LUPIN: A Legume with A Future

Lupin can serve as a cost-effective substitute for soybeans in many food formulations such as tempe, miso and tofu. Research into the nutritional and processing properties of this high protein and high fibre legume also suggests good potential for its application in bread, noodles and beverages.

By Vijay Jayasena & Ken Quail

SOYBEANS are used for human food and animal feed applications throughout the world and is a particularly valuable source of protein with high nutritional value and functional properties. Australia and Southeast Asia are net importers of soybeans and soy products with a significant cost to the region. On the other hand, lupins offer properties comparable with soy, at less than half the cost. Although extensively used in stockfeed applications, lupins remain under-utilised in potential food applications.

Table 1: Chemical compositions of lupins and soybeans (%)

	L. angustifolius	*L. albus*	Soybean
Protein	32	36	40
Fat	6	9	20
Ash	3	3	5
Crude Fibre	15	10	4

Source: Petterson and Fairbrother 1996; Kyle 1994

Table 2: Anti-nutritional factors of lupins and soybean

	L. angustifolius	*L. albus*	Soybean
Phytate (%)	0.58	0.79	1.59
Trypsin inhibitors (mg/g)	0.14	0.13	17.9
Saponins (mg/kg)	573	Nd	19000
Total phenolics (%)	0.32	0.37	0.57

(Source: Adapted from Kyle 1994) *Nd – Not detected*

A less pricey plant protein

Lupin is a grain legume which has proved highly effective in crop rotations to support the sustainability of wheat and barley production in Australia. Australia has become the worlds largest producer of lupins with typical annual production of more than one million metric tonnes. Three main types of lupins are grown in Australia. *Lupinus angustifolius*, or Australian Sweet Lupin (ASL), is the most popular and is produced in Western Australia. *Lupinus albus* (white lupin) and *Lupinus luteus* (yellow lupin) are the other two commercially grown species.

Demand for both animal and vegetable proteins has increased in the last few decades and this trend is expected to continue. The limited supply and high cost of animal protein and concerns over diseases such as Bovine Spongiform Encephalopathy and Avian flu have driven interest in the potential of unconventional proteins sources such as lupin. To date, lupin has largely been used for animal feed. However, new opportunities for food applications are being identified as its high nutritional value and functional properties have been revealed. With lupins competitively priced against soybeans, it is expected that they will become a major source of plant proteins in the future.

Composition of lupin

Typical chemical compositions of some of the cultivated lupin varieties are presented in Table 1. Compared to soybean, lupins have lower protein and oil contents, but higher dietary fibre content.

Protein

In line with other grain legumes, lupin proteins are low in sulphur-containing amino acids (methionine and cystine) and high in lysine. The amino acid profile of lupin protein is similar to that of soybean.

Oil

In terms of processing, low oil content is one of the main drawbacks of lupin compared to soybean. The oil content of ASL is around 6% compare to around 20% in soybean. The nutritional value of lupin oil is high due to the high proportion of unsaturated (34% monounsaturated and 44% polyunsaturated) fatty acids (Petterson & Fairbrother 1994). The amount of oil in most of the cultivated lupin varieties is considered as economically unattractive for extraction.

Development of lupin varieties with high oil content would open exciting new opportunities for the future development of lupin processing industry. Pearl lupin (*L. Mutabilis)*, which has been cultivated for more than a century, offers comparable advantages to soybean in terms of protein (~40%) and oil (~20%) contents. However, commercial production of Pearl lupin is limited at present.

Non-Starch Polysaccharides

Lupin contains hardly any starch. Carbohydrates are present mainly in the form of non-starch polysaccharides (NSP). This high level of NSP is one of the main advantages of lupin compared to soybean. Lupin NSP constitutes a good source of dietary fibre with various health benefits including lowering cholesterol and blood glucose levels and reducing obesity. Tasteless, odourless and of a light brown colour, lupin NSP may be one of the best low cost dietary fibre supplements for various food formulations.

Anti-Nutritional Factors

Many legumes contain various anti-nutritional factors (ANF). Compared to soybean, ASL grains are low in ANF commonly found in grain legumes (see Table 2 on page 16).

Bio-Active Compounds

Grain legumes have been identified as excellent sources of a range of bio-active compounds including phytoestrogens associated with protection against cancer, and phytosterols which can reduce blood cholesterol levels. Lupin seeds have a higher phytosterol content than soybeans. Although the seeds have a low level of phytoestrogens, it has been shown that the they can be significantly increased (300 fold) by sprouting (Wang et al. 2004).

Functional properties of Lupin Protein Isolate

Lupin flour can be fractionated into a number of components such as lupin protein concentrate (LPC) with more than 70% protein on a dry basis (db), Lupin Protein Isolate (LPI) with more than 90% protein (db) and dietary fibre in the process of protein isolation. Various means of protein isolation are available and alkali treatment followed by isoelectric precipitation seems to be the most applicable method for the lupin industry. The main functional properties of proteins that are important in food formulations include: Emulsion Activity (EA), Emulsion Stability (ES), Foaming Capacity (FC), Foam Stability (FS), Water Holding Capacity (WHC) and Gel Forming Ability (GFA).

