# LEGUME PERSPECTIVES

## To feed and to heal... What else?

### Legume quality and health benefits

The journal of the International Legume Society

Issue 9 • September 2015

# IMPRESSUM

**ISSN**
2340-1559 (electronic issue)

**Quarterly publication**
January, April, July and October
(additional issues possible)

**Published by**
International Legume Society (ILS)

**Co-published by**
CSIC, Institute for Sustainable Agriculture, Córdoba, Spain
Instituto de Tecnologia Química e Biológica António Xavier
(Universidade Nova de Lisboa), Oeiras, Portugal
Institute of Field and Vegetable Crops, Novi Sad, Serbia

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**Front cover art:**
*Pulses in Flower Form*
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## EDITORIAL

*The present issue of our journal* Legume Perspectives *was designed to boost our audience attention on the potential of legumes to control malnutrition (over and under) and prevalent chronic diseases.*

*Different stakeholders, from agrifood industry associations and processors to social scientists, nutritionists and breeders, were invited to contribute with their views covering panoply of related subjects and dealing with different legumes specificities.*

*New challenges in breeding for quality in chickpea, common bean, faba bean, grass pea, lentil, lupins and pea, were reviewed focusing on the development of improved raw materials that may be incorporated in healthier and flavourful food formulations. With an increase on higher quality legume consumption, advisable due to their role in chronic diseases prevention and treatment, the expected new opportunities for food processors were also discussed. The different market opportunities and economic/ ecological advantages of a higher legume production were examined, as well as the consumers' behaviour in relation to novel legume food products, as they should provide focus on the legume quality improvement.*

*I hope that the information provided here will be useful to the readers and further stimulate their legume daily consumption.*

*On behalf of the International Legume Society, I wish to thank all the authors for their valuable contributions!*

***Maria Carlota Vaz Patto***
*Managing Editor of* Legume Perspectives *Issue 9*

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Carte blanche to…


… M. Carlota Vaz Patto

# Grain legumes: Missing links for delicious health…

*Grain legumes are exceptional quality food with obvious benefits for human health. Still we assist to a reduction in legume food consumption even in their most traditional market regions.*

*The emergence of novel fast food habits, associated with a reduced investment on seed quality breeding and food innovation, resulted in a reduced attractiveness of legume food products.*

*To increase grain legume intake, breeding objectives and consumer preferences should be more aligned in a demand driven approach. This would contribute to transform the consumption of legumes in an even more attractive, convenient and delicious option.*

*Particular grain legumes components might act as health-promoting agents as well as anti-nutrients, influencing both taste and consumers' acceptability. Due to this high quality traits interaction, the development of the necessary selection tools for such fine-tuning of breeding programs requires an integrative approach.*

*Molecular markers associated with nutritional and organoleptic qualities, as well as spectroscopic tools for key quality traits are becoming available to routinely implement quality objectives in breeding programs. But the needed integrative strategy for such tools development is still missing for several grain legumes.*

*Efforts must concentrate on identifying nutritionally enhanced germplasm, allocating breeding resources also for sensorial and processing quality evaluation. Equally important, efforts should focus on developing attractive, convenient ready-to-eat and tasty legume-based food formulations that will contribute to the diversification of diets.*

*Such a targeted effort on quality traits could be predicted to lead to enhanced legume cultivation and consumption, increasing diversification of healthier and more nutritional diets,and leading to a reduction in the global economic burden caused by malnutrition and prevalent chronic diseases.*

*Let the legume a day, keep the doctor away!*

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# Potential role of non-soy grain legumes in preventing hypercholesterolemia

by Anna ARNOLDI*, Giovanna BOSCHIN, Chiara ZANONI and Carmen LAMMI

**Abstract:** Although the health benefits provided by soy protein are known from decades, especially in the area of cholesterol control, non-soy legumes have been only rarely investigated. This is a pity considering the environmental relevance of these seeds: indeed a better knowledge of their beneficial role in the diet may become an important tool to promote their consumption. We summarize here available results either from animal investigations or human trials in the area of hypercholesterolemia prevention. This body of data indicates that a regular consumption of grain legumes is useful for maintaining a correct lipid profile.

**Key words:** cardiovascular disease, cholesterol, coronary heart disease, grain legumes, plant protein

## Introduction

Many studies have shown that the consumption of soybean protein is useful for dyslipidemia prevention (10). This activity was also strongly validated by the US Food and Drug Administration (FDA) approval of the "health claim" on the role of soy protein in reducing the risk of coronary heart diseases (FDA, Federal Register 1999: 64, 57699-57733). During the following years, this prompted some research also on other legumes that will be briefly described in this review.

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## Animal studies

Whereas the first studies on the potential hypocholesterolemic effects of soybean (*Glycine max* (L.) Merr.) dated back to the '70s, it was not until the '90s that some researchers started to dedicate resources and time to non-soy legumes, stimulated by the similarities among the sequences of the main protein fractions in legumes. Most of the experimentation was performed *versus* casein or lactalbumin as control proteins using the rat model of hypercholesterolemia. Table 1 reports a summary of the results of some of these investigations, which have involved numerous legumes (for a complete list see (2)). All studies reported significant and generally very large decreases of the lipid parameters versus the control diet, with the exception of lentil that was the least effective. Certainly, these data gave clear indication that these seeds may be beneficial for dyslipidemia prevention.

Particular attention was dedicated to lupin (*Lupinus* spp.) that, owing to its exceptional protein content, may be considered a valuable substitute of soy in food formulation. In this case, besides the usual investigations on rats, other animal models were also applied, such as hamster, pig and rabbit. Rabbit is a model of the atherosclerotic plaque, since a small perivascular injury may induce the development of a focal plaque at both common carotid arteries. After recovery from surgery, animals were fed cholesterol-rich diets containing casein (control) or a protein isolate from white lupin (treatment) for 90 days (9). Cryosection analyses of the carotids indicated a significant reduction in focal lesion progression in the lupin *vs.* the casein group (-37.4%). Therefore, lupin protein not only reduces cholesterolemia, but also exerts a protective activity against atherosclerosis progression. A study on hamster has instead shown that a lupin diet reduces the level of liver steatosis (accumulation of fat in the liver) (6).

**Table 1. Effects of grain legumes on lipid metabolism evaluated in the hyperlipidemic rat model (2)**

| Grain legume | Tested ingredients | Duration (days) | Total cholesterol change vs. control (%) | VLD-C + LDL-C or non-HDL-C change vs. control (%) |
|---|---|---|---|---|
| Butter bean | Whole cooked flour | 56 | -24.0 | -38.8 |
| Chickpea | Cooked flour | 16 | -34.1 | -43.2 |
| Common bean | Whole cooked flour | 56 | -36.3 | -53.0 |
| Cowpea | Cooked flour | 28 | -48.5 | -54.2 |
| Faba bean | Whole flour | 14 | -36.8 | -56.3 |
| Lentil | Cooked flour | 56 | -6.7 | -32.2 |
| Narrow-leafed lupin | Protein isolate | 28 | -55.3 | -61.1 |
| Pea | Protein isolate | 28 | -51.6 | -58.1 |
| White lupin | Protein isolate | 21 | -22.7 | -30.2 |

## Human studies

The results on the clinical studies on non-soy legumes are analyzed in a few reviews (1, 4, 5) that give clear indication that a diet rich in these seeds is useful to decrease total cholesterol and low density lipoprotein cholesterol (LDL-C). We have recently published another very comprehensive review (2), whose relevant data are summarized here.

Up to now 20 papers dealing with non-soy legumes and cholesterol have been published for a total of 22 different trial arms. These studies may be classified into four groups: 1) twelve unblind studies on whole seeds; 2) one unblind study on a model beverage from white lupin (*L. albus* L.) seed; 3) two blind studies (three arms) on model foods containing whole kernel flours; 4) five blind studies (six arms) on purified fiber or proteins. Considering gender, twelve studies were on both genders, ten on males alone, and, surprisingly, none on females alone. All controlled studies were randomized, about one half had a parallel design, whereas the other had a crossover design. The durations span from 3 weeks to one year, but a 4-weeks duration is prevalent.

The quantity of legumes consumed daily in the studies of Group 1 varied as well as the number of servings per week, which spanned from 4 to 7. Most of them showed significant decreases in total cholesterol (from -8 mg dl$^{-1}$ to -56 mg dl$^{-1}$) and LDL-C (from -7 mg dl$^{-1}$ to -51 mg dl$^{-1}$) (2). Group 2 comprises only an uncontrolled 3-months study evaluating a daily intake of 500 ml of a model lupin drink on smokers. Significant decreases in total and LDL-C were observed in respect to the stabilized lipid values during the previous diet. Group 3 includes two blind studies on model foods containing whole kernel flour. The former, on broad bean (*Vicia faba* L.) flour mixed to smashed potato, reports segregated results for normocholesterolemic patients (mean initial cholesterol equal to 200 mg dl$^{-1}$) and moderate hypercholesterolemic (mean initial cholesterol equal to 240 mg dl$^{-1}$). Both groups of patients showed decreases of total and LDL-C that were higher in the hypercholesterolemic group. On the contrary, no significant changes were observed in the latter study, based on normolipidemic subjects who consumed bread, biscuits and pasta added with lupin flour.

With the exception of a paper on a pea (*Pisum sativum* L.) protein isolate which was practically inactive, all studies of Group 4 are on narrow-leafed lupin (*L. angustifolius* L.). The ingredients (fiber or protein isolate) were included in different kinds of foods. The kernel fiber, added in breads, muffins, and other foods, produced small, but significant decreases of total and LDL-C (7). Instead, lupin protein (25 g) incorporated into a lupin drink did not change the lipid profile in a statistically significant way versus the control. Two studies were based on dietary bars containing either the lupin protein isolate or casein (control bar). In the former comparable decreases of the lipid parameters were observed either in the treatment or in the control. This was possibly due to the lack of a run-in period aimed to stabilize the lipid parameters before the intervention, which in our experience is crucially important in dietary studies. The latter study (11) on similar bars, in which the run-in period was correctly performed, gave instead better results. In spite of their unsatisfactory sensory properties, the bars containing lupin protein produced a significant decrease of total cholesterol (-11.6 mg dl$^{-1}$, -4.2%), whereas no plasma cholesterol changes were observed in the control group. Finally, very interesting results were obtained in a very recent study (3), where the patients received a portfolio of different lupin food items, very similar to normal foods: in fact, statistically decreases of both total cholesterol (-11.0 mg dl$^{-1}$, 4.4%) and LDL-C (-6.0 mg dl$^{-1}$, 3.6%) were observed. Possibly, the effectiveness of this study may be explained with the improved compliance consequent to the varied portfolio of products that the subjects could easily include in their daily diet.

## Conclusions

Available animal and human experimentation clearly indicates that legumes are useful in high cholesterol prevention. Different seed components may be responsible of this activity: certainly the fiber, but also the protein or, better, specific peptides derived from the proteins that are able to interfere with cholesterol metabolism in hepatic cells (8). It would thus be very advisable to increase the daily consumption of these seeds: to achieve this objective, it would be useful to have an easier access to different food items based on legumes, such as in the current market of soy foods.

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# Legumes: An emerging source of ingredients for health and wellness foods and their potential for application in various products

by Zhen MA[1] and Joyce I. BOYE[2]*

**Abstract:** With the growing demand for adequate supplies of food to feed the ever increasing world population, opportunities exist for food processors to develop novel foods fortified with legume ingredients or based primarily on legume ingredients which are healthy and convenient and which take advantage of the techno-functional properties of legume flours and fractions. Several studies have focused on developing new products, such as low-fat meatballs, extruded snacks, weaning food, bread, and macaroni, by using legume flours and legume fractions (protein isolates, starch and fiber fractions) as ingredients. Further research is still needed to expand the availability of these legume based products and to optimize the quality of these legume-based products for specific markets.

**Key words:** food supplementation; legume flours; legume fractions; value-added products

Legumes, including pulses, such as beans (*Phaseolus* spp.), peas (*Pisum sativum* L.), chickpeas (*Cicer arietinum* L.) and lentils (*Lens culinaris* Medik.), and oilseeds, such as soybeans (*Glycine max* (L.) Merr.) and peanuts (*Arachis hypogaea* L.) have served as a major source of food and feed in many cultures for eons. With their high protein, starch and fiber content, these crops provide a valuable energy and nutrient source that can contribute to the nutritional requirements of both humans and animals. Many legumes have, nevertheless, remained underexploited in most emerging and developed economies, partially due to the length of time required for their preparation (e.g., cleaning, soaking, and cooking), and the need to remove undesirable beany flavors and antinutritional compounds.

Growing concerns about the potential negative health impacts of consuming food with high amounts of fat and cholesterol has increased interest in using plant-derived foods such as legumes which contain low-fat and are cholesterol free in food formulation. Whole legumes can be milled into flour (Fig. 1) or fractionated into protein, starch and fiber fractions, and these components can be incorporated into commercial food products as functional or replacement ingredients, thereby facilitating their use.

Recent research studies have, furthermore, suggested that consumption of legumes may have potential health benefits including reduced risk of cardiovascular disease, cancer, diabetes, hypertension, gastro-intestinal disorder, adrenal disease and reduction of LDL cholesterol (9). Such studies have spurred interest in using whole legumes and their fractions in developing a variety of novel food products.

Extensive studies have been carried out on the development of legume-supplemented products with unique functionality and enhanced nutritional profile including bakery, meat, extruded, pasta, beverage, yogurt and salad dressings products. The challenges associated with the incorporation of legume flours and ingredients into foods are being addressed through research and examples of some of these studies are provided in Table 1.

For bakery, pasta, and extruded products, the addition of legume flours to cereals can improve nutritional quality by enhancing protein, fiber, vitamin and mineral content and through amino acid complementation. Another advantage of legume ingredient addition is lowering of the glycemic index of the finished food product which is beneficial for people with diabetes. For some applications, the greater viscosity of some legume starches compared to cereals and their high resistance to swelling and rupture offers functional characteristics of interest (5). For other applications (e.g., during extrusion), the appropriate formulation must be identified as adding legume flours could result in harder and unevenly distributed texture of the extrudates during processing mainly due to the high fiber content which prevents maximum air expansion, and also due to differences in the particle sizes of the flours used (e.g., legume and cereal) (2). Berrios et al. (3) suggests that in such instances, addition of increased levels of sodium bicarbonate to legume flours could help to increase extrudate expansion.

Incorporation of legume flours and fractions into meat products is another trend in food formulation and product development. Macromolecules from legumes (i.e., protein and starch) can form three-dimensional gel networks with meat proteins upon heating, through various forces such as van de Waals' electrostatic and hydrogen bonding. The fine particles of emulsified meat or the meat matrix make up this complex network with starch and non-meat proteins as fillers (4). Generally, the addition of binders such as legume fractions into low-fat comminuted meat products can improve textural properties including firmness, chewiness and hardness as well as sensory appeal which may help to address challenges resulting from reducing fat levels (8).

