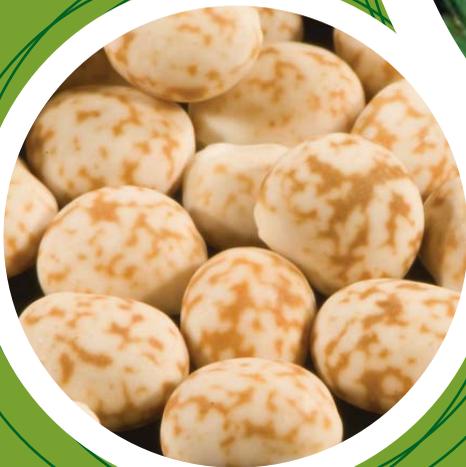


Australian Sweet Lupin

A very healthy asset

Department of Agriculture and Food
Government of Western Australia
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What is “Australian Sweet Lupin”?

‘Australian sweet lupin’ refers to the legume crop of *Lupinus angustifolius* (narrow-leafed lupin) cultivated in Australia. Australian sweet lupin is related to other legumes, including peanuts and soy.

There are 12 lupin species within the *Lupinus* genus, all of which are native to Europe and the Mediterranean regions. Three of these are now fully domesticated for agriculture: the Australian sweet lupin or narrow-leafed lupin, *Lupinus angustifolius*, the European white lupin, *Lupinus albus* and the yellow lupin, *Lupinus luteus*.

While the European white lupin has been used as a human food since the time of the ancient Egyptians, the wild type of *L. angustifolius* has bitter seeds, shattering pods, an impermeable seed-coat and is late flowering, making it unsuited to modern farming and human consumption. During the 1960s, Australian scientists domesticated this species to create the Australian sweet lupin of today - an earlier flowering, sweet-seeded version of its wild relative with non-shattering pods and a permeable seed coat. Food Standards Australia New Zealand has recognised Australian sweet lupin as fit for human consumption since 1987.

In Europe, the European white lupin has been used as a food ingredient for many years and the Australian sweet lupin was approved for general human consumption in

1999. In Europe, lupins are used to replace cereal grains or soy in food products such as baked goods, small goods and noodles and pasta. In fact it is estimated that 500,000 tonnes of food products in Europe contain European white lupin and Australian sweet lupin as an ingredient.

The Department of Agriculture and Food Western Australia has the world’s largest breeding team for Australian sweet lupin. Since the 1970s, the plant breeding efforts of this Western Australian breeding team have led to more than a doubling of yield of Australian sweet lupin - from 0.7 to 1.5 tonnes per hectare.

Australia is the world’s largest producer of Australian sweet lupin - with Australian farmers producing about one million tonnes of the grain each year. During the past 20 years, Australia has exported more than 15 million tones of Australian sweet lupin to countries all over the world including Spain, The Netherlands, Indonesia, Japan, South Korea, Thailand and Taiwan.



Potential Health Benefits of Australian Sweet Lupin

Dieticians and medical scientists in Europe and Australia are researching the health benefits of Australian sweet lupin, which has a low glyceamic index and could potentially play a role in combating obesity and its associated health problems of diabetes and heart disease.

There is supportive scientific evidence that consuming foods enriched with Australian sweet lupin can provide a feeling of 'fullness' that results in people eating less and consuming fewer kilojoules. Other possible health benefits of eating the lupin include a more balanced blood glucose level, a lowering of cholesterol and improved bowel health.

Low GI (glyceamic index)

Like soybean, the Australian sweet lupin is high in protein (30-35%) but is significantly higher in dietary fibre (30%) and lower in oil (6%), while containing minimal starch. Consequently, Australian sweet lupin has a very low glyceamic index or GI, which has positive implications for the increasing incidence of obesity, diabetes and cardiovascular disease in developed countries.

Australian sweet lupin and the European white lupin have the lowest GI of all commonly consumed grains. A 2005 study

found that eating white bread enriched with the kernel flour of Australian sweet lupin significantly reduced blood glucose and insulin responses compared to those eating plain white bread.¹

Low GI foods are known to:

- Lower post-digestion glucose rise
- Reduce daily mean insulin levels
- Lower total and LDL cholesterol levels
- Reduce liver cholesterol synthesis
- Decrease serum Apolipoprotein B levels
- Decrease 24h urinary C-peptide output
- Result in a higher satiety rating, which controls appetite

Suppresses appetite

Replacing meat fat with lupin fibre reduced the fat content of sausage patties by more than a third and resulted in the people eating the patties consuming fewer kilojoules throughout the remainder of the day.²



Similarly, people eating bread enriched with lupin kernel flour at the expense of wheat flour ate 20 per cent less and reported an increased feeling of fullness.³