Emulsifying Properties

Examples of food emulsions are ice cream, butter, margarine, sauces, mayonnaise, salad dressings and frozen desserts. Comparative studies have shown that Soy Protein Isolate (SPI) and LPI have comparable emulsifying properties (see Figure 1, Jayasena et al. 2004; Kyle 1994).

Foaming Properties

Products such as cake and pavlova are examples of food products in which FC and FS play an important role. Egg white is one of the most commonly used food ingredients for foaming properties. A number of studies have shown that SPI and LPI have similar foaming properties (see Figure 2, Jayasena et al. 2004; Kyle 1994). Lupin protein fraction with unique FC and FS similar to egg white (superior to SPI) has been isolated from lupin (Jayasena et al. 2004; Sipsas 2004). Further studies are in progress to characterise this protein fraction.

Protein Solubility

Solubility is one of the most important parameters that determine the applicability of proteins in food and beverage formulations. The solubility of proteins is dependant upon

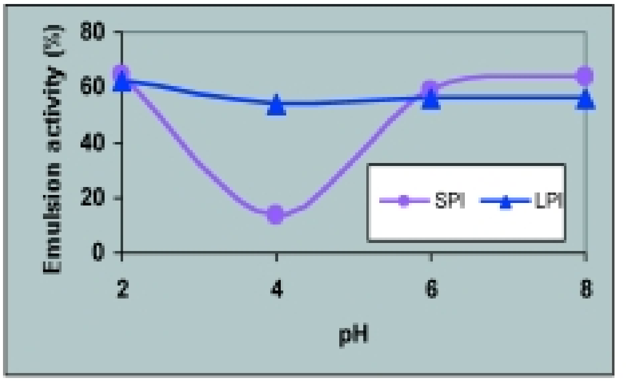

Figure 1. Emulsifying Activities of LPI and SPI.

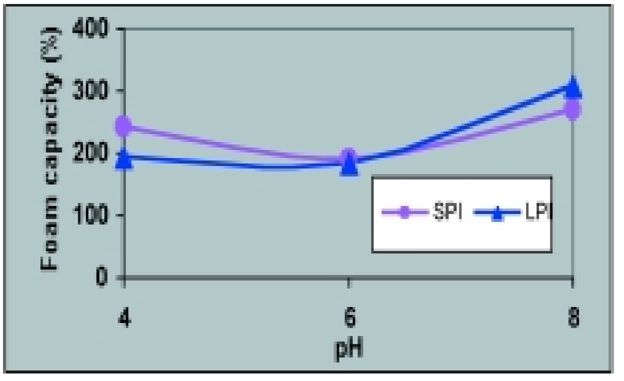

Figure 2. Foaming Capacities of LPI and SPI.

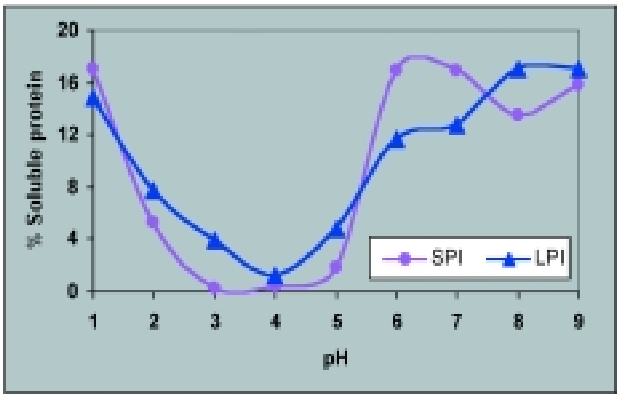

Figure 3. Solubility Profiles of LPI and SPI.

various factors including pH, temperature and ionic strength. Jayasena *et al*. (2004) found that both LPI and SPI have similar protein solubility profiles over a wide pH range (see Figure 3).

Water Holding Capacity

A number of factors such as hydrophilic-hydrophobic balance of amino acids and molecular size and shape influence the Water Holding Capacity of proteins. For a number of reasons, food manufacturers prefer to incorporate food ingredients with high WHC in their food formulations. Such reasons include the economic benefits resulting from adding water to a product priced according to its weight, and the positive impact on the shelf life. A comparative study has indicated that the WHC of LPI is better than that of SPI (Jayasena et al. 2004).

Gel Forming Ability

Protein gels can be formed as a result of heat, salts, acids, alkalis and other chemical treatments. Heating and cooling of protein-water systems is one of the most common means of gel formations in food processing. Jayasena et al. (2004) found that SPI and LPI formed gels at 12% and 16% respectively indicating slightly poorer Gel Forming Ability of LPI compared to SPI.