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**Table 1. Examples of some value-added products containing legume flours and fractions**

| Ingredients | Applications | Characteristics |
|---|---|---|
| | | Legume flours |
| Small red, black, pinto, and navy bean flour | Tortilla | Tortillas with acceptable texture and improved nutritional profile were produced at the 25% substitution level. Dough rheology, firmness, cohesiveness and rollability of the tortillas were, however, negatively affected as bean flour content increased. |
| Chickpea, blackeye bean, lentil flour | Low-fat meatball | Legume flour supplementation at the 10% level slightly increased the toughness of the meatballs. Sensory evaluation, however, showed the supplemented meatballs to have acceptable characteristics. The study concluded that legume flour can be successfully used in meatballs as extenders. |
| Lentil flour mixed with corn flour | Extruded snack | Extruded snacks were successfully made, however, the functionality of the extrudates decreased with the addition of lentil flours. An interaction effect between extrusion conditions and material properties was found which would require optimization to yield products with acceptable quality. |
| Extruded chickpea flour | Weaning food | Weaning foods prepared with the combination of extruded chickpea flour (78.8%) and nixtamalized extruded maize (21.2%) showed high protein quality and digestibility which could be used to support the growth of infants. |
| Soy protein concentrates and chickpea flour | Cheddar cheese | The product prepared from a blend in which 25%, 20%, 27.5% and 27.5% of solids-non-fat was supplied from Cheddar cheese, whey protein concentrate, soybean protein concentrate and chickpea flour, respectively, was the most acceptable and had fine consistency. |
| Chickpea, green and red lentil, yellow pea, pinto and navy bean flour | Cracker snack | At a 100% substitution level, pulse based crackers showed similar physical and nutritional characteristics to products on the market and were scored highly in consumer acceptance tests. The products generally exhibited a light colour, good flavour and crisp texture. |
| Pea ingredients (flour, starch, and fiber) | Sausage | Adding pea ingredients to low-fat formulations decreased cooking and purge losses, indicating that the binders (i.e., pea ingredients) improved water retention in the sausage. |
| Split pea or faba bean flour | Pasta | The cooking quality of pasta was impacted when substituted with the pulse flours at the 35% level. Supplementation decreased the optimal cooking time for low temperature dried pasta and resulted in lower water uptake and higher cooking losses. |
| Chickpea flour | Sponge or layer cake | At 50% and 100% substitution levels, lowered cake volume and a firmer texture were observed for chickpea flour fortified cakes compared with the ones made with regular wheat flour. |
| Lentil flour (raw and thermally treated) | Salad dressing | At a 7% lentil flour supplementation, a significantly increased thickening effect and increased color intensity were observed associated with the addition of legume flours, pre-boiling of lentil flour significantly increased this thickening effect. In addition, the quantitative descriptive sensory analysis scores showed promising results. |
| | | Legume fractions |
| Modified pea starch | Low fat or fat free ice cream | Sensory attributes, such as coldness and firmness, for the low fat samples were not significantly different from those for ice cream with regular fat content. Scores for viscosity, smoothness and mouth coating were, however, generally lower for the low fat ice cream prepared using modified pea starch. |
| Field pea hulls | Bread | Field pea hull (containing 55.1% crude fiber) was successfully incorporated at the 15% substitution level. Pre-hydration of the fiber for 20 h before blending of the flours increased loaf volume and bread quality. |
| Dietary fiber from pea cotyledon | Sausage | Supplementation of pork sausage at the 4% level did not change elasticity, cohesiveness, and springiness of the sausage compared with controls. Fiber addition, however increased gumminess and chewiness. |
| Lentil flour | Yogurt | Supplementation of yogurt with lentil flour (1% - 3%) enhanced acid production during fermentation suggesting a prebiotic effect. Syneresis increased at 1% - 2% supplementation, however, the 1% - 2% lentil flour supplemented yogurt showed comparable sensory properties to yogurt prepared with 1% - 2% skim milk powder. |
| Dietary fiber from field beans | Sponge cake | At ~5% supplementation, slight changes of physical characteristics were observed, including reduced pH levels of the cake batter and a reduction of cake volume. The fortified cake, however, had 5.7 g $l^{-1}$ more fiber than the regular cake without change to sensory characteristics. |

Food allergy affects an estimated 4% - 8% of children and 2% - 4% of the adult population. Opportunities exist for the use of pulse ingredients in the development of allergen-free or hypoallergenic foods (8). In particular, the gluten-free sector presents a promising market for 100% pulse-based products. Depending on the pulse ingredient used, the typical beany flavour of pulses may need to be overcome through product formulation prior to product commercialization. Enrichment of foods with pulse fractions also exists in the growing market of crackers and snack products where they can provide superior protein nutritional quality compared to the traditional wheat or corn based products. The incorporation of protein concentrate into products such as breads and cookies generally leads to a less beany flavour and yields acceptable products at substitution levels of up to 10% (1). Breads, bakery goods, and cereal products have been traditional vehicles for fiber enrichment and remain one of the most attractive for the addition of pulse ingredients.

Legumes are also frequently used in the preparation of soups and the market for ready-to-serve soups remains another attractive sector for innovation. Though very few studies have been conducted on the development of legume-supplemented products such as beverages, salad dressings and glazes, significant potential exists to use legumes and their fractions as additives, binders, emulsifiers, thickening or gelling agents in these innovative products due to their attractive functional properties. In our previous work, we studied the characteristics of legume flours and investigated the potential of using pulse flours (including raw and thermally treated ones) to supplement salad dressings (6, 7). The addition of legume flour contributed to the rheological and sensory properties of salad dressing emulsions, owing to the increased numbers of rigid particles and the interactions between the legume flour and other ingredients in the salad dressing.

**Figure 1. Dried legume seeds and their grounded flours**

As a result of their many health-benefiting properties, opportunities exist to apply legumes and legume-derived ingredients in the development of nutraceutical and functional food products. This market is likely to continue to grow as consumers look for health and wellness foods with disease prevention effects. The sector is, therefore, a promising target for the introduction of legume ingredients and the development of innovative value-added legume-derived food products. In general, supplementation of traditional foods with legume flour and their fractions can help to improve the nutritional quality of foods by enhancing protein, fiber, vitamin, mineral content and sometimes through amino acid complementation. A significant amount of work has been done in the last two decades on the primary, secondary and tertiary processing of legumes which has made legume flours and their fractions as well as some new and innovative legume foods more readily available commercially. Further research is still required in order to expand the availability of these healthy, nutritious ready-to-eat, ready-to-cook, ready-to-use legume-products and to optimize the quality of these legume-based products for specific markets.

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# Consumer behavior and public health in relation to novel legume food uses

by Jean-Baptiste TRAVERSAC[1]* and Daniel TOMÉ[2]

It is usually unknown that the part of protein from plant in the human diet is twice the part from animal origin in the world (7). Cereals represent the main share followed by pulses and oilseeds. Protein consumption depends from local habits and customs establishing geographical differentiations in relation with income level. The more the income is high, the more the vegetable share of the protein delivery drops. A worldwide typology of food consumption models defines an international differentiation, Mediterranean vs northern European countries, Latin vs North America. Despite a relative disinterest on the value and potential of Legumes in feeding the world, the attributes of the Ancient and Novel Protein Foods based on vegetable sources present a potential of interesting effects on human welfare with a wide range of direct and indirect consequences.

From a public health consideration, Legumes are food of interest for improving social well-being considering four types of perspectives.

## > Food security developing perspective

The lowest cost of Legume proteins and their environmental externalities guarantee a sustainable food offer to the world population. In a view of the high cost of the conversion of plant proteins into animal proteins, Legumes in human consumption present food security arguments for increasing the availability of protein to meet protein needs in developing countries but also as a substitute to animal protein in developed countries. Specialists estimate that wasting 1 kg of boneless beef has approximately 24 times the effect on available calories as wasting 1 kg of wheat (*Triticum aestivum* L.), because of low yield in converting feed to animal calories and proteins (9). Compare to the cereal, Legumes are rich in proteins (0.20 in pea, *Pisum sativum* L., and 0.11 in wheat) and contain a reduce level of lipids compare to soy-bean (*Glycine max* (L.) Merr.). The lower content of essential amino acid of Legume protein induces a risk of deficiency for some of these amino acids. This can be overcome by the association of different protein sources with complementary amino acid composition. The improve usefulness of diverse sources of protein in traditional diets (meat/legume, cereal/legume) ascertains the opportunity of multiple protein origin meals. In addition, the usually and lower digestibility of Legume protein can be improved by specific cooking preparation*. There are considerable economic and political issues of a change in protein diets at the European as well as at the World scales. The dietary transition opportunities offered by mixed diet with Legume, Cereals, and Meat, challenge the Meat and Milk consumption (8). Indeed a change in the protein consumption will divert the trajectory of the whole agrifood chains. A reduction of feed uses to fatten pig, beef, and poultries, will have unpredictable incidences on food industry employment. The over consumption of meat protein is nonetheless an excessive luxury if humanity want to reach a sustainable access to more balance diet.

## > Nutritional habits perspective

Many chronic non-infectious diseases are correlated to inadequate diet. For instance, meat consumption provides a high level of fat associated to a high level of protein. If the over-protein absorption is of secondary and specific incidence in health, high levels of meat consumption are positively correlated with saturated fat (1), which are recognized as risk factors for obesity and cardiovascular diseases. A Legume shift can contribute to partially prevent the problem (2). The protein quality outcomes on health are of a very complex nature (Fig. 1). Physiologic and metabolic responses to protein consumption have short and long term outcomes of complex nature with negative as well as positive incidences on health. Contemporary medical literature goes deeper in the protein functions in human metabolism. Proteins are involved in various fundamental functions related to tissues growth and repair, muscle and skeletal athletic performance, but also to immune function, mental performance, and detoxification. More and more, authors observe and specify protein long term outcomes on chronic diseases (cancer, hypertension, oxidative damage, repair systems, and age related functional losses). In addition, Legumes are also an interesting source of fibres which usually improve gut

*The only truly valid measures of protein quality for humans are those that assess directly the effectiveness of different protein sources to provide for normal growth and, or other functions dependent on adequate protein nutrition in subjects that represent the target population.

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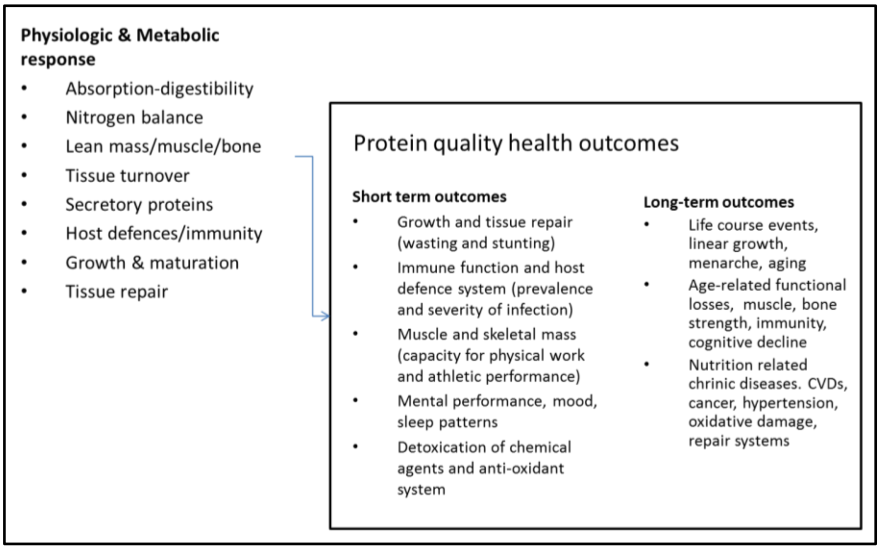


**Figure 1. Framework depicting short- and long-term potential protein quality-related health outcomes; based upon the FAO Food and Nutrition Paper n°92 (4)**

motility and different metabolic biomarkers. The social cost of chronic diseases is better and better understood: e.g. the economic burden of coronary heart disease, closely related to food habits, is estimated to cost 1 point of GDP by OECD.

## > Food safety perspective

Less attention to food safety and rise of food flaws in emerging countries led to an increase in the spread of infectious diseases originating from animals, such as the avian flu (5). The contamination of meat by growth-promoting antibiotics, hormones, bacteria, such as E. coli, or toxins, such as dioxin, is a related but serious risk to human welfare. The replacement of meat by legume will reduce contamination and the cost of the cold chain to ensure the safety of meat products. This issue is of particular importance in developing countries considering the lack in industrial tools and regulation.

## > Diet transition perspective

A major change in protein consumption will have interesting result for economic and ecological sustainability of the food systems. Indeed food choice motives are very difficult to transform. Although consumers do acknowledge the positive aspects in meat substitutes, it is not something they are aiming for in a food product (6). In west countries, people continue to overeat. A substantial number of consumers do not appreciate the idea that they would have to eat less meat (3). Unhealthy foods pose serious public health questions. Indeed major health campaigns promote the reduction of fat consumption and go in the sense of developing meat substitute. Nevertheless health campaigns never targets fresh legume consumption.

## Conclusion

The line of our presentation was how the Legume food could be the drivers of important changes in the health economics. One important feature of the development of the future public policies is on the understanding of local protein sources variability. Forage experts recommend a new amino acid analyses of local food sources (10).

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# Market opportunities for pulses in food manufacturing

by Elisabeth LUSTRAT

**Abstract:** As the world's population and pressure on natural resources increases, we must increasingly turn to alternative sources of protein. Pulses are an excellent solution, for their significant benefits for agriculture (nitrogen fixing) and health (protein, fibre, micronutrients, low allergenicity). Industry and public authorities are launching initiatives to drive uptake of pulse farming. However, progress is needed in terms of stabilizing yields. From a food-processing point of view, careful consideration of the target consumers' highly diverse preferences and usages is also necessary to ensure market success of processed products using pulses.
**Key words:** consumer preferences, plant proteins, pulses, sustainable agriculture

Global food production is in a constant state of growth, largely due to the sustained progression of the world's population: projections are suggesting a jump to over 9 billion people by 2050. In parallel, global meat consumption has tripled in the last 50 years, adding ever more pressure to finite natural resources. By nature a greedy consumer of farmland, water and energy - between 10 to 15 kg of plant proteins are needed to produce a single kilogram of animal protein - animal production is clearly not a sustainable option for ensuring an adequate protein supply for the world's population in the decades to come.

In this context, the interest of plant protein production, most notably pulses, immediately sparks interest from a sustainability standpoint. A closer look at the technical and economic characteristics of pulses casts an even more favourable light. To begin with, the production of pulses requires five to ten times less arable land than animal proteins. Furthermore, pulses demonstrate a genetic diversity allowing them to adapt to a large range of climates and to large scale farming methods. Finally, the cropping of pulses is sufficiently flexible to allow for insertion into agricultural systems at a variety of points (winter or spring for crop rotations, for example), not to mention their agricultural advantages in terms of nitrogen fixing.

The overwhelming obstacle to increased uptake of pulse production, however, remains their low level of cost-effectiveness in comparison to other crops, in particular cereals. Focusing on the economic advantages of pulse production could prove one way of boosting this uptake. For example, over the last few years, the price of pea (*Pisum sativum* L.) protein (concentrate and isolate) has increased sharply, translating a supply and demand imbalance for these ingredients, known for their low allergenicity, unlike wheat (Triticum *aestivum* L.) and soy (*Glycine max* (L.) Merr.) (4). In the short term, the Common Agricultural Policy is also maintaining subsidies linked to plant protein productions. On a national level in France, a number of initiatives between government instances and professional organisations are aiming to stimulate pulse production: two French ministries (Agriculture Ministry and Economic Development Ministry) as well as the French federation of protein and oil crop producers (*Fédération Française des Producteurs d'Oléagineux et de Protéagineux*) and Coop de France are offering incentives to encourage pulse crops.

The economic and agricultural advantages, although numerous, are not the only reasons for government and national bodies to throw their support behind pulse production. It is in terms of their nutritional value that pulses present another highly compelling argument (Table 1).

**Table 1. Main constituents in terms of percentage of dry matter of three main pulse varieties (1, 2)**

| Pulse variety | Protein (%) | Starch (%) | Lipid (%) | Seed coat (%) |
|---|---|---|---|---|
| Smooth spring pea | 25 | 50 | 1.8 | 13 |
| Chick pea | 19.4 | 54.9 | 5.6 | 25.6 |
| Spring faba bean | 31 | 48 | 1.5 | 18 |

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The nutrition-health benefits of pulse consumption demonstrated by Table 1 are numerous.

*Positive nutritional benefits*. The main interest, of course, is their high protein content (despite tendencies in some countries to classify pulses primarily as starchy foods), but also in complex carbohydrates and in dietary fibre, the latter being of particular interest in developed countries where fibre intake remains well below recommendations. Other non-negligible advantages are the low percentage of dietary fats (lipids) and the significant levels of vitamins (B group vitamins) and minerals (magnesium, potassium, iron, zinc). As mentioned above, pulses also present low allergenicity, a strong argument for their use in industrial food production.

*Absorption of sugars*. Pulses have a low glycaemic index, and are consequently well-adapted to specific diets (diabetes etc.) on the condition that they have not been "degraded" by secondary processing.

*Effect on gut health*. An increased intestinal transit thanks to their high fibre levels.

*Hunger suppressant qualities*. The high protein and fibre levels of pulses combined with their low glycaemic index can indicate a satiety-inducing effect (hunger suppression, reduction of food intake etc.) of foods in which they have been incorporated.

For all the compelling nutritional arguments for pulses consumption, consumer acceptability of pulses remains hugely variable throughout the world, in both developed and developing countries. Annual world per capita consumption in 2011 was 6.8 kg, but can vary from 16.8 kg in Brazil to less than 2 kg in Russia or France (3). In their basic form, the general sensory characteristics of pulses are not terribly well regarded by the Western palate, with reproaches including bitterness, a "green/vegetal" flavour, and the floury texture of the cooked grains. However, even in countries where overall pulse consumption is low, traditional recipes can be found where pulses take centre stage, as is the case with lentils (*Lens culinaris* Medik.) or haricot beans (*Phaseolus vulgaris* L.) in such French classics as *petits salés aux lentilles* or *cassoulet*. A renewed interest in tradition/*terroir*/rediscovery of roots as well as vegetarianism as a growing trend (outside of Anglo-Saxon countries where vegetarianism is well established) is driving recent demand for pulses. Given that a large divide exists between consumer perception of meat and pulses in terms of their sensory characteristics, attempts to capitalise on vegetarianism applied to pulses has mainly taken the form of processed products designed to mimic the texture and format of meat (lentil steaks, for example) in an attempt to transpose the successful economic model of soy products.