Lowers cholesterol

The soluble nature of lupin fibre acts to reduce total cholesterol without affecting the 'good' or HDL cholesterol. Research carried out in 2005 found that eating a diet enriched with Australian sweet lupin fibre for one month lowered total blood cholesterol by 4.5 per cent and 'bad' LDL cholesterol by 5.4 per cent.⁴

Lowers blood pressure

Lupins are one of the best natural sources of the amino acid - arginine, which is thought to improve blood vessel performance. In a recent study, including lupins in the diet of salt loaded rats protected the rats from developing high blood pressure.⁵

Improves bowel health

Australian sweet lupin shows potential for improving bowel health - including kernel fibre of Australian sweet lupin in the diet reduced transit time, and lowered colon pH (anti cancer) in participants of two recent studies.^{6,7}

Gluten and GMO free

Lupins are gluten free and are therefore potentially suitable for people with coeliac disease. In Western Australia, government policy ensures that the Australian sweet lupin is totally free from GMO.

An allergy caution

Like other legumes such as peanuts and soybean, consuming or coming into contact with Australian sweet lupin may cause allergic reactions (including anaphylactic shock) in some individuals, although such incidents are rare. Products made with Australian sweet lupin should therefore carry an allergy warning.



Use of Australian Sweet Lupin in Foods

Australian sweet lupin improves the nutritional value, health benefits and consumer acceptance of a variety of foods. In addition, being low cost, food manufacturers will also benefit from using lupin as a protein and fibre substitute. Potential food applications for Australian sweet lupin include:

- Sprouts
- Fermented foods such as tempe and miso
- High protein and high energy drinks
- Snacks and ready to eat meals
- Milk type beverages, yoghurts probiotics and tofu
- Baked foods such as breads, cakes, muffins, biscuits and donuts
- Vegetarian food products
- Lupin substituted meat and sausages

- Whipped products, fillings and glazes
- Ice cream, cream desserts, mayonnaise and dressings
- Noodle and pasta products
- High dietary fibre foods, including weight reduction diets

Australian sweet lupin sprouts

Australian sweet lupin can be germinated to produce large, crispy sprouts for use as a vegetable. Australian sweet lupin sprouts out perform soybean and mung bean sprouts on the following properties:

Higher sprout yield Australian sweet lupin produces 7.5 kg sprouts per kg of seed compared with 5 kg sprouts per kg of seed for soybean and mung bean.

Better sensory qualities Australian sweet lupin sprouts are wider and longer than soybean sprouts with excellent colour and freshness, all of which contribute to a very high consumer appeal.

No lateral roots While soybean sprouts require chemical treatments to inhibit lateral root growth, Australian sweet lupin sprouts remain free of lateral roots even when fully developed.

Better taste Australian sweet lupin sprouts are crispier and have less 'beany' flavour than soybean sprouts. This difference is



particularly evident after boiling, making the Australian sweet lupin sprout ideal for traditional Chinese “Huoguo” (火锅) cooking.

Source of isoflavones (nutraceuticals)

Australian sweet lupin sprouts are an excellent source of isoflavones; a group of molecules often referred to as ‘phytoestrogens’.

Isoflavones are natural antioxidants and consuming them may play a role in lowering disease risk. The isoflavones diadzein and genistein may improve bone health by conserving calcium and thereby reducing the risk of osteoporosis. Some isoflavones are believed to inhibit the growth of cancerous cells and in some studies have slowed prostate cancer growth by killing prostate cancer cells in a similar way to many common cancer drugs.⁸⁻¹²

Traditional fermented foods

Australian sweet lupin is an excellent substrate for bacterial and fungal fermentations, which are used to make foods such as tempe, miso and traditional soy sauces.

Tempe Australian sweet lupin is a better substrate than soybean for fermentation, because more proteins and complex carbohydrates are broken down into simpler and more digestible organic structures.¹⁵

Miso In one study, a Japanese expert panel found miso made from Australian sweet lupin more acceptable than soy miso for colour and overall appearance and equally as acceptable for flavour and texture.¹⁴

Sauces Australian sweet lupin could be used to make sauces similar in flavour and texture to the traditional soy sauces of Japan¹⁸ and China.¹⁵ Australian sweet lupin has been found to be a better substrate than soya beans to make Korean paste and sauce.¹⁷

Noodles and pasta

Adding about 10 to 15 per cent lupin flour to wheat flours produces products with similar properties to the full wheat product, but increases the amino acid score from less than 40 per cent to more 70 per cent relative to egg albumin.^{19,23} The lupin component can be increased to 20 per cent before losing the integrity of the product.¹⁹ According to several international studies, lupin-enriched pasta has been received well in many countries.^{21,22,24}





Dairy substitutes: milk, yoghurt, ice-cream and tofu

Both the kernels and the protein extract from the kernels of Australian sweet lupin can be used to make milk. Like soy milk, Australian sweet lupin milk is a nutritionally balanced plant-based beverage, without the saturated fat found in dairy milk. Australian sweet lupin milk can in turn be used to make excellent yoghurt and probiotics.^{26,25,28}

German researchers from the Fraunhofer Institute for Process Engineering and Packaging IVV in Freising have made an ice cream exclusively from Australian sweet lupin proteins and canola oil. The balanced proportion of omega-3 and omega-6 fatty acids and cholesterol-lowering lupin protein provides the ice-cream with nutritional physiological benefits. The lupin protein present in the ice-cream is easy to process and has excellent sensory properties.