Human consumption of lupin

Although lupins remain an unknown grain legume in some parts of the world, the human consumption of lupin dates

back centuries. However, the cultivation of lupin on a commercial scale did not commence until the 1960s.

The earlier use of lupin was limited by the presence of toxic alkaloids and other anti-nutritive compounds. In response to this, sweet lupin varieties with low levels of alkaloids and ANFs have been developed by breeders and are being cultivated at present. One of the main advantages of ASL, compared to soybean, is that heat treatment is not required to destroy ANFs in order to incorporate it into food formulations.

Grain legumes, including lupins, have low levels of sulphur amino acids, but are rich in lysine. In contrast, cereal grains such as wheat are poor in sulphur amino acids, but low in lysine. As a result, the nutritional quality of cereal-based products can be significantly improved by the incorporation of lupins.

In view of the limited supply and the high cost of animal and soy proteins, there is a significant interest in incorporating lupin flour and lupin protein in food formulation. The cost of lupin is less than 50% of the cost of soybean at present.

Whole Seeds

Lupin seeds have been used for centuries as a human food. Traditionally, seeds were soaked in water to remove toxic compounds. ASL grains can be consumed in various processed forms including roasted, boiled or preserved in brine.

Fermented Foods

Tempe is a traditional mould-fermented soy-based food common in Indonesia and in other Asian countries. Lupin is an excellent low cost substitute for soybean in tempe manufacturing. The nutritional value of the lupin-substituted tempe is likely to be superior due to its high dietary fibre content.

Indonesia imported more than one million tons of soybeans in 2002, at a cost approximating $600/ton. It is estimated that around 30% of this soybean was used for tempe manufacturing. A substantial cost saving could be achieved if soybean is, at least partially, replaced by lupin.

A new research initiative aimed at substituting lupin for soybean in tempe and other fermented food products is in progress. The project is conducted in collaboration with the Grain Foods Cooperative Research Centre (Dr Ken Quail) in Sydney, Curtin University of Technology in Perth (Dr Vijay Jayasena) and the Indonesian Institute of Sciences in Indonesia (Dr Leonardus Kardono).

Evidence suggests that lupin can substitute soybean in the manufacturing process of Miso, kecap and soy sauces. Miso represents a range of seasoning products prepared by the fermentation of soybean and rice with added salt and is a popular food product in Asian countries. Miso is becoming more and more popular in western countries.

New opportunities for lupin in food applications are being identified as its high nutritional value and functional properties have been revealed.

Milk, Milk-based Products and Tofu

Lupins have been used to prepare milk-type beverages. A lupin-based milk was used for a nutritional program in Chile for several years. UHT processed lupin milk was acceptable after 2 years of storage (Petterson and Fairbrother 1996). A new process to produce lupin based milk and dairy substitutes has been patented (Sipsas 2004). Cheese, yoghurt and tofu with lupin substitution have been produced. Soybean can be replaced by up to 30% lupin in tofu manufacturing.

Bread

Health benefits (due to high dietary fibre and lysine contents) and high water holding capacity have generated an interest for using lupin flour as an ingredient in bread formulations. Lupin flour incorporation improves the amino acid balance. According to Pollard et al. (2002), 5% lupin flour substitution had no effect on loaf volume and crumb structure of bread. According to Clark and Johnson (2002), 5% lupin fibre addition had no significant effect on bread acceptability.

Adding lupin flour to bread formulations results in increased water absorption, extended shelf life and reduced mixing time (Feldheim 2004; Pollard et al. 2002). Lupin enriched bread may be an effective means of improving the nutritional status of developing nations.

Pasta and Noodles

Up to 20% lupin flour can be incorporated when preparing pasta products. According to Feldheim (2004), appearance, cooking performance and acceptability of noodles made with 10% lupin flour were better than the control. The high carotenoid content of lupin flour could be responsible for the better appearance and acceptability of the lupin added pasta products. A number of pasta products with added lupin flour are currently available in the market. Clark and Johnson (2002) showed that 6% lupin fibre could be incorporated into pasta without affecting its acceptability.

Potential future applications

Various lupin products such as lupin flour, LPI, LPC and lupin fibre can be incorporated into a range of food products to improve their nutritional value, health benefits, organoleptic properties and consumer acceptability. In addition, food manufacturers would benefit by the substitution of a low cost food ingredient. Potential food applications include:

- High protein or high energy drinks, snacks and ready-to-eat meals
- Lupin based (or lupin substituted) fermented food products
- Baked goods (bread, cakes, muffins, biscuits and donuts)
- Vegetarian meat-like products
- Lupin substituted meat and sausages
- Whipped products, fillings and glazing
- Ice cream, cream desserts, mayonnaise and dressings
- Noodles and pasta products
- High dietary fibre foods, including weight reduction diets
- Foods rich in functional compounds such as isoflavones and carotenoids.

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