Whatever the general perception or current pulse consumption levels, a closer look at the usages and preparation modes is essential for evaluating market potential for a particular application, as these vary significantly from one country to another. Starting at the lower end of annual per capita consumption (2 kg), the French associate pulses with meat-based dishes rather than vegetarianism and prefer processed products (ready to eat/heat dishes) rather than pulses in their basic form. In Russia (1.8 kg per capita per year), dried peas and faba beans (*Vicia faba* L.) are considered a traditional regional food, again associated with meat and with little relation to vegetarian or specialised foods for which there exists very little infrastructure (specialised or dietetic stores, for example). Continuing up the scale of per capita consumption, in the USA and Canada (3.8 kg and 11.8 kg respectively), dried peas and beans can be a regular part of meals with consumers favouring the usage of dried or canned pulses in slow-cooked sauces and stews. Finally, in Brazil, at the top end of per capita pulse consumption (16.8 kg), pulses are consumed daily with pressure cookers increasing speed and ease-of-use for dried beans selected for their colour and size (very little consumption in canned/pre-cooked forms).

In conclusion, the ecological arguments for developing the pulse industry sector remain compelling, with emerging economic opportunities reinforcing the interest expressed by government and professional bodies seeking to boost production. While a number of agricultural and technical points have been identified as hampering industry development, R&D initiatives are multiplying on national and European levels to find durable solutions to these problems, be it stabilising yield or avoiding perceived sensory defects to pulse-based products and ingredients. Essential, however, to a successful capture of market opportunities for pulses is an overall approach, from "farm to fork", pooling knowledge and expertise to overcome identified obstacles, but also allowing consumers to provide focus and drive for successful product development and market launches, throughout the world.

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# When traditional Western crops meet Eastern microbial eukaryotic fermenters for the production of innovative "gourmet" food

by Catarina PRISTA

**Abstract:** The growing demand for healthier and/or special consumption behaviors, together with the curiosity for new diets and the availability of new food products, led to a change of Gastronomy focus towards the development of innovative Functional Foods. Fermented foods from Eastern countries, based on legumes and grain fermentations are among the most desired by consumers for their nutrition value and potential as Functional foods, and by top Chefs for their diversity and originality. Chefs and scientists are now collaborating to produce new Eastern-derivative fermented products, with new textures and flavors, based on Western traditional crops. These new fermented foods are used as "gourmet" foods, adding value to low cost raw materials, and helping to disseminate new healthier consumer habits and to increase consumers demand.

**Key words:** Eastern-derivative fermented foods, food innovation, Western traditional legumes

The growing consumer interest in healthier and/or special consumption behaviors together with curiosity for new diets, and the availability of new food and beverage brought by globalization, is transforming the food industry as we know it, and redefining the relationship between food, nutrition, and health. A focus of the modern food industry is now to develop Functional Foods, healthier and more flavorful. Among these, fermentations are time-honored methods of food processing (3).

The fermentation process of legumes, results in a significant increase in their soluble fraction, and decrease in indigestible and toxic compounds, and thus increases their nutrition value and potential as Functional foods. The quality of the proteins increases (3, 7), the lipid content is reduced and often the content of water-soluble vitamins is increased, while the anti-nutritional factors decline during fermentation (6, 9). Also, the digestibility of starch increases (2, 8), phytic acid is degraded (1), the trypsin inhibitor is inactivated, and the amount of several oligosaccharides (e.g. stachyose and raffinose) which usually cause flatulence are significantly reduced (1).

Today, many consumers are curious and adventurous, regularly seeking out opportunities for discovery, challenge, and education in their dining experiences and appreciating the increasing availability of such occasions. Combining novelty and health, the interest and curiosity about some popular fermented ethnic foods such as Asian foods experimented a noticeably rise in the last years in occidental countries. They include, but are not limited to, well know fermented foods and seasoning obtained from the fermentation of legumes like "miso" and soya (*Glycine max* (L.) Marr.) sauce but also traditional foods like "natto" and tempe among other less recognized specialities. Meals based on these products frequently focus on legumes, fruits and grains, with meat frequently substituted by fermented legume-based products. These Eastern fermented products stimulate the mind as well as the senses, contributing to some of the most innovative flavors and trends of the 21st century.

Figure 1. Miso made from white lupin

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The increasing importance of new fermented foods found echo on the more up-to-dated tendencies of important restaurant Chefs of the Western world. These professionals (together with the scientific teams with whom many of them collaborate) are now developing new fermented products by adapting firmly grounded ancient fermentation practices to traditional occidental raw-materials (10) producing innovative foods with intriguing textures found nowhere else that are at the intersection of tradition and innovation (4, 5).

In recent years, both our research lab at ISA and CookLab company (a R&D company from INOVISA start-up center dedicated to the study of gastronomical phenomena) have been collaborating on the Fermented Food development research field. As a result of this activity, a significant collection of bacteria, yeast and mold pure strains related to fermented foods were specifically isolated and purified from Asian fermented foods and their inocula (koji and "red rice", miso, tempe, and natto). Taking advantage of the strain collection, and in straight collaboration with Portuguese restaurant Chefs, novel fermented foods from Asian and traditional Portuguese substrates such as miso from white lupin (*Lupinus albus* L.) (Fig. 1), tamari, and tempe from green peas (*Pisum sativum* L.), white lupin and black beans (*Phaseolus vulgaris* L.) (Fig. 2) have been developed and the fermentation process was optimized for some of the Portuguese top chefs (e.g. the two Michelin stars José Avilez) interested in being up-to-date with the new gastronomical tendencies. The development of fermented foods and derivatives under controlled conditions, as well as the creation of new textures and flavors, has been utilized by the Chefs in a "gourmet" perspective.

Using these products, new recipes have been created under a "gourmet" perspective, combining simplified house-holding processes for production of the fermented food together with suggestions of new recipes and applications for these products (Fig. 3). This approach, simultaneously scientific and gastronomical, will certainly contribute for the promotion of legume acceptance by consumers.

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**Figure 2. Tempe made from white lupin (a) and black beans (b)**

**Figure 3. White lupin tempe snacks**

# Use of rich L-DOPA *Vicia faba* seeds for the Parkinson's disease treatment

by Carmen BURBANO, Carmen CUADRADO, Mercedes M. PEDROSA and Mercedes MUZQUIZ*

**Abstract:** Faba bean (*Vicia faba*) cotyledons contain more than 90% of proteins, carbohydrates and lipids while testa contains the majority of fibre, mineral salts and vitamins. Processing generally improves their nutrient profile by increasing *in vitro* digestibility of proteins and carbohydrates from around 40% up to 98%. Faba bean compared with other legumes is relatively devoid of protein antinutrients, being the main compounds the pyrimidine glycosides implicated as the causative agents of favism: vicine and convicine and the aminoacid L-DOPA. The nonprotein amino acid L-DOPA only appeared in the embryo axis of *Vicia faba* seeds being the precursor of the neurotransmitter dopamine. Clinical studies have shown that faba bean sprouts, rich in L-DOPA, have anti-Parkinson's effects without any side effects of the pure synthetic form. From a nutraceutical point of view, the use of germinated beans FEVITA® free of vicine, convicine and tannins, and rich in L-DOPA can be of great interest for a possible treatment for Parkinson's.

**Key words:** faba bean, FEVITA, germination, molecular markers, vicine-convicine

The legume family is one of the largest in regard to number of species and the genus *Vicia* L. is used as an important protein source for animal and human feeding in various parts of the world due to its nutrient composition. The enormous importance of plant foods is now recognised all over the world. Faba bean (*V. faba* L.) seeds are high in protein, carbohydrates and fibre, low in fat and provide many vitamins and minerals. Nevertheless, when plant foods are consumed they are often associated with a series of compounds, known as antinutrients, which generally interfere with the assimilation of some nutrients. In some cases these can be toxic or cause undesirable physiological effects (for example, flatulence). However, recent epidemiological studies have demonstrated that many antinutrients may be beneficial, in small quantities, in the prevention of diseases like cancer and coronary diseases. For this reason they are now often called nutritionally active compounds because, although they may lack nutritive value, they are not always harmful (10).

The chemical composition of faba bean has been analyzed in the whole seed and in every one of its components (cotyledon pair, embryo axis and testa). Cotyledons contain more than 90% of proteins, carbohydrates and lipids while testa contains the majority of fibre, mineral salts and vitamins (11).

Processing generally improves the nutrient profile of legume seed by increasing *in vitro* digestibility of proteins and carbohydrates from around 40% up to 98% (4). At the same time there are reductions in some antinutritional compounds (8).

Among the traditional processing techniques we can outline: a) Heat processing, such as cooking at atmospheric pressure, autoclaving or roasting and b) Non-heat processing such as imbibition, germination, dehulling or fermentation. Most antinutritional factors are heat-labile, such as protease inhibitors and lectins, so cooking would remove any potential negative effects from consumption. Tannins, saponins and phytic acid, on the other hand, are heat stable but can be reduced by dehulling, soaking, germination and/or fermentation.

Faba bean compared with other legumes is relatively devoid of protein antinutrients, such as lectins, but it does contain protein inhibitors, α-galactosides, phytates, saponins, tannins and pyrimidine glycosides: vicine and convicine and the aminoacid L-DOPA (5). These pyrimidine glycosides are implicated as the causative agents of favism, a genetic disease that causes haemolytic anaemia in males which lack glucose-6-phosphate-dehydrogenase in their erythrocytes (9). The effect of germination on the content of the main nutritionally active factors in cotyledon pair and embryo axis of seeds and seedlings of *Vicia faba* L. var. Alameda and var. Brocal has been studied (5).

The nonprotein amino acid L-DOPA (L-3,4-dihydroxyphenylalanine) only appeared in the embryo axis of *Vicia faba* seeds being the precursor of the neurotransmitter dopamine (6). Clinical studies have shown that faba bean sprouts, rich in L-DOPA, have anti-Parkinson's effects without any side effects of the pure synthetic form (1).

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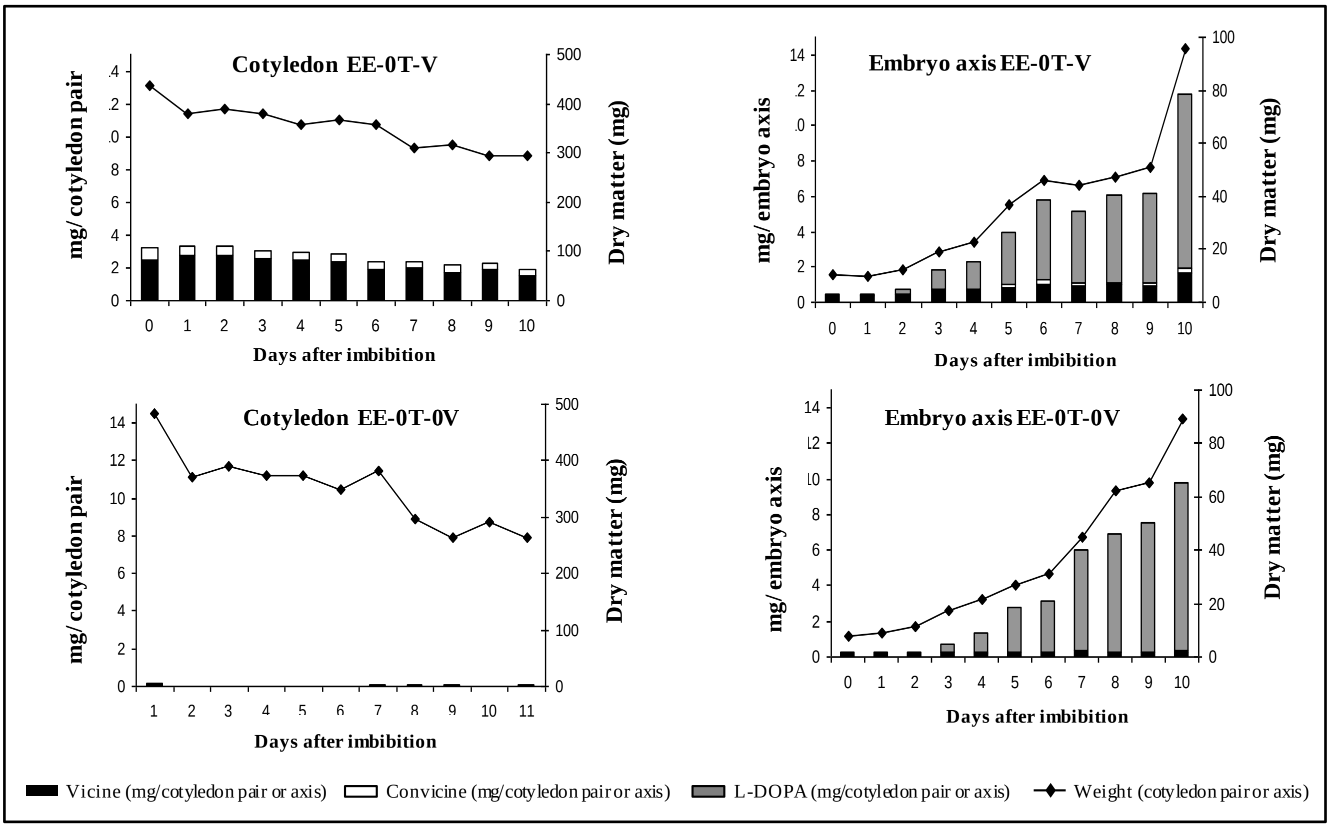


**Figure 1. Content and distribution of vicine, convicine and L-DOPA and changes in dry weight during 10 days of germination**

Recently, a cultivar of beans without tannins and low in vicine-convicine, has been registered as FEVITA®. The quality of the seeds is based on the presence of one of the two genes (*zt1* or *zt2*) which remove tannins and gene vc- which dramatically reduces the content of vicine-convicine (3).

The content and distribution of vicine, convicine and L-DOPA have been analysed during the germination (Fig. 1) of two lines (EE-0T-0V and EE-0T-V) nearly isogenic (NILs) of FEVITA® beans. The effectiveness of molecular markers closely linked to the gene vc- developed by Gutierrez et al. (7) has also been tested in this lines differing in the vicine-convicine content.

The pyrimidine glycosides, vicine and convicine, were predominantly found in the cotyledon and their content in the EE-0T-0V line was 15 times less than the line EE-0T-V (0.62 mg cotyledon pair$^{-1}$ and 9.39 mg cotyledon pair$^{-1}$, respectively). L-DOPA, however, was detected in the embryonic axis and presented a nearly identical content on both lines (0.028 mg plant$^{-1}$ and 0.023 mg plant$^{-1}$, respectively). The evolution of these compounds was similar in the two accessions during their germination (Fig. 1). However, while vicine and convicine just dropped on its initial content, levels of L-DOPA were increasing in the embryonic axis as germination progressed. The content was highest at 10 days, resulting 9.85 mg plant$^{-1}$ in EE-0T-V line (492 times higher than the initial) and 9.42 mg plant$^{-1}$ in the EE-0T-0V genotype (350 times greater than the initial) being, in both cases, the epicotyls more rich in L-DOPA than the hypocotyls (11).

The pattern obtained with the SCAR $SCAB12_{850}$ marker, linked to the allele vc-, has demonstrated its efficiency in the identification of genotypes free of v-c for quality control required in the certification of seeds (Fig. 2). From a nutraceutical point of view, the use of germinated beans FEVITA® free of v-c and tannins, and rich in L-DOPA can be of great interest for a possible treatment for Parkinson's.

