies showed that addition of pulse flours had no negative effect on appearance, hardness or mouthfeel. Broad-bean and yellow-pea flours significantly increased consumer liking of the crackers, compared with ‘wheat-only’ cracker.

![Nutritional value](image1)
![Moisture content & water activity](image2)
![Colour](image3)
![Texture & hardness](image4)

**Sensory analysis: 9pt hedonics**

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c) **Effects of germination and toasting of pea flour on dough rheology and bread baking properties:**

Wheat flour was substituted by 30% with yellow pea flour. The textural and flavour challenges of pea flour application were addressed using **thermal (toasting)** and **non-thermal (germinating)** processing methods. The baking characteristics and loaf quality of the resulting breads were assessed.

- Microscopy highlighted the starch and protein structures within the pea flours vs wheat flour. Compared to the highly organised and compact starch-protein matrix in wheat, that of the pea flours was much less structured. Germinated and toasted pea flours had a fragmented protein structure, with signs of damaged starch following germination.
- Crumb cell size is a key indicator of carbon dioxide captured during proofing and has a significant effect on the crust texture and sensory properties of bread. There were no significant differences found in cell size or the non-uniformity results, indicating the crumb structure was maintained and not impacted following addition of the processed pea flours. Slice area was significantly reduced following the addition of germination pea flour (p<0.05), correlating with the reduction in loaf specific volume ($r^2 = 0.8856$).
- Addition of pea flour increased crumb hardness, which may be attributed to the reduced water absorption, increase in protein and fibrous materials. However, results were not significant.

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e) **Sensory properties/consumer acceptability of breads enriched with raw or toasted pea flour:**

Breads produced from raw pea flour had significantly higher contents of aldehydes, while toasted pea flour resulted in a higher concentration of pyrazines, resulting from Maillard reactions. Using flash profiling, eight trained panellists generated 79 semantically different attributes to discriminate between the different breads, grouped under appearance, texture, aroma, flavour, taste and aftertaste. A check-all-that-apply (CATA) questionnaire established appearance and texture attributes as the key drivers for consumer liking. Using a 9-point hedonic scale, consumers rated the breads between 4.2 and 6.5 for overall acceptability. Aerated, soft, fresh and springy were the attributes that had the highest association with consumer liking while the changes in volatile profile were not detected by consumers. Results suggest that appearance and texture...
were the most affected sensory properties following the addition of pea flour and were also considered to be the most important attributes for consumer acceptability.

5. **Opportunity/Benefit:**
Following the use of new ingredient blends and the development of a range of baked products which contain pulse ingredients, advice, consultancy work and/or technical services can now be provided in this area through Teagasc’s fee-paying service. Commercial trials can be conducted in the test bakery and Prepared Consumer Food Centre at Ashtown and in the flavour chemistry facility at Moorepark.

6. **Dissemination:**

**Peer-reviewed publications:**


**Conference abstracts and presentations:**


7. **Compiled by:** Dr. Eimear Gallagher.