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# 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.



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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 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 ($P<0.05$).




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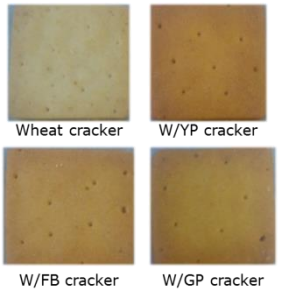
**b) Effects of pulse flour inclusions on the physical and technical properties of crackers:**

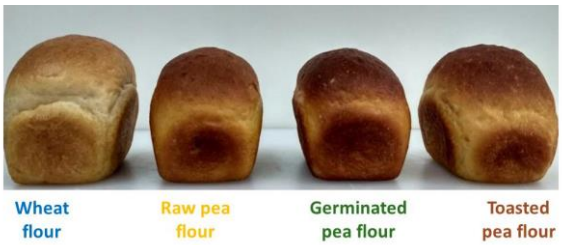
- Wheat+pulse-flour crackers were produced using broad-bean, yellow-pea and green-pea flours. Substitution of wheat flour with pulse flours (40%) significantly increased the protein and total dietary fibre contents by up to 55%. Phenolic content and antioxidant activity were also significantly increased.
- 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



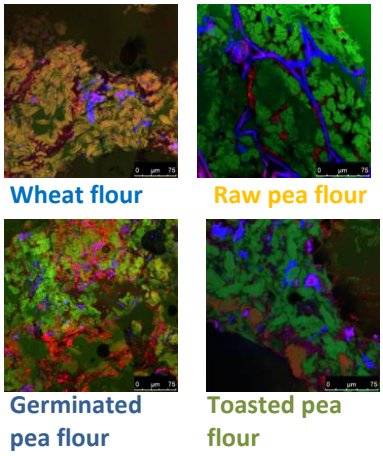


**c) Effects of germination and toasting of pea flour on dough rheology and bread baking properties:**

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 crumb 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 ($r2 = 0.8856$).
- 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.




**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



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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:**

Millar, K., Crofton, E., Kilcawley, K., Garvey, E. Burke, R., McCarthy, S., Barry-Ryan, C. and Gallagher, E. (2020). Sensory properties and consumer acceptability of protein-enriched breads as determined by volatile analysis (HS-SPME, GC-MS), flash profiling and check-all-that-apply (CATA). In preparation for submission to Food Structure.

Millar, K., Gallagher, E., Burke, R., McCarthy, S. and Barry-Ryan, C. (2019). Proximate composition and anti-nutritional factors of fava-bean (Vicia faba), green-pea and yellow-pea (Pisum sativum) flour. Journal of Food Composition and Analysis. https://doi.org/10.1016/j.jfca.2019.103233

Millar, K.A., Barry-Ryan, C, Burke, R., McCarthy, S. and Gallagher. E. (2019). Dough properties and baking characteristics of white bread, as affected by addition of raw, germinated and toasted pea flour. Innovative Food Science and Emerging Technologies; https://doi.org/10.1016/j.ifset.2019.102189

Millar, K.A., Barry-Ryan, C, Burke, R., Hussey, K., McCarthy, S. and Gallagher. E. (2017). Effect of pulse flours on the physiochemical characteristics and sensory acceptance of baked crackers. International Journal of Food Science and Technology; https://doi.org/10.1111/ijfs.13388

**Conference abstracts and presentations:**

Millar, K., Crofton, E., Kilcawley, K., Garvey, E.C., Burke, R., McCarthy, S., Barry-Ryan, C. and Gallagher, E. (2019). Sensory properties and consumer acceptability of protein-enriched breads as determined by flash profiling, check-all-that-apply and volatile analysis. 13th Pangborn Sensory Science Symposium, Edinburgh, Scotland.

Millar, K. A., Barry-Ryan, C., Burke, R., McCarthy, S. and Gallagher, E. (2019). Raw, germinated and toasted pea flour as a novel ingredient in bread-baking: The effects on dough rheology and bread quality. 48th Annual Food Science and Technology Conference, University College Cork, Ireland.

Millar, K. A., Barry-Ryan, C., Burke, R., McCarthy, S. and Gallagher, E. (2018). Structural and rheological characteristics of processed pea flour as a novel ingredient in bread-baking. 32nd EFFoST International Conference, Nantes, France.

Millar, K. A., Barry-Ryan, C., Burke, R., McCarthy, S. and Gallagher, E. (2018). Dough rheology and bread-baking properties of germinated and toasted pea flour. Cereals & Grains International Conference, London, England.

Millar, K. A., Barry-Ryan, C., Burke, R., McCarthy, S. and Gallagher, E. (2018). The effect of germinated and toasted yellow-pea flour addition on the textural and structural properties of white bread. 7th European Sensory Science Society Annual Symposium, Dublin, Ireland.

Millar, K. A., Barry-Ryan, C., Burke, R., McCarthy, S., Gallagher, E. (2017). Pulse flours enhance the nutritional properties and antioxidant activity of wheat-flour crackers. Sao Paulo School of Advanced Sciences on Reverse Engineering of Processed Foods. UNICAMP, Sao Paulo, Brazil.

Millar, K. A., Barry-Ryan, C., Burke, R., McCarthy, S., Gallagher, E. (2016). Application of molecular gastronomy principles in the design of pulse based functional foods. 18th World Congress of Food Science and Technology, Dublin Ireland.

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



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