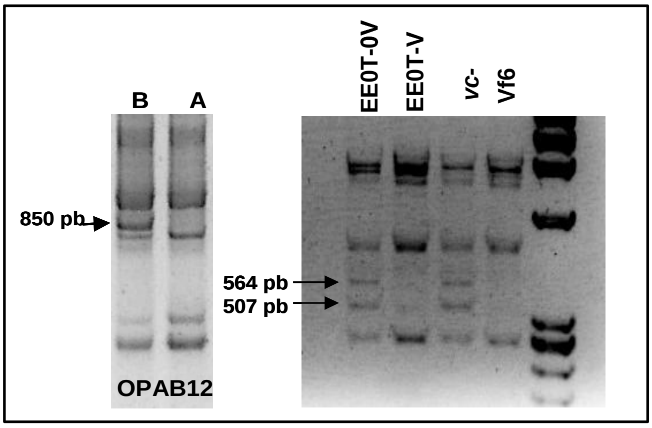


**Figure 2. (left) Original RAPD which difference genotypes B (low content in v-c) and A (high content); (right) pattern of amplification of the SCAR, SCAB12$_{850}$ after digestion with *RsaI* in beans with high (EE-0T-V y Vf6) and low (EE-0T-0V and vc-) content in vicine, convicine; the polymorphic bands are indicated with arrows**


**Acknowledgements**

The authors wish to thank Dr. G Duc for supplying the FEVITA® lines and to Dr. A. Torres and Dr. N. Gutierrez for the SCAR marker analysis.


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# Achievements and challenges in improving pea seed quality for food

by Claire DOMONEY

**Abstract:** Sustainability and sustainable intensification are currently at the top of the agricultural agenda and increasing the rate at which legume crops such as peas and beans are incorporated into crop rotations is very desirable in attaining this goal. One way to promote legume and pulse crops is to improve end-use traits to meet the demand for high quality in extant or emergent new markets. This is one of the challenges being addressed within the Defra-funded Pulse Crop Genetic Improvement Network (PCGIN, 2015-2017) and the EU LEGATO project (FP7-KBBE-2013-7-613551).
**Key words:** food quality, pea, sustainability

Legume crops contribute positively to lowering inputs: firstly nitrogen inputs over the whole rotation are decreased since legumes require no nitrogen themselves and, secondly, they provide the nitrogen fixed in their nodules to the following crop in the rotation. Legume crops are also an excellent choice where a third crop is needed in a cereal - oilseed rape (*Brassica napus* L.) dominated system and, under CAP reform, fulfill the requirements of 'greening measures'. To encourage choices in favour of legume crops, there is a need to ensure that the return on growers' investment is high. Where both yield and quality of the marketable crop are consistently high, the high-value home and export markets that exist should provide large incentives in favour of legume crops.

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For pea (*Pisum sativum* L.), the very diverse food markets that exist for vegetable and combinable crops and derivatives of the latter mean that several types of seeds are used, often representing diverse genetic groups.

For vegetable pea products, immature pea seeds (vining pea for frozen or canned products), pods (sugar snap or mange tout) or whole shoots as salad components are used. In addition dried mature pea seeds, such as marrowfats, are used as dried or canned products, or processed to yield flour for a wide variety of food applications. Add to this the demands for an ideal composition for feed use to provide a snapshot of the plethora of seed quality traits that are desired by end-users.

For food use, the market demands are fairly clear. Visual as well as compositional traits are closely linked with crop value. Many visual traits are linked to plant health status so, for example, blemished seed coats and holes in seeds reflect disease and/or insect attack. While improving the genetics of disease and insect susceptibility may be desirable, incidences of attack may be low and sufficiently controlled by chemicals that are currently permitted. For other visual traits, a combination of improved genetics and harvest management is required, for example in maintaining seed colour stability in pea seeds. Compositional traits are related to texture and linked closely to the balance of starch, sugar and protein which is determined by genetics and the environment. Besides the desired visual, taste and flavour traits, there is increasing emphasis on the varied health benefits afforded by such foods as are derived from pea and other legumes (2). A major challenge is to provide breeders with tools and resources to improve crop quality traits without compromising yield.

## Improved tools and resources to breed for quality

Mutations affecting starch accumulation have been exploited widely in foods, since blocking starch synthesis leads to a higher content of sucrose and other sugars, many of which contribute to sweetness. However, starch is a major determinant of product weight or yield, and is essential not only to productivity but also to seed vigour. In pea, two naturally occurring mutations have been exploited commercially (*r* and *rb*). These disrupt two distinct steps (starch branching enzyme and ADP-glucose pyrophosphorylase, respectively) of the pathway leading from sugars to starch (11). Most vining peas in the UK are the *r* genotype, but recently novel cultivars generated in a number of countries have entered breeding programmes, either as single mutants or in combination with the *r* mutation. The term 'supersweet' has been used to describe lines having both mutations. However this term has also been used to describe a distinct genotype of pea, where there is a mutation in a third gene, *pgm*. *Pgm* mutations have been identified in mutagenised populations within research programmes and at least one of these has entered breeding programmes. All three gene mutations lead to a wrinkling of the seed and selection of mutants by breeders has been based hitherto on phenotype. Degrees of wrinkling can identify the different types and their combinations but this approach is very prone to mis-scoring, on top of the fact that environmental effects on seed appearance can be large. Knowledge of the mutations that are currently in use and the ability to screen for these rapidly within breeding programmes will greatly facilitate the combination and selection of mutations. DNA-based screens have been developed

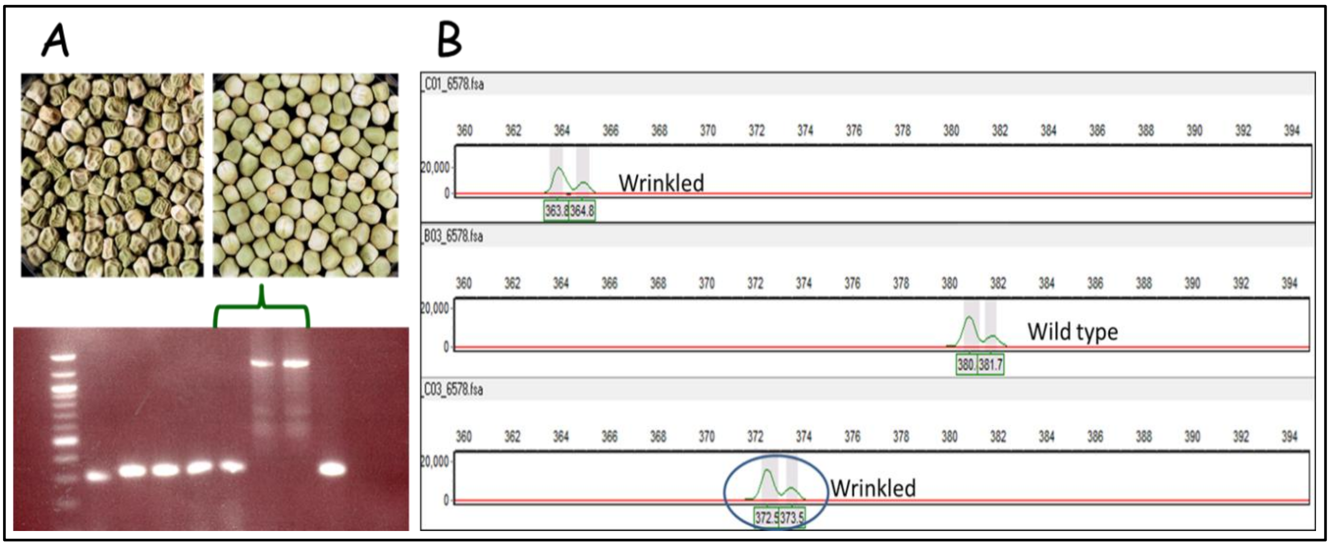


**Figure 1. DNA-based screens distinguish *RRRbRb* from *rrRbRb* genotypes (lower panel, A), and *RRRbRb* from *RRrbrb* genotypes (B) among starch mutants in pea (A, top panel, left). In A (lower panel), a larger amplicon identifies the naturally occurring *r* allele in two of three wrinkled-seeded genotypes (bracketed) among eight lines screened; markers are shown on the left of the gel where the strongest bands are 500 and 1000 base pairs. In B, three *rb* alleles are distinguished, using a fluorescent marker screen. One of these identifies a mutant *rb* allele (circled); the smallest amplicon was present in a *rrRbRb* genotype**

that can distinguish *r* and *rb* alleles (Fig. 1) and identify lines carrying both mutations. Including a third assay in the genetic screen defines whether the *pgm* mutation is present or not. In this way, two types of so-called 'supersweet' UK breeding lines have been identified genetically as *r*/*rb* in one case and *r*/*pgm* in the other. The effects of these mutations and combinations thereof have implications for the many vegetable uses of pea; a higher sweetness is valued by the consumer of immature and mature seed products and reducing the amounts of sugars added to processed products offers economic and perceived benefits to the industry.

Protein is a second very valuable component of mature legume seeds which, alongside cereal grain products, can offer a high quality balanced and healthy diet as an alternative to animal products. Protein quality varies enormously among legume seeds, in part reflecting variation in the concentration of anti-nutrients. In pea, lectin, pea albumin 2 and the trypsin/chymotrypsin inhibitors have been highlighted as having negative impact as components of animal feed (1, 3, 10). There is little evidence that these proteins are a problem for human food, although pea albumin 2 is closely related to a chickpea (*Cicer arietinum* L.) allergen (10). However, the ability to change the profile of protein products in seeds is afforded by identifying mutations, both natural and induced, that have major impact on the accumulation of particular gene families. A null albumin 2 mutant was identified as a natural variant in pea germplasm (10; Fig. 2), while screening fast neutron mutagenised lines has yielded a range of knock-out mutations affecting a range of vicilin and lectin proteins (3). The induced mutations may be combined with each other and with natural variants, either null or quantitative variants, to produce germplasm with higher protein quality. These new variants may be predicted to offer advantage in terms of processing quality (5, 6) and possibly organoleptic advantage, although the determinants of the latter are less clear. Different classes of pea proteins contribute, for example, to gelling, emulsification and foaming properties and compositional variation offers benefit to the industrial processing of different types of foods (5, 6, 9). Quantitative variants for lipoxygenase (LOX) enzymes have been identified in pea; individual LOX enzymes have been implicated in the development of flavours, both positive and negative, or with loss of colour through co-oxidation reactions (4, 7). A null variant for pea LOX-2 (4) may be exploited by the food industry, where the derived intrinsically flavourless flour offers potential for developing products based on flavours derived purely from added components.

## Improving both quality and yield

The concentrations of seed starch and protein are both associated with yield. A major question is whether by extending the range of genetic variation that is available to breeders, it might be possible to improve both quality and yield. An allelic series of starch mutations at the *r* and *rb* loci in pea (11) is being exploited to examine this question, and novel protein mutants (3) will allow the relationship between protein concentration and yield to be unravelled. Additionally, sucrose-derived oligo-saccharides have been shown to impact on seed vigour in *Medicago truncatula* Gaertn. (8). Quantitative variation exists for this range of compounds in pea (Fig. 3), which needs to be explored in terms of impact on both quality and yield as a consequence of early seed establishment. Through a combination of natural and induced diversity, an understanding of how quality may be improved without detriment to plant health and overall yield may be reached, with delivery of improved tools and resources to the breeding industry.

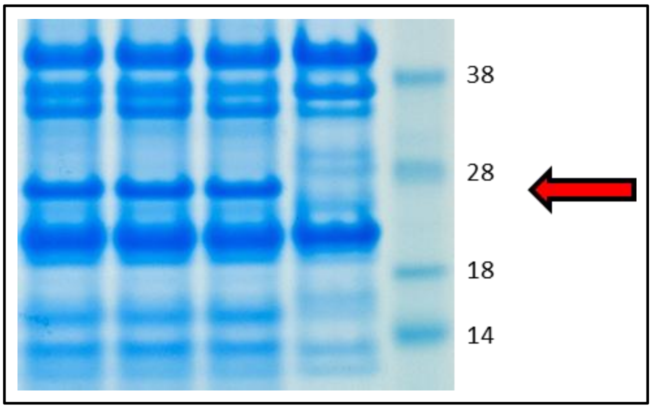


**Figure 2. Analysis of proteins in pea seeds showing the mutant lacking pea albumin 2 (arrowed), of approximate M, 26,000, compared with three other genotypes. Markers are shown on the right of the gel (x $10^{-3}$), a 4-12 % Bis/Tris gradient, using MES buffer (Invitrogen)**

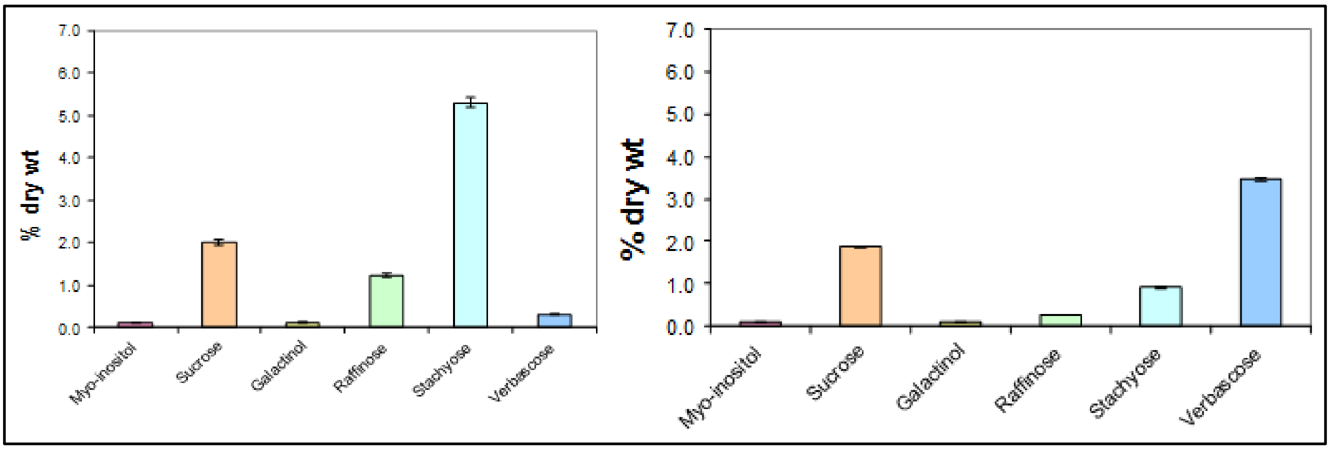


**Figure 3. Quantitative analysis of oligosaccharides and their precursors in mature pea seeds by gas chromatography-mass spectrometry; note the higher raffinose and stachyose concentration in an exotic pea line (left), compared with a cultivated pea (right)**

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# Achievements and new challenges in improving lentil quality for food

by Albert VANDENBERG

Pulse crops supply environmental benefits in crop rotations through nitrogen fixation ability and nutritional benefits in human diets because of their ability to supply complementary protein with cereals, complex carbohydrates and micronutrients. In spite of these well-documented benefits, on a global scale, the crop group is losing ground. From 1973 to 2013, the human population grew by 80% and the total production (1973-1978 mean vs 2008-2013 mean) of pulses rose by just over 65% (FAOSTAT, 2013). About 10 pulse crops provide most of the 73 Mt of total pulse production. During the same 40 year period, world lentil (*Lens culinaris* Medik.) production has increased by 264%, more than three times the growth in population (Fig. 1).

What can we conclude from these data? Simply put, per capita consumption of lentil is rising much faster than almost all other pulses. The most logical explanation for this is the fact that lentils have relatively small seeds, they have a flat shape which favours rapid imbibition, and most lentils are consumed after they are dehulled, resulting in a product that typically cooks faster than milled rice (*Oryza sativa* L.).

**Figure 1. A field of lentil**

Most minor crops like lentil are in a state of "nutritional competition" with dozens of other grain crops that are being marketed on the same basis of health and nutrition. The basic food quality status of lentil was reviewed by Bhatty (1). An updated review of the lentil nutritional profile was provided by Erskine et al. (3), and efforts to biofortify lentil for micronutrients, particularly iron and zinc were described. Improving plant-based iron from seeds remains both an agronomic and a genetic challenge from the standpoint of increasing the total concentration of bioavailable iron and zinc. In the case of lentil, consumption after dehulling improves iron bioavailability (2). Additional research is underway for characterization the baseline profile of folates, carotenoids and other micronutrients in lentil. These efforts could lead to further investments in breeding and genetics if the perceived future value placed on lentil on the basis of nutritional profile is justifiable.

For relatively small crops like lentil, a limitation in crop improvement is that it has a large genome, which poses limitations on investment in genetic and genomic analysis at this time. Although the genome is now being sequenced, the problem of the high cost and complexity of nutritional phenotyping still remains. One of the challenges that lies ahead is developing coordinated approach to improvement of nutritional quality keeping analytical costs minimized.

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**Figure 2. A wide variety of colours and patterns of seed coat and cotyledon colours in lentil**

Lentil seeds have many colours and patterns of seed coat, three cotyledon colours and a wide range of seed weight (Fig. 2). These combinations create a range in flavour, texture and colour that can form the basis for supplying traditional markets and creating new consumer products. In Montana, a group of farmers who were initially interested in using a black small-seeded lentil (cv. Indianhead) for environmental benefits as a green manureplowdown, eventually created a high end culinary market for it by renaming it 'Beluga' (www.lentilunderground.com). Seed coats of black lentil have a unique polyphenolic profile that gives them a unique flavour. Another marketing achievement is the development of a market for green cotyledon lentil – a small but growing market for a trademarked product marketed as 'Queen Green'. A detailed analysis of the biochemistry and the associated genetics of lentil seed coats is underway (6) to gain a deeper understanding of how to improve lentils with respect to dehulling characteristics and economics. One of the challenges in the lentil industry is to determine how to develop more efficient dehulling, through genetics or processing methods, and to also maximize the value of the nutrients of the removed hull fraction. Genetic mapping of the various traits that determine the basis of consumer visual preference has begun, and soon it will be possible to design breeding projects on the basis of using molecular assisted breeding technologies (5).

Fundamentally, consumers are demanding more lentils, and they are willing to pay higher prices for a lower yielding grain legume like lentil compared to most other pulse crops because of their desire for quick-cooking whole food. From that perspective, one of the foremost "qualities" of lentil is lower cooking cost and time, and it is possible to reduce this even more by reducing seed size.

Lentil has considerable untapped genetic resources for future breeding potential, since 5 of the 6 wild species are accessible genetically (7). Most of the efforts to expand potential through introgression of wild species are focused on increasing tolerance to biotic stresses (usually diseases) and abiotic stresses (usually drought). All of the wild species have much smaller seeds than cultivated lentil, so genetic potential exists to reduce seed size and cooking time further. The nutritional profile of wild lentil may also provide additional genetic variability for nutritional traits like increase micronutrients, folates or protein components - these analyses are in progress. This challenge remains largely unexplored but more effort will be directed toward this type of genetic improvement over the next decade.

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# Deciphering the grass pea (*Lathyrus sativus*) quality riddle

by Letice GONÇALVES and M. Carlota VAZ PATTO*

**Abstract:** Grass pea (*Lathyrus sativus*), is considered a model crop for sustainable agriculture, most promising as source of calories and protein in drought-prone areas. Significant diversity has been detected among a range of grass pea seed components suggesting a high potential for quality improvement. However, different components may act as anti-nutrients as well as health-promoting agents and an integrative approach is central to tackle this breeding objective. The evaluation of grass pea collections is starting now to consider also the quantification of certain health beneficial components in this species. This will open the way for the establishment of this robust, highly nutritious and environmental friendly grain legume species as an excellent response to present health and agriculture sustainability consumers concerns.
**Key words:** anti-nutritional factors, breeding for quality, health-beneficial components

Grass pea (*Lathyrus sativus* L.), a cool season legume, is considered one of the most promising yet underutilized source of calories and protein for populations in drought-prone areas of Asia and Africa. It has high potential for introduction in Australia, North America, Southern and Central Europe and China due to its robustness and high nutritional value (13). This dual purpose grain legume, was already in use in Neolithic times, and is presently considered as a model crop for sustainable agriculture (12).

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As part of the traditional heritage of many European dry land communities, grass pea still represents an important source of revenue for the local economies. Specific traditional varieties are still conserved by farmers for gastronomic purposes. Worldwide it can be consumed in many diverse ways, uncooked as a green snack, cooked in a stew, milled into flour, fermented or by roasting the seed (12).

As in other grain legumes, high trait interaction exists which often causes quality concerns. Several nutritional beneficial and health promoting components of grass pea may cause them to taste bitter or astringent, a common reason for disinterest of consumers. But even more worrying, and depending on the diet, these same components can be considered anti-nutritional factors, limiting nutrient absorption, mineral availability and protein digestibility. In fact, *L. sativus* seeds are characterized by a high protein content (cca 30%), low in sulphur amino acid such as methionine, but also by the presence of anti-nutritional factors such as trypsin and amylase inhibitors, lectins, tannins, phytate, oligosaccharides and in particular of a toxic non protein amino acid β-ODAP (β-N-oxalyl-L-α,β-diaminopropionic acid) (12). β-ODAP has been associated with the development of the neurolathyrism disorder when grass pea is consumed alone in large quantities and for extended periods (5).

Nevertheless grass pea is also an interesting source of health beneficial dietary lipids, with a high unsaturated fatty acids proportion (7), and phenolic compounds, with high antioxidant activity (8). It is also rich in homoarginine, an alternative substrate for nitric oxide biosynthesis, with advantages in cardiovascular physiology and general wellbeing (11). Another potential beneficial application of *L. sativus* seeds may be in ameliorating diabetic symptoms, as they possess glycosylphosphatidylinositol with insulin-mimetic activity (6). Even ODAP, as an activator of protein kinase C, may have also therapeutical potential in such areas as Alzheimer´s disease, hypoxia and long-term neurons potentiating, essential for memory (11). It is also possible to use ODAP as a haemostatic agent during surgery (4).

Presently limited data on orchestrating grass pea seed quality is available as the primary focus has been on reducing ODAP content. As a result of various national and international breeding initiatives several cultivars with low ODAP content have been released (ODAP content inferior to 0.1%), although with strong environmental effects and none ODAP-free (3). This breeding focus is slowly changing since there is an agreement today that ODAP content itself does not seem to be a problem because grass pea is harmless to humans and animals when consumed as part of a balanced diet (5). Also, risks of over-consumption of β-ODAP can be reduced by the fortification of grass pea with cereals rich in sulphur amino acids and condiments rich in anti-oxidants, such as onion, garlic, and ginger (1). In addition seeds can be partly detoxified by various processing methods such as fermentation, pre-soaking in alkaline solutions and cooking, contributing all to a general improvement of their nutritional value (13).

With the paradigm change on grass pea breeding, it is the moment to concentrate efforts on the implementation of integrated quality objectives.

Quality aspects of food crops are key issues with important market economic repercussions. Consumers are increasingly discriminating and health conscious, demanding tasty and convenient ready-to-eat foods, with a reduce carbon footprint (14). Breeding for improved end-user´s quality is however a complex task in legumes due to high trait interaction and, as already mention, the presence of particular components that might act as anti-nutrients as well as health-promoting agents, influencing both taste and consumers' acceptability.

**Figure 1. Grass pea seeds from traditional Portuguese varieties**

Although still under-investigated, genetic variation has been detected among a range of grass pea seed components, other than ODAP, in several international and national germplasm collections (Fig. 1). For instances, genetic variation for homoarginine content in *L. sativus* Italian ecotypes has been identified (9). Using a geographically broader grass pea collection, Granati et al. (2) detected significant differences in protein, ash, 100 seed weight and ODAP content, suggesting that it should be possible to independently manipulate these grain´s quality traits. Climatic condition may also influence the physicochemical and nutritional traits. Piergiovanni et al. (10), using Italian grass pea germplasm cultivated in two different climatic conditions, found a significant positive correlation between β-ODAP and trypsin inhibitor contents. The lowest levels of these two compounds were associated with the highest amount of rainfall during the plant vegetative cycle.

These results anticipate potential interest for quality breeding purposes in grass pea. They are also the preliminary necessary steps to implement integrated quality objectives in breeding programs essential for the establishment of the robust, highly nutritious and environmental friendly grass pea as an excellent response to present health and agriculture sustainability consumers concerns.

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# Foods incorporating lupin flour: Current evidence of metabolic syndrome protective effects in humans

by Jonathan HODGSON[1], Casiana Blanca VILLARINO[2,3], Vijay JAYASENA[4], Ranil COOREY[2] and Stuart JOHNSON[2*]

**Abstract:** Flour from milled, dehulled lupin (*Lupinus angustifolius* L.) kernel is gaining international interest as a high protein, high fibre food ingredient with potential health benefits. Human clinical trials investigating the effects of consuming lupin-containing foods such as bread, biscuits and pasta, on risk factors of metabolic syndrome have recently been reported. Post-meal studies have identified beneficial effects of lupin foods on blood glucose, appetite and food intake. Longer term studies have reported that diets containing lupin foods can provide beneficial effects on insulin and blood pressure. Further long term human trials in, for instance, those with type 2 diabetes are now required.

**Key words:** blood pressure, cholesterol, glycaemic index, lupin, metabolic syndrome, obesity

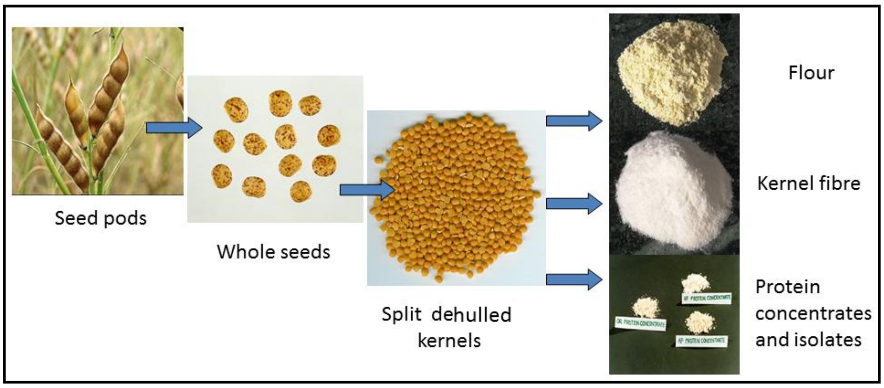


**Figure 1. Photographic images of lupin (*Lupinus angustifolius*) seed pods, whole seeds, split dehulled kernels and lupin flour, kernel fibre and protein ingredient**

## Introduction

The majority of the world's lupin seed is the low alkaloid Australian sweet lupin (*Lupinus angustifolius* L.) harvested in Western Australia, where it is an important nitrogen-fixing rotation crop crucial for sustainable cereal production. This lupin seed is used primarily for animal feed. However, there has been a resurgence of interest in the use of lupin flour (Fig. 1) for human food due to its high protein and fibre content and increasing evidence, from human clinical studies, of its potential to reduce metabolic syndrome (8). In addition the gluten free, non-genetically modified and low phytoestrogen status of lupin may add to its consumer appeal.

The metabolic syndrome is a cluster of risk factors for the development of cardiovascular disease, carried by up to a quarter of the world's population. These risk factors include abdominal obesity, insulin resistance (measured using blood glucose and insulin concentrations), dyslipidaemia (including elevated blood total cholesterol), and elevated blood pressure. The unique combination of high protein and dietary fibre, with very low starch and sugars found in lupin flour could provide benefit to a number of these risk factors.

## Appetite and body weight reduction

Foods that strongly reduce appetite after eating (highly satiating) may assist in longer term reduction of food intake and therefore help maintain healthy body weight. An equal energy breakfast of wheat (*Triticum aestivum* L.) bread containing 40% lupin flour led to higher levels of self-reported satiety and lower energy intake at lunch, compared to wheat-only bread in a study of 16 healthy adults (7). In a second study however, no difference in self-reported satiety nor in energy intake at lunch were reported between wheat-only and lupin-wheat bread (3), possibly due to the lower level of lupin flour (10%) in the bread. A similar study in 20 healthy adults also found a higher perception of self-reported satiety after lupin-wheat bread consumption, but no difference between the two breads for energy intake at lunch (5).

Stronger evidence of the anti-obesity potential of foods can be gained from longer term studies in which the foods of interest (Fig. 2) are incorporated into the daily diet for several weeks or months. Eighty eight overweight or obese adults consumed a diet containing either 40% lupin flour bread or wheat-only bread for 16 weeks (4), however no difference in body weight and composition were seen between participants on each diet. In a second study (1), 131 overweight or obese adults consumed a diet containing bread, biscuits and pasta (with 25% - 40% lupin) or a control diet with equivalent cereal flour-only products for 8 months. Again no difference was observed on the two diets for body mass or composition (1). The level of lupin incorporation into these diets may have been too low to observe significant reductions in energy intake and body weight, and/or the duration of the studies was too short.

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**Figure 2. Examples of lupin-containing foods (right) and control foods (left) that can be used in dietary intervention studies**

## Blood glucose and insulin lowering

The impact of a food on blood glucose and insulin levels after the meal (glycaemic and insulinaemic responses) can be compared to those from an equal serving of available carbohydrate (such as glucose) to obtain a glycaemic index and insulinaemic index. A breakfast of lupin-wheat bread (containing 7 g of lupin flour) gave a beneficially lower glycaemic index, but a higher insulinaemic index than a breakfast of wheat-only bread in a study of 11 healthy adults (3). Only one published study has investigated the effect of consuming lupin containing foods in diabetics in which a 50 g glucose drink containing 50 g lupin flour gave a lower glycaemic and a higher insulinaemic responses than the glucose drink alone in 24, type 2 diabetic adults (2). The ability of lupin flour to stimulate insulin and reduce post meal blood glucose response indicates it's potential to help manage type 2 diabetes and provide longer-term benefits on insulin sensitivity.

Lowered fasting glucose and insulin is related to better blood glucose control and insulin sensitivity. In one long term study, no difference in fasting blood glucose and insulin levels between a lupin-containing diet and the non-lupin control diet was observed (4). Whilst in a second study, no effect on fasting glucose, but lowered fasting insulin concentrations on the lupin-containing diet were reported (1). Additional studies are needed to confirm this potential benefit in those with type 2 diabetes or at elevated risk of its development.

## Cholesterol and blood pressure lowering

The effect of specific foods when incorporated into a long term diet on blood lipids and blood pressure can provide valuable information on the ability of that food to reduce risk of cardiovascular disease. In the 6 week lupin bread dietary intervention study (4) described above, study participants showed slightly elevated total cholesterol after the lupin diet compared to the control diet, suggesting that the lupin-containing diet did not provide any beneficial effect on blood lipid levels.

The effect on blood pressure of a 16 week diet, in which either lupin-wheat bread (40% lupin) or wheat-only control bread was used, has been reported (6). Eighty-eight overweight or obese men and women took part in the study which demonstrated a beneficial blood pressure lowering effect of the lupin-containing diet compared to the control (6). Similar beneficial effects on blood pressure were also reported in the study of the effects of a diet containing lupin foods (bread, biscuits and pasta) versus cereal-flour equivalents on cardiovascular disease risk factors (1). These studies are consistent in demonstrating that increased protein and fibre from lupin flour can reduce blood pressure.

## Conclusion

In relation to the metabolic syndrome, the short-term effects on satiety of adding lupin flour to carbohydrate-rich foods appear to be quite strong, though whether these effects might translate into longer-term benefits on energy intake and body weight is not yet clear. Studies exploring potential benefits on glucose and insulin indicate that the addition of lupin flour to carbohydrate-rich foods, such as bread, could help with the management of type 2 diabetes. Longer-term studies are however needed to substantiate these benefits. Studies indicate that in the absence of elevated blood cholesterol, lupin flour probably has little impact on blood lipids, however the benefits of lupin flour intake on blood pressure are consistent and potentially important for reducing risk of hypertension and cardiovascular disease.

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# Common bean (*Phaseolus vulgaris* L.): Underexplored attributes for food development

by Elsa MECHA[1]*, Maria Eduardo FIGUEIRA[2], M. Carlota VAZ PATTO[1] and Maria Rosário BRONZE[1,2,3]

**Abstract:** Common bean (*Phaseolus vulgaris* L.), bean from now on, is one of the most worldwide consumed crops, consequence of its interesting nutritional composition. However, Food and Agriculture Organization data indicate a reduced Europeans' beans consumption. The misconception that beans are responsible for weight gaining, the use of beans as ingredients in traditional high fat caloric dishes, the prolonged cooking time, not compatible with modern lifestyle, all contribute to explain this low consumption. To revert this situation we propose the development of innovative bean food products, based on improved varieties, with more interesting nutritional attributes, associated to an increase marketing investment, focused on the younger generations, that should take into account consumers' preferences.

**Key words:** common bean, consumers, food development challenges, interdisciplinary approach, quality

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As an important protein source (200 g kg$^{-1}$ - 250 g kg$^{-1}$) rich in lysine, starch (390 g kg$^{-1}$ - 510 g kg$^{-1}$), fibre, minerals (e.g. calcium, magnesium, phosphorus, potassium and zinc) and vitamins (e.g. B vitamins, folate and vitamin K), legumes should be included in human daily diets (13). In developing countries, where protein-calorie (PCM) and micro-nutrient (MNM) malnutrition are major problems, beans (*Phaseolus vulgaris* L.) may be considered as a substitute of the expensive and sometimes scarce animal protein, to complement cereals, in lysine balance (9, 10). In developed countries, where increasing life expectancy (7) is accompanied by the development of chronic diseases (e.g colon cancer, obesity, diabetes *mellitus* type 2, cardiovascular diseases),these beans should be regularly included in diet as a cheap source of dietary fibre, vitamins and antioxidant compounds with beneficial health effects in weight, intestinal function, glycaemia and LDL cholesterol levels (9, 10). Some of these positive properties are due to non-nutritive, functional components (e.g. protease inhibitors, lectins, oligosaccharides, saponins and tannins), commonly named as anti-nutritional components since they can interfere with protein and starch digestibility (Fig. 1; 3). These also influence processing, taste and consumer food acceptance (15).

Generally grain legumes are underused in Europeans' diet (12). Food and Agriculture Organization of United Nations (FAO) data suggested that in European Union, during 2010-2011, dry bean represented only 7 kcal capita$^{-1}$ day$^{-1}$ (8). This low consumption is even more alarming if we consider the European Food Information Council (EUFIC) recommendation for beans intake of 80 g day$^{-1}$ (73 kcal capita$^{-1}$ day$^{-1}$) (6).

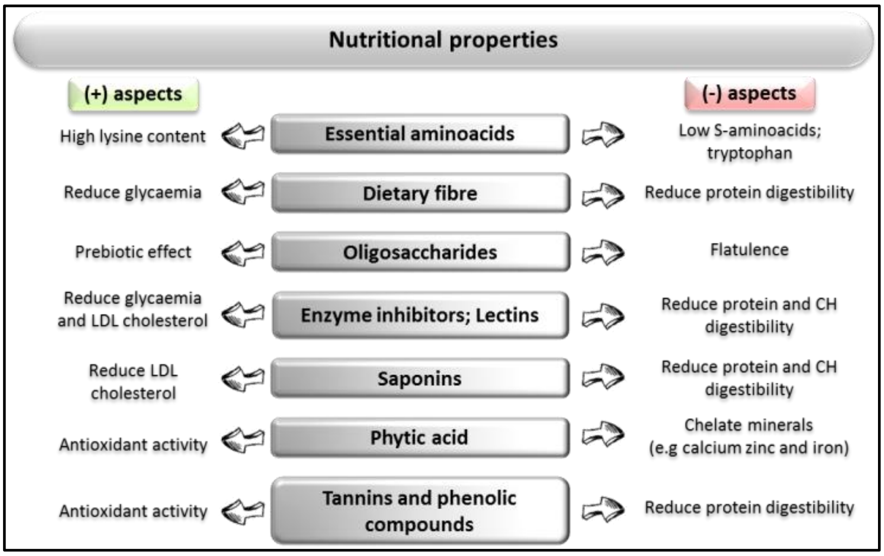


**Figure 1. Negative and positive aspects of the different nutritive and non-nutritive bioactive components present in common bean seeds (8)**

This low dry beans consumption may be caused by the misconception of consumers, regarding the link between dry beans intake and weight gain, including common bean in traditional high caloric recipes, the problem of flatulence, the old-fashioned military image associated to dry beans, and the scarcity of new innovative, ready-to-eat products (12).

In order to increase consumers' acceptability and consumption of beans, an interdisciplinary approach involving farmers, breeders, food scientists, food manufacturers and consumers is required.

## Common beans quality from farmer to consumer

For a farmer, the most relevant aspects of bean quality include high stable yields, resistance to diseases and uniform seeds (3). For consumers, attractive sensory traits (texture and flavour), safety, nutritional and functional attributes, and convenience (ready-to-eat or with a reduced cooking time), are the priority requirements (1, 2, 3, 11). Another aspect to take into consideration is the consumer cultural background (5). This may influence, for instance, the consumer perception of seed coat or the preference for a particular seed colour or shape (3).

The most important demands of food industry rely on high stable market supply of safe, traceable, environment-friendly raw materials and provision of a wide range of products that comply with different types of consumers' demands (12). All these aspects are decisive in the development of new bean varieties(3).

Breeding for higher nutritional, organoleptic and end-use quality varieties is extremely important to provide market with high quality raw materials (15). The study of traditional varieties that were once forgotten, but that are still used locally due to their quality attributes can be an important approach to look for sources of nutritional and organoleptic interesting traits. In Portugal a project entitled "Exploiting Bean Genetics for food Quality and Attractiveness Innovation" (BEGEQA) is currently underway. A diverse collection of Portuguese traditional bean varieties are under study on an integrated approach for quality improvement and development of adequate quality breeding/selection tools.

The development of materials with improved nutritional composition can be achieved through the breeding of varieties with higher sulphur amino acids (methionine, and cysteine) and higher micronutrients (iron, zinc, folate, and provitamin A) content (10). These approaches may have an astonishing contribution to eradicate PCM and MNM in developing countries (10). More recently, bean varieties with increased content of other interesting components, mostly related to antioxidant, anticarcinogenic and anti-inflammatory activities are also gaining the attention of legume breeders (10). The selection of such varieties would be an asset in the development of functional products.

The nutritional components content in bean based food products is dependent on the processing method. Boiling is the most common method applied. It may be done on whole dry beans, whole soaked beans or on cotyledons obtained after dehulling. Other processing techniques, mostly applied in Eastern countries, include fermentation and germination (3). Processing may also be used to improve bean quality (3) through the inactivation of antinutritional factors (enzymatic inhibitors and lectins) and improvement of protein and carbohydrate digestibility.

Despite some aversion of consumers to the use of additives in canning products, and the reported losses in soluble proteins and minerals (K, P and Mg), canning is among the most widely convenient methods used to process bean seeds (1).

Taking all the previous into account a good strategy to increase beans consumption must rely on the selection/improvement of high nutritional and organoleptic quality varieties, not forgetting the traditional varieties as a good source of interesting quality traits, which respond to industry and especially to consumers' demands. These would be the perfect raw materials for innovation in food products associated with more healthy, secure and easy to prepare products.

## Promoting common bean consumption

In order to increase the daily bean intake, consumers must be more aware of their nutritional and health benefits. In particular, this must be accomplished through educational sessions that reinforce the current scientific evidence on their benefits for ageing population, sportspeople, women in fertile age and children. Also there is a need to modernize dry beans' image by marketing campaigns emphasizing their health beneficial effects, their local origin and providing practical instructions for use and innovative recipes well adapted to the modern lifestyle (12).

The development of necessary innovative bean based food products may be hampered by the lack of adequate processing methodology. As an example, food industry has been searching for an adequate bean extrusion-cooking process in order to incorporate beans in cereal based products (1, 2). Nevertheless, products as breakfast cereals, snacks, cookies, drinks, soups, sauces, disserts, breads, pastas, tortillas, noodles, meat products (e.g burgers, sausages, nuggets) and infant food integrating bean flour are under development (2, 15).

## Conclusions

Despite the recognized beneficial nutritional and health effects, bean consumption in European countries is reduced, suggesting that beans' properties remain unknown to consumers and its potential continues to be underexplored by farmers and food industry. To supply world population with nutritional, functional, convenient and ready-to-eat bean based food alternatives, quality parameters must be studied in a concerted action of different stakeholders. To increase consumer's demand and food industry investment in bean products, nutrition education efforts and marketing campaigns should be a priority for modern societies.

**Acknowledgments**

Authors acknowledge FCT (Fundação para a Ciência e Tecnologia, Portugal) for Research Unit and project funding(UID/Multi/04551/2013, PTDC/AGR-TEC/3555/2012), for EM PhD fellowship (SFRH/BD/89287/2012) and MCVP Research Contract (IF/01337/2014).

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# Achievements and challenges in improving nutritional quality of chickpea

by Pooran M. GAUR[1], Srinivasan SAMINENI[1], Sobhan SAJJA[1] and Ravindra N. CHIBBAR[2]

**Abstract:** Chickpea (*Cicer arietinum* L.) grains are an excellent source of protein, carbohydrates, minerals, vitamins, dietary fibre, folate, β-carotene and health promoting fatty acids. Their consumption provides consumers with a variety of nutritional and health benefits. Limited breeding efforts have been made on nutritional quality traits of chickpea. Potential exists for further enhancing contents of protein, minerals (iron and zinc), folate and β-carotene and reducing the contents of flatulence causing raffinose family of oligosaccharides (RFOs).
**Key words:** *Cicer arietinum*, dietary fibre, minerals, raffinose, protein, vitamins

Chickpea (*Cicer arietinum* L.), also called garbanzo bean, is globally the second most important food legume after common bean and grown in over 55 countries on an area of about 13 million ha (2). There are two distinct types in chickpea, *desi* (thick and darker coloured, mostly brown, seed coat) and *kabuli* (thin and cream-coloured seed coat) (Fig. 1 and 2).

**Figure 1. Desi (top) and kabuli (bottom) chickpea varieties**

**Figure 2: Desi (left) and kabuli (right) chickpea grains**

The desi types account for about 80% to 85% of the global chickpea area and largely grown in South Asia, Eastern Africa, and Australia and mainly consumed in South Asia. Though the total chickpea area under kabuli type is less (15 to 20%), the production and consumption of kabuli type is globally more wide spread than the desi types. Chickpeas are mainly used for human consumption and a very small proportion as animal feed. The dry chickpea grains are used whole (after soaking and/or cooking, roasting or parching) or dehulled to make splits (*dal*) or ground to produce flour (*besan*). The soaked/cooked chickpea grains are used in salads, making vegetable curries (*Chhole*) and several other preparations, such as falafel (deep fried balls or patties) and hummus (chickpea dip or spread). The chickpea flour is used in making a wide variety of snack foods, soups, sweets, and condiments besides being mixed with wheat flour to make Indian bread (*roti or chapati*). Invariably, splits (*dal*) and flour are made from desi type, while hummus is made from kabuli type. Chickpea leaves are used as leafy vegetable and immature green grains are eaten raw or after roasting and also used as vegetable.

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Chickpeas are an excellent source of proteins, carbohydrates, dietary fibre, minerals and vitamins (Table 1). There is a growing interest in consumption of chickpea for promoting healthy diet and reducing risk of some diseases and other health problems. Chickpeas are rich in protein (20% - 22%) and the digestibility of chickpea protein is high as compared to several other legumes. Chickpea when consumed with cereals provide balanced amino acids in the diet because, like other pulses, it is high in lysine but limited in sulfur-containing amino acids (methionine and cysteine), while cereals are limited in lysine and rich in sulfur-containing amino acids. Chickpeas have high fibre content and low glycemic index (GI) value. The diets high in fibre and low in GI value are known to help in weight loss, management of type-2 diabetes, reducing cholesterol, and lowering risk of colon cancer. Chickpeas are low in sodium and fat and help in reducing the risk of coronary and cardiovascular diseases. Chickpeas are also known to reduce blood lipids that may help some serious complications of diabetes. Flour made from chickpeas is gluten free and can benefit people with celiac disease.

Market for chickpea products is growing even in developed countries. Hummus, a Middle Eastern dip, prepared from cooked and mashed chickpeas with optional ingredients, became very popular in the USA during the past two decades. The retail sales of hummus in the USA increased from $5 million in 1997 to $250 million in 2013. Hummus is preferred over other similar products (e.g. peanut butter) because of low fat and high protein content.

Chickpea is a part of regular diet of large number of people in developing countries and thus further enhancing its nutritional quality traits such as contents of protein, minerals and vitamins will help in improving nutrition and health of people. The protein content of currently available varieties of chickpea generally ranges from 20 % to 22%. Germplasm lines with high protein content (> 28%) have been identified and are used in breeding programs at ICRISAT and few other institutes. Improving the protein content by 20% - 25% appears feasible. The high protein cultivars will improve protein availability to the poor people by 20% to 25% from the same amount of chickpea consumed. ICRISAT and the University of Saskatchewan are working together on molecular mapping of genes / quantitative trait loci controlling chickpea protein content.

**Table 1. Chemical composition and nutritive values in mature grains of chickpea (6)**

| Grain type | Kabuli | Desi |
|---|---|---|
| Proximates (g $100g^{-1}$) | | |
| Protein | 17.9-30.8 | 20.3-27.5 |
| Starch | 38.2-43.9 | 33.1-40.4 |
| Amylose (% of total starch) | 24.4-29.2 | 20.5-25.9 |
| Fat | 5.5-6.9 | 4.4-5.9 |
| Acid Detergent Fibre | 3.0-5.7 | 12.7-13.5 |
| Neutral Detergent Fibre | 4.2-7.7 | 10.1-13.6 |
| Minerals (mg $100g^{-1}$) | | |
| Calcium (Ca) | 80.5-144.3 | 115.0-226.5 |
| Copper (Cu) | 0.7-1.4 | 0.5-1.4 |
| Iron (Fe) | 4.3-7.6 | 4.6-7.0 |
| Potassium (K) | 816.1-1580.1 | 1027.6-1479.1 |
| Magnesium (Mg) | 152.9-212.8 | 143.7-188.6 |
| Manganese (Mn) | 2.3-4.8 | 2.8-4.1 |
| Phosphorus (P) | 294.1-828.8 | 276.2-518.6 |
| Zinc (Zn) | 3.6-5.6 | 2.8-5.1 |
| Vitamins (mg $100g^{-1}$) | | |
| Ascorbic acid (C) | 0.28-2.40 | 0.67-3.01 |
| Thiamin (B1) | 0.39-0.78 | 0.22-0.34 |
| Riboflavin (B2) | 0.10-0.34 | 0.16-0.24 |
| Niacin (B3) | 0.48-1.49 | 1.43-2.28 |
| Folic acid (µg/100g) | 153.8-486.5 | 109.0-294.4 |
| Fatty acid (% in oil) | | |
| Palmitic (C16:0) | 8.52-10.30 | 8.56-11.05 |
| Stearic (C18:0) | 1.21-1.68 | 1.04-1.60 |
| Oleic (C18:1) | 27.70-42.46 | 18.44-28.51 |
| Linoleic (C18:2) | 42.25-56.59 | 53.13-65.25 |
| Linolenic (C18:3) | 2.23-3.91 | 2.54-3.65 |
| Sugars (g $100g^{-1}$) | | |
| Sucrose | 3.10-4.41 | 1.56-2.85 |
| Raffinose | 0.48-0.73 | 0.46-0.77 |
| Stachyose | 1.76-2.72 | 1.25-1.98 |
| Verbascose | Not detected | Not detected |
| Oligosaccharides (raffinose + stachyose + verbascose) | 2.32-3.44 | 1.72-2.75 |
| Phytic acid (g $100g^{-1}$) | 0.78-1.25 | 0.63-1.24 |

The deficiencies of iron and zinc are widespread among people, especially in South Asia and sub-Saharan Africa. Chickpea has the potential to contribute to daily iron and zinc intake, and can help alleviate these problems of micronutrient malnutrition. Limited number of accessions evaluated for the contents of iron and zinc suggest that, like other pulses, chickpea has higher content of iron and zinc as compared to staple cereals (wheat and rice) (4).

Recent studies conducted at ICRISAT over two years (2011 and 2012) showed the existence of large genetic variability for Fe (35 ppm - 150 ppm) and Zn (25 ppm - 50 ppm) contents in cultivated and wild chickpea accessions (PM Gaur, unpublished results). These genotypes are being used for developing chickpea cultivars with enhanced iron and zinc contents.

Among various carotenoids, β-carotene is the most important carotenoid present in chickpea and converted into vitamin A more efficiently than the other carotenoids. Limited studies available on the availability of β-carotene in chickpea suggest that chickpea has a higher amount of β-carotene than 'golden rice' (1) or red-coloured wheat (5). There is a need to assess genetic variability for β-carotene in the germplasm of cultivated and wild *Cicer* species and identify high β-carotene lines for use in breeding programs.

The only negative factor associated to chickpea consumption is the flatulence caused by RFOs (mainly raffinose, stachyose, verbascose and ciceritol) which are α-galactosides carbohydrates and present in all legume seeds. As the humans lack galactosidase enzyme, the RFOs are not digested and accumulated in the large intestine resulting in the production of hydrogen, methane and $CO_2$, major components of flatulent gases. Despite numerous well-proven health benefits, RFO-induced flatulence reduces the acceptance of chickpea. A recent study showed a wide genotypic variation in total RFO concentration in both desi (1.58 mmol 100 $g^{-1}$ to 5.31 mmol 100 $g^{-1}$) and kabuli (2.11 mmol 100 $g^{-1}$ to 5.83 mmol 100 $g^{-1}$) chickpea (3), indicating possibility of developing varieties with low RFO contents. Moderate broad sense heritability values (0.25-0.56) observed for RFOs (3) suggest that the selection for low RFOs should be carried out in advanced generations and based on evaluation in multilocation trials.

The chickpea breeding programs have so far not given much emphasis on nutritional quality traits in chickpea. There is a need to assess genetic variability available in the germplasm of cultivated and wild species for various quality traits. Studies are also needed on establishing genetics, linkage relationships and G × E interactions for many of these traits and identification of molecular markers/candidate genes associated with these traits. The wild *Cicer* species, induced mutations and transgenic technology have potential to provide additional genetic variability for exploitation in breeding programs. An integrated breeding approach would help in making rapid progress in developing chickpea varieties which are further enhanced for nutritional quality traits. Such varieties will help in improving nutritional security of the poor in the developing countries.

**Acknowledgements**

Partial funding support from CGIAR Research Program on Grain Legumes.

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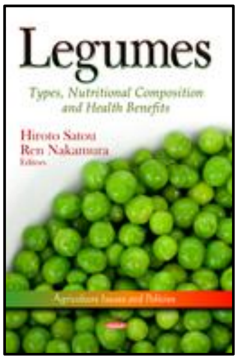



## Legumes: Types, Nutritional Composition and Health Benefits

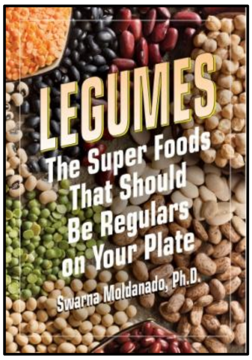
Editors: Hiroto Satou and Ren Nakamura

Publisher: Nova Science Publishers, New York

Year: 2013

ISBN: 978-1-62808-281-4

In this book, the authors present topical research in the study of the types, nutritional composition and health benefits of legumes. Topics discussed include legumes (*Bituminaria bituminosa*) for grazing and health; nutritional characterization of wild legumes (*Lathyrus* and *Vicia* genera); legumes leading the war against "Diabesity-the obesity-diabetes epidemic"; soybeans nutritional profile and implications for nutrition and health effects; fermentation of lesser known legumes; dark and bright facets of nutritional value of grass pea (*Lathyrus sativus* L.) seeds; lentils (*Lens culinaris* Medik.) and their link to better human health; *Medicago truncatula* as a model organism to study the biology of agriculturally important legume crops; antihypertensive potential of protein hydrolysates from velvet bean (*Mucuna pruriens*); use of the herbicide Roundup on soil metals lability and on radish metal uptake; chemical and structural composition of arabinogalactan proteins (AGP) of mesquite (*Prosopsis* spp); common bean as an emerging model grain legume; the health benefits of legumes; and current update in methodologies for extraction and analysis of proteins and isoflavones.




## Legumes: The Super Foods That Should Regulars on Your Plate

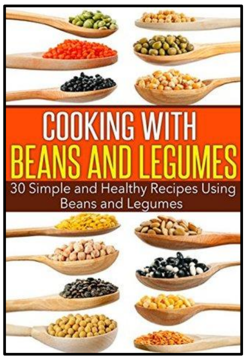
Author: Swarna Moldanado

Publisher: Basic Health Publications, Laguna Beach

Year: 2014

ISBN: 978-1-59120-353-7

As an educator, the Indian-born and US-resident author was curious to learn why legumes were so overlooked in the United States. Her subsequent research turned up a number of misconceptions and inaccuracies as reasons for the prevailing lack of interest in them. This, in turn, let her to research legume-based diets in other parts of the world to ascertain what, if any, impact they had on health and disease in those locales. The information the author accumulated was very enlightening - across the board it showed there were major advantages to be gained by adding legumes to the diet. The first five informative chapters discuss all the aspects of super-food legumes - their history, their food value, their health implications, and which legumes are most commonly eaten around the world. The next two chapters contain the final payoff for readers as they are recruited to participate in preparing and eating the legumes they've been learning about. Any reader interested in optimizing or simply maintaining their health would do themselves a favor by adding this important book to their must-read list.




# Cooking With Beans and Legumes: 30 Simple and Healthy Recipes Using Beans and Legumes

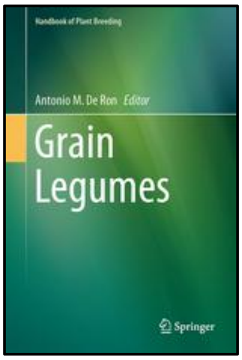
Author: Angela Herrera

Publisher: CreateSpace Independent Publishing Platform, Colorado Springs

Year: 2014

ISBN: 978-1500408169

This book contains proven steps and strategies on how to become a truly unique legume and bean chef in your own kitchen. Legumes and beans are beneficial to a persons overall health in more ways than one. Legumes in themselves are very versatile and one of the most nutritious foods on the market. One one hand, they are low in fat and contain no cholesterol. One the other hand, legumes are high in folate, potassium, iron and magnesium. Another benefit is that they contain fats and fiber, both soluble and insoluble. This book provides a wealth of information concerning the health benefit of legumes, the types of legumes available on the market, and healthy recipes that include legume beans within them. The book also includes 30+ recipes about cooking with bean and legumes all of which are healthy and easy to make. If you do not develop your chef skills, using these simple healthy ingredients, you stand to gain a wealth of information, on legumes and other ingredients.




# Grain Legumes

Editor: Antonio M. De Ron

Publisher: Springer-Verlag, New York

Year: 2015

ISBN: 978-1-4939-2796-8

This book is devoted to grain legumes and include eight chapters devoted to the breeding of specific grain legume crops and five general chapters dealing with important topics which are common to most of the species in focus. Soybean is not included in the book as it is commonly considered an oil crop more than a grain legume and is included in the Oil Crops Volume of the Handbook of Plant Breeding.Legume species belong to the *Fabaceae* family and are characterized by their fruit, usually called pod. Several species of this family were domesticated by humans, such as soybean, common bean, faba bean, pea, chickpea, lentil, peanut, or cowpea. Some of these species are of great relevance as human and animal food. Food legumes are consumed either by their immature pod or their dry seeds, which have a high protein content. Globally, grain legumes are the most relevant source of plant protein, especially in many countries of Africa and Latin America, but there are some constraints in their production, such as a poor adaptation, pest and diseases and unstable yield. Current research trends in Legumes are focused on new methodologies involving genetic and omic studies, as well as new approaches to the genetic improvement of these species, including the relationships with their symbiotic rhizobia.

# Global Year of Pulses - 2016

Global Pulse Confederation (CICILS-IPTIC)

CICILS – IPTIC, shortly to be renamed Global Pulse Confederation is head quartered in Dubai and licenced under the Dubai Government authority, Dubai Multi Commodity Centre (DMCC). CICILS is the not for profit peak body for the whole global pulses industry value chain. As the sole international confederation for the industry it enjoys membership from 18 national associations (federations) and over 600 private sector members in an industry worth over $100 Billion at the retail level and over 60 million tonnes in pulse production and distribution in over 55 countries. The organisation represents the common good of all sectors of the global pulse industry value chain from growers and researchers, through input and logistics suppliers, traders, exporters and importers to government bodies, multilateral bodies, processors, canners and consumers. CICILS works for transparency and sustainability in all sectors and aspires to contribute in as many ways possible to global food security and improved health and nutrition. The CICILS Executive Board consists of up to 30 members from all over the world elected from the membership. Board positions are voluntary, non-profit and carry no remuneration.

## OUR VISION

To create an inclusive global pulse organization recognized for its integrity, professionalism and ability to work together across the entire pulse value chain to resolve issues and grow the industry.

## OUR MISSION

To lead the global pulse industry to major crop status by facilitating free and fair trade and increasing production and consumption of pulse crops worldwide.

## OUR GOALS

- To expand the permanent membership of CICILS to include the broadest base of organisations and companies involved both directly and indirectly in the global trade of pulses.
- To ensure a reliable, consistent and safe pulse value chain delivering pulses that meet the requirements of the industry's existing and future customers and consumers - and to encourage all industry sectors that impact on production, marketing and service delivery for Pulses to operate ethically and at world's best practice.
- To identify, select, fund and/or otherwise support approved research and development activity that leads to increased production and consumption of pulse crops to address the critical health, sustainability and food security issues around the world.
- To work towards harmonisation of the global pulse trade and removal of all barriers to trade for pulses world wide, and where possible develop new markets.
- To hold annual conventions of the highest calibre, that unite CICILS-IPTIC global membership in friendship, provide a focus for exchange of ideas and information, and a forum for discussion and amicable resolution of industry issues.
- To support national and regional member associations through active participation in local country activities by local CICILS members ("Ambassadors").

## Themes

CICILS and its IYOP partners have identified a series of thematic areas that will be the focus for activities during the International Year. These areas represent the key issues where new and increased efforts could help make a difference in promoting sustainable agriculture and livelihoods, as well as healthy diets, through increased production, trade and consumption of pulses.

We are working on more than 100 activities and projects related to 2016, four of them have already been launched in the areas of branding, school programs, recipes, and market access. Fifteen external partners have been recruited to work on the year, from major science centres, health institutes, academia to farm groups. Additionally, a total of 30 national committees have begun activities in every continent.

These activities will be built around four thematic areas:

### 1) Creating Awareness

IYOP 2016 is an opportunity to increase awareness and global demand for pulses. We aim to reach an audience of 20-40 million people worldwide using social media, websites and global media outreach.

### 2) Food & Nutrition Security & Innovation

IYOP has set the ambitious targets of helping initiate:

- 20 governments to commit to including pulses as part of their food security policies.
- 100 research projects substantiating the ability of pulses to combat nutrition and health issues.
- 100 research projects into functional and nutritional properties for food product advancement.

### 3) Market Access & Stability

IYOP is an excellent opportunity to open a dialogue on improving the regulatory framework in which trade occurs. We hope to reduce trade barrier costs that are borne by farmers, processors, traders and consumers while introducing greater efficiencies to enhance food security, reduce price volatility and enhance the return to growers.

### 4) Productivity & Environmental Sustainability

IYOP 2016 is a perfect chance to draw the focus of the scientific community. We hope to see the completion of a 10-year plan of action on pulse research by the end of 2016 and the genome sequencing of three pulse crops by 2018.

## National Committees

CICILS has convened a worldwide network of promotional teams to ensure wide-reaching and global coordination of activities on the 2016 International Year of Pulses. The National Groups are made up of experts with “great ideas” who plan and coordinate the most important activities of IYoP outreach, from the ground up. Their work is essential to the successful dissemination of the key thematic areas of the Year.

The Groups will meet via a conference call every two months. The purpose of the calls is to provide an update on activities, exchange ideas, identify gaps and coordinate a global approach on the key themes of the IYoP. As of February 2015, there were 30 countries on the National Promotions Group mailing list and additions to this list will follow over the course of 2015 and 2016.

## Join Us!

We know you all love pulses, which is why we want to give you 10 ideas on what you and/or company can do to help promote the 2016 International Year of Pulses.

1. Include a link to iyop.net in your website.
2. Spread the word! Have your communications team promote pulse stories in the media. Messages like: "What Are Pulses and Why Are They Important?" can help.
3. Donate your recipes to the global collection, and feature the recipes on your web site. Send your recipes to IYOP@emergingag.com.
4. Donate your photos to our Photo Gallery.
5. Be social and talk about us! Follow us on Twitter and use the hashtag#IYOP2016.
6. Make use of your own connections to get more supporters. Do you know a local company who could be a sponsor? Perhaps you know someone in the Agricultural Department in your country? We are here to coach you and to provide you materials on how to get them on board.
7. Share your news. Send us your pulse related news to include in the News pages of iyop.net.
8. Submit your event to iyop.net to include on our Event Calendar.
9. Translate materials on iyop.net into your national language.
10. And finally… to welcome the Year, have an Event on January 5th, 2016 and serve pulses!

Celebrating 2016 INTERNATIONAL YEAR OF PULSES

good for planet, good for people

First Announcement

# 2016 International Conference on PULSES

## FOR HEALTH, NUTRITION AND SUSTAINABLE AGRICULTURE IN DRYLANDS

Rabat, Morocco, 13-15 April, 2016

ORGANIZED BY

International Center for Agricultural Research in the Dry Areas (ICARDA) and
Institut National de la Recherche Agronomique (INRA), Morocco

ICARDA
Science for Better Livelihoods in Dry Areas

IN COLLABORATION WITH

United Nations Food and Agriculture Organization (FAO)
OCP Foundation and
CGIAR Research Program (CRP) on Grain Legumes

## Pulses in Drylands

Chickpea, faba bean, lentil, common bean, field pea, mung bean, black gram, pigeon pea, cow pea, and grasspea are the major pulse crops produced globally. They specially play an important role in food and nutritional security and sustainable agricultural production systems in the drylands which cover over 40% of the world's land area and are home to approximately 2.5 billion people. These crops are the mainstay of agriculture and diets in these regions, constituting a major source of protein for billions. With an ever-growing health conscious population, the demand for pulses is increasing and so is the opportunity.

*ICARDA research station at Marchouch, Morocco*

## Pulses: Good for the Planet, Good for the People

Given the World Economic Forum's recent assessment on water scarcity posing a significant risk to sustainable development goals, pulses may offer a part of the solution – pulses are efficient users of water and nutrients, offering more crop per drop in terms of protein and micro-nutrients. With prevailing child malnutrition at 27% in Africa and as much as 37% in India, the high-protein, micronutrient-rich caloric values of pulses offer the opportunity for eradicating malnutrition in challenging soil and climatic environments.

According to UNCCD, today 52% of the land used for agriculture is moderately or severely affected by degradation of soil, a non-renewable resource. The worsening land degradation scenario is challenging sustainable food production, particularly in drylands where natural resources are scarce. Pulses have the ability to replenish soil nutrients through nitrogen fixation, making them valuable to improve production systems through crop rotation.

## About the Conference

The International Conference on Pulses for Health, Nutrition and Sustainable Agriculture in Drylands is being held on the occasion of the 2016 International Year of Pulses to provide a platform to various stakeholders, including scientists, policy-makers, extension workers, traders and entrepreneurs, to discuss the various contributions of pulses to food and nutritional security and ecosystem health. Challenges ahead to driving greater production and benefits for all will be addressed with a focus on Central and West Asia, and North Africa. A roadmap will be developed for increasing productivity and profitability of pulses through diversification and intensification of cereal/livestock-based cropping systems.

The Conference, to be held April 13-15, 2016 in Rabat, Morocco, is being organized by ICARDA and INRA (Morocco) in partnership with FAO, OCP Foundation and CRP Grain Legumes. Conference advisory partners include (alphabetically):

- Ethiopian Institute of Agricultural Research (EIAR), Ethiopia
- General Directorate of Agricultural Research and Policy (GDAR), Turkey
- Indian Council of Agricultural Research (ICAR), India
- Institut National de la Recherche Agronomique (INRA), France
- Institute for Sustainable Agriculture (CSIC), Cordoba, Spain
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
- University of California, Davis (UC Davis), USA
- The University of Western Australia (UWA), Perth, Australia

## Conference Themes

1. Global pulses scenarios – production, consumption and trade
2. Innovative techniques for pulses improvement and adaptation
3. Diversification & sustainable intensification of agri-food systems through pulses
4. Seed systems, input markets and mechanization
5. Nutrition, fortification, health and food security
6. Social, economic and policy issues – increasing adoption and impacts assessment
7. Country successes, lessons learnt and challenges (knowledge-sharing event)

## Preliminary Conference Program

- Six technical sessions with keynote addresses by distinguished scientists
- A poster exhibition around major themes
- A knowledge-sharing event on country experiences for mutual learning
- A field visit to research experiments on pulse crops at the Marchouch Research Station and farmers' fields

## Call for Papers

Participants of the Conference are invited to contribute abstracts of papers for oral or poster presentation on pulses on areas that pertain to themes 1 to 6. Abstracts should not exceed 250 words and must be submitted online.

## Important Deadlines

- Submission of Abstract: Dec 31, 2015
- Notification of Acceptance: Jan 31, 2016
- Submission of Full Paper: March 30, 2016

## Date and Venue

### 13-15 April, 2016 in Rabat, Morocco

ICARDA has established its Global Research Platform for Intensification and Diversification of Cereal-Based Production Systems in Morocco and the office for its North Africa Regional Program in Rabat, both graciously hosted by the Institut National de la Recherche Agronomique (INRA).

Rabat is the capital city of Morocco, one of the most diverse countries in Africa, rich in culture and nature. The weather in Rabat is pleasant with temperatures around 15-25°C during April.

## Conference Organizing Committees

### International

- Dr. Mahmoud Solh (ICARDA), Chair
- Prof. Mohamed Badraoui (INRA), Morocco
- Dr. David Bergvinson (ICRISAT), India
- Mr. Dost Muhammad, Regional Plant Production Officer, FAO/RNE
- Mr. Nawfel Roudies (Program Director, OCP-Foundation), Morocco
- Dr. Masum Burak (GDAR), Turkey
- Dr. B.B. Singh (ICAR), India
- Dr. Asnake Fikre (EIAR), Ethiopia
- Dr. Fred Muehlbauer (USDA/ARS), USA
- Dr. Doug Cook (UC-Davis), USA
- Prof. Kadambot Siddique (University of Western Australia), Australia
- Prof. Diego Rubiales (CSIC), Spain
- Dr. Marie Hélène Jeuffroy (INRA), France
- Dr. Michael Baum (ICARDA), Morocco
- Dr. Shoba Sivasankar (ICRISAT)
- Dr. Ennaany Driss,Mohamed VI Polytechnic University, Morocco

### Local

- Dr. Rachid Dahan INRA, Chair
- Dr. Shiv Kumar Agarwal, ICARDA
- Dr. Mohamed El Mourid, ICARDA
- Dr. Rachid Mrabet, INRA
- Dr. Mohamed El Asri, INRA
- Prof. Ahmed Bamouh, IAV- Hassan II
- Mr. Rouini Imadeddine, OCP Foundation
- Ms. Hassina Moukhariq, OCP Foundation
- Dr. Ashutosh Sarker, ICARDA
- Dr. Sripada Udupa, ICARDA
- Dr. Seid Kemal, ICARDA
- Dr. Ahmed Amri, ICARDA
- Dr. Moustafa El-Bouhssini, ICARDA

**Registration fee: 250 USD**
(to cover lunches, Conference dinner, coffee breaks)

A conference website will be launched soon, providing event updates and allowing online registration, abstract/paper submission and fee payment (for latest information, visit www.icarda.org).

**For more information, contact:**

Dr. Michael Baum
Director, Biodiversity and Integrated Gene Management Program
ICARDA
Rabat, Morocco
m.baum@cgiar.org

Dr. Shiv Kumar Agrawal
Food Legumes Coordinator
ICARDA
Rabat, Morocco
sk.agrawal@cgiar.org

www.icarda.org

ICARDA
Science for Better Livelihoods in Dry Areas

# Second International Legume Society Conference (ILS2) *2016: Legumes for a Sustainable World*

Tróia, Portugal, 12-14 October 2016

http://www.itqb.unl.pt/meetings-and-courses/legumes-for-a-sustainable-world/welcome#content

The International Legume Society and the Instituto de Tecnologia Química e Biológica of the Universidade Nova de Lisboa cordially invite you to join us at the Second International Legume Society Conference, scheduled from 12-14 October, 2016 at Tróia resort, in the vicinity of Lisbon, Portugal.

In a world urgently requiring more sustainable agriculture, food security and healthier diets the demand for legume crops is on the rise. This growth is fostered by the increasing need for plant protein and for sound agricultural practices that are more adaptable and environmentally sensitive. Food, feed, fiber and even fuel are all products that come from legumes – plants that grow with low nitrogen inputs and in harsh environmental conditions. The Second Legume Society Conference will be held during 2016 - the United Nations' International Year of Pulses. The goals of this UN International Year include: the encouragement of connections throughout the food chain that would better utilize pulse based proteins; increase global production of pulses; better utilization of crop rotations; and to address challenges in the trade of pulses.

The conference will address the following themes: Legume Quality and Nutrition; Farming Systems/Agronomy; Abiotic and Biotic Stress Responses and Breeding; Legume Genetic Resources; and New "Omics" Resources for Legumes. The health and environment benefits, as well as, the marketing of legumes will be transversal topics throughout the conference. Special attention will be given to foster the interaction of researchers and research programs with different stakeholders including farmers and farmer associations, seed/feed and food industries, and consumers. For this, the conference will also be the site of the Final Meeting of the EU-FP7 ABSTRESS project, the Annual Meeting of EU-FP7 LEGATO project; and final dissemination events of EU-FP7-ERANets MEDILEG and REFORMA. The results and conclusions from these four important research programs will be shared with conference attendees.

Please join us in beautiful Tróia, Portugal from 12-14 October, 2016! Plan now to include the Second ILS Conference in your busy agenda. Kindly share this information with any colleagues dealing with legumes.

*Diego Rubiales, on behalf of the Scientific Committee*
*Pedro Fevereiro, Carlota Vaz Patto and Susana Araújo, on behalf of the Organizing Committee*

ABSTRESS Improving the resistance of legume crops to combined Abiotic and Biotic STRESS

LEGATO LEGumes for the Agriculture of TOmorrow

EUROLEGUME 2014-2017

medileg

REFORMA

## Local Organizers

The Instituto de Tecnologia Química e Biológica / Universidade Nova de Lisboa (ITQB/UNL) will be responsible for organising the Conference, in cooperation with the International Legume Society. The official language of the Conference will be the English.

INSTITUTO DE TECNOLOGIA QUÍMICA E BIOLÓGICA ANTÓNIO XAVIER /UNL
Knowledge Creation

## Conveners

Pedro Fevereiro - Universidade Nova de Lisboa (ITQB/UNL)
Carlota Vaz Patto - Universidade Nova de Lisboa (ITQB/UNL)
Susana Araújo - Universidade Nova de Lisboa (ITQB/UNL)

## Scientific Coordinator

Diego Rubiales - CSIC, Córdoba, Spain

## Local Organizer Committee (in alphabetic order)

Nuno Almeida - ITQB/UNL
Susana Araújo - ITQB/UNL
Ana Barradas - Fertiprado
Manuela Costa - Universidade do Minho
Isabel Duarte - Instituto Nacional de Investigação Agrária e Veterinaria (INIAV)
Sofia Duque - ITQB/UNL
Pedro Fevereiro - ITQB/UNL
Susana Leitão - ITQB/UNL
Eduardo Rosa - Universidade de Trás-os-Montes e Alto Douro
Marta Vasconcellos - Escola Superior de Biotecnologia, Universidade Católica
Carlota Vaz Patto - ITQB/UNL
Manuela Veloso - INIAV

## Scientific Committee (in alphabetic order)

Michael Abberton - IITA, Nigeria
Shiv Kumar Agrawal - ICARDA, Syria
Paolo Annicchiarico - CREA-FLC, Italy
Stephen E. Beebe - CIAT, Colombia
Charles Brummer - University of California, USA
Adrian Charlton - FERA, UK
Gerard Duc - INRA, France
Noel Ellis - ICRISAT, India
Pedro Fevereiro - ITQB/UNL, Portugal
Judith Lichtenzveig - Curtin University, Australia
Kevin McPhee - North Dakota State University, USA
Aleksandar Mikić - Institute of Field and Vegetable Crops, Serbia
Eduardo Rosa - Universidade de Trás-os-Montes e Alto Douro, Portugal
Diego Rubiales - Institute for Sustainable Agriculture, CSIC, Spain
Fred Stoddard - University of Helsinki, Finland
Richard Thompson - INRA, France
Tom Warkentin - University of Saskatchewan, Canada

## Venue

The conference will be held in Tróia in the vicinity of Lisbon, Portugal. Tróia is a beautiful sand peninsula dividing the Sado River from the Atlantic Ocean.

The nearest airport is the Lisbon International Airport, about 50 Km away. Shuttles will be made available from and to Lisbon International Airport.

During the period of Roman occupation, date from the 1st century to the 6th century AD, Tróia was an island of Sado delta, called Ácala Island.

The Sado Estuary Nature Reserve, where dolphins swim, and the Serra da Arrábida Natural Park, where a full developed Mediterranean forest can be seen, are two of the main natural attractions nearby Tróia peninsula.

The Tróia Golf Championship Course is considered the best course in Portugal in the categories of difficulty and variety. It also stands in 20th place in the list of the best golf courses in Europe drawn up by the Golf World magazine.







## First tentative programme

## October 10th and 11th, 2016

Ascochyta Workshop
Satellite projects meetings (to be defined)

## October 11th, 2016

Evening: ILS2 Conference Registration

## October 12th, 2016

08:00 Registration
09:00-09:30 Welcome addresses

**09:30-10:30 Session 1, plenary: Legumes vale chain: market requirements and economic impact**
09:30-10:00 Key lecture 1
10:00-10-30 Key lecture 2

**10:30-11:00 Coffee break**

**11:00-12:00 Session 2, plenary: Legumes and environment**
11:00-11:30 Key lecture 1
11:30-12:00 Key Lecture 2

**12:00-13:00 Poster viewing**

**13:00-14:30 Lunch**

**14:30 – 16:00 Parallel sessions**
**Session 3, parallel: Session 3, parallel: Mechanisms of beneficial legume-microbe interactions**
14:30-15:00 Key lecture
15:00-15:15 Oral presentation 1
15:15-15:30 Oral presentation 2
15:30-15:45 Oral presentation 3
15:45-16:00 Oral presentation 4

**Session 4, parallel: Genetic resources**
14:30-15:00 Key lecture
15:00-15:15 Oral presentation 1:
15:15-15:30 Oral presentation 2
15:30-15:45 Oral presentation 3
15:45-16:00 Oral presentation 4

**16:00-16:30 Coffee break**

**16:30-17:30 Parallel sessions**
**Session 5, parallel: Legumes value chain: market requirements and economic impact (cont.)**
16:30-16:45 Oral presentation 1
16:45-17:00 Oral presentation 2
17:00-17:15 Oral presentation 3
17:15-17:30 General discussion on Legumes value chain

**Session 6, parallel: Legumes and environment (cont.)**
16:30-16:45 Oral presentation 1
16:45-17:00 Oral presentation 2
17:00-17:15 Oral presentation 3
17:15-17:30 General discussion on Legumes and environment

**17:30-18:30 Poster session 1**
Slots of 3 min flash presentations (+ 2 min questions) from 12 selected posters on the sessions of the day

**20:45** Third International Legume Football Cup: semi-finals

## October 13th, 2016

**8:30-10:00 Session 7, plenary: Legumes in food and feed and other alternative uses**
08:30-09:00 Key lecture 1
09:00-09:30 Key lecture 2
09:30-10:00 Highlighted oral presentation

**10:00-10:30 Coffee break;**

**10:30-12:00 Session 8, plenary: Frontiers in legume genetics and genomics**
10:30-11:00 Key lecture
11:00-11:30 Highlighted oral presentation
11:30-12:00 Highlighted oral presentation

**12:00-13:00 Poster session 2**
Slots of 3 min flash presentations (+ 2 min questions) from 12 selected posters from the sessions of the day

**13:00-14:30 Lunch**

**14:30 – 16:00 Parallel sessions**
**Session 9 parallel: Legumes in food and feed and other alternative uses (cont.)**
14:30-14:45 Oral presentation 1
14:45-15:00 Oral presentation 2
15:00-15:15 Oral presentation 3
15:15-15:30 Oral presentation 4
15:30-15:45 Oral presentation 5
15:45-16:00 General discussion on Legumes in food and feed and other uses

**Session 10 parallel: Frontiers in legume genetics and genomics (cont.)**
14:30-14:45 Oral presentation 3
14:45-15:00 Oral presentation 4
15:00-15:15 Oral presentation 6
15:15-15:30 Oral presentation 7
15:30-15:45 Oral presentation 8
15:45-16:00 General discussion of genetics and genomics

**16:00-16:30 Coffee break;**

**16:30-18:00 Parallel sessions**
**Session 11, parallel: Frontiers in plant and crop physiology**
16:30-17:00 Key lecture
17:00-17:15 Oral presentation 1
17:15-17:30 Oral presentation 2
17:30-17:45 Oral presentation 3

**Session 12 parallel: Integrated pest and disease management**
16:30-17:00 Key lecture
17:00-17:15 Oral presentation 1
17:15-17:30 Oral presentation 2
17:30-17:45 Oral presentation 3

**17:45-19:00 ILS General Assembly**

20:45 Third International Legume Football Cup: finals

## October 14th, 2016

**8:30-10:00 Session 13 plenary: Frontiers in legume breeding**
08:30-09:00 Key lecture
09:00-09:30 Highlighted oral presentation
09:30-10:00 Highlighted oral presentation

**10:00-10:30 Coffee break;**

**10:30-12:00 Session 14, plenary: Frontiers in legume agronomy**
10:30-11:00 Key lecture
11:00-11:30 Highlighted oral presentation
11:30-12:00 Highlighted oral presentation

**12:00-13:00 Poster session 3**
Slots of 3 min flash presentations (+ 2 min questions) from 12 selected posters from the sessions of the day

**13:00-14:30 Lunch**

**14:30 – 16:00 Parallel sessions**
**Session 15, parallel: Advances in legume breeding (cont.)**
14:30-14:45 Oral presentation 1
14:45-15:00 Oral presentation 2
15:00-15:15 Oral presentation 3
15:15-15:30 Oral presentation 4
15:30-15:45 Oral presentation 5
15:45-16:00 General discussion on advances in legume breeding

**Session 16 parallel: Advances in legume agronomy (cont.)**
14:30-14:45 Oral presentation 1
14:45-15:00 Oral presentation 2
15:00-15:15 Oral presentation 3
15:15-15:30 Oral presentation 4
15:30-15:45 Oral presentation 5
15:45-16:00 General discussion on advances in legume agronomy

**16:00-16:30 Coffee break;**

**16:30-18:00 Parallel sessions**
**Session 17, parallel: Seed technology, marketing and knowledge-transfer**
16:30-17:00 Key lecture
17:00-17:15 Oral presentation 1
17:15-17:30 Oral presentation 2
17:30-17:45 Oral presentation 3
17:45-18:00 Oral presentation 4

**Session 18 parallel: Resistance to biotic and abiotic stresses**
16:30-17:00 Key lecture
17:00-17:15 Oral presentation 1
17:15-17:30 Oral presentation 2
17:30-17:45 Oral presentation 3
17:45-18:00 Oral presentation 4

**18:00-19:00 Concluding session**
Posters and oral presentations awards
ILS Honorary member's awards

**20:00 Farewell Dinner**

## International Legume Society (ILS)

is publicly announcing

# A CALL FOR TENDERS
# TO HOST
# THIRD ILS CONFERENCE (ILS3)
# IN 2019

All interested organisations
are kindly invited to express their interest to
Professor Diego Rubiales, the ILS President,
at diego.rubiales@ias.csic.es,
at the earliest convenience.

The venue of ILS3 will be defined and announced
by the ILS Executive Committee
in December 2015.

**12th European Nitrogen Fixation Conference**
**Budapest, Hungary, 25-28 August 2016**
**http://enfc2016.hu/**

**20th Eucarpia General Congress**
**Zurich, Switzerland, 29 August - 1 September 2016**
**http://eucarpia2016.org**

**26th General Meeting of the European Grassland Federation**
**Trondheim, Norway, 5-8 September 2016**
**http://www.egf2016.no**

**XIV Congress of the European Society for Agronomy**
**Edinburgh, UK, 5-9 September 2016**
**http://esa14.org.uk**

**10th World Soybean Research Conference**
**Savannah, USA, 10-16 September 2017**
**http:// www.wsrc10.com**

*Legume Perspectives* is an international peer-reviewed journal aiming to interest and inform a worldwide multidisciplinary readership on the most diverse aspects of various research topics and use of all kinds of legume plants and crops.

The scope of *Legume Perspectives* comprises a vast number of disciplines, including biodiversity, plant evolution, crop history, genetics, genomics, breeding, human nutrition, animal feeding, non-food uses, health, agroecology, beneficial legume-microorganism interactions, agronomy, abiotic and biotic stresses, agroeconomy, sociology, scientometrics and networking.

The issues of *Legume Perspectives* are usually thematic and devoted to specific legume species or crop, research topic or some other issue. They are defined by the Editorial Board, led by the Editor-in-Chief with the help from Assistant Editors, who select and invite one or more Managing Editors for each issue. Having accepted the invitation, the Managing Editor agrees with the Editorial Board the details, such as the deadline for collecting the articles and a list of the tentative contributors, from whom he, according to his own and free choice, solicit the articles fitting into the defined theme of an issue. A possibility that every member of the global legume research community, with a preference of the International Legume Society members or established authorities in their field of interest, may apply to the Editorial Board to be a Managing Editor and suggest a theme for his issue is permanently open and can be done simply by contacting the Editor-in-Chief by e-mail, with a clearly presented idea, structure and authors of the potential issue.

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