Tofu Incorporating up to 30 per cent Australian sweet lupin milk with soymilk before the coagulation stage produces a very acceptable tofu, with the advantage of a lower unit cost of production.^{26,27}

Breads, biscuits, and cakes

Incorporating up to 20 per cent lupin flour with wheat or wholemeal flours produces more nutritious bread; the blend of cereal and legume helps to balance out the amino acid profile and make it a more complete food.

Adding more than about five per cent lupin flour into most wheat flours results in a slight loss of loaf volume, because lupin proteins lack the strength and elasticity of wheat gluten.³⁰ However when stronger flours, such as hard red wheat from Canada, are used it is possible to add up to 15 per cent lupin flour and still retain loaf integrity and produce a quality product. The lupin-wheat combination increases the water-holding capacity of the product and the resultant texture, flavour and yellow colour is appealing to many consumers.³¹





In Australia, some bread manufacturers use lupin hull flour to produce high fibre breads. A gluten-free lupin loaf containing about 30 per cent kernel flour is available in some Australian states; while a wheaten bread with 5-10 per cent lupin kernel flour is also available. Ultrafine kernel flour has an attractive yellow colour, good dispersion in aqueous systems and good emulsifying properties. A French company produces lupin kernel and hull flours for the bakery trade (Terrena).

Adding up to eight per cent lupin flour (*L. albus*) to maize flour to produce humitas, a traditional Chilean food, improved the biological value of the protein, without adversely affecting sensory qualities.³²

Protein concentrates and isolates

Protein concentrates and isolates of Australian sweet lupin can be used as binding and emulsifying agents in pâté, potted mince, sausages and mousses and as a substitute for meat and egg proteins. Incorporating the protein isolate at one per cent either fully hydrated or stabilized in a pre-emulsified state improved both the processing characteristics and consumer acceptability of the final product.³³

Australian sweet lupin protein stabilises the structure and texture of meat preparations

due to its synergistic interaction with other meat additives such as gums, hydrocolloids and phosphate. Using protein concentrates of Australian sweet lupin in meat preparations can offer one or more of the following properties:

- emulsifies free animal fat
- binds with added water/ice
- absorbs meat juice
- binds larger meat particles ("sticking" effect)
- promotes softness and creaminess in spreadable sausages
- dry-out controller and accelerator in dry/fermented sausages
- strengthens gel and inhibits syneresis in cooked sausages

Composition of Australian Sweet Lupin

Australian sweet lupin has a typical dicotyledonous structure. The seeds coat comprises 25 per cent of the total seed weight and is mostly cellulose and hemicellulose. It is the cotyledons (kernels) that are most suitable for use in food product development. The composition and nutritional value of Australian sweet lupin kernels is shown in Table 1.

Table 1: Chemical composition of Australian sweet lupin kernels

	% of kernel weight
Moisture	12
Protein	41
Fat	7
Ash	3
Lignin	1
Polysaccharides	29
Oligosaccharides	6
Minor components	1
Total	100

Within the kernels, energy is stored mostly in the form of thickened cell wall material (25%) and oil bodies (6%). There is very little starch in the Australian sweet lupin which is in marked contrast to crops such as rice, wheat and other legumes such as field peas and lentils.

Carbohydrates

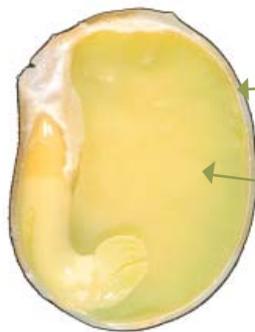
The seed coats (hulls) and cotyledons contain different types of carbohydrate. Lupin hulls contain predominantly structural polysaccharides; cellulose, hemicelluloses and pectins along with small amounts of protein and lipid. One hundred grams of lupin hull contains 95 grams of fibre. Xylose is present in large quantities, followed by uronic acid. The composition of the lupin hull resembles closely that of the soy hull.

The main carbohydrate reserves of the cotyledons are the non-structural polysaccharides of the cell walls, predominantly galactose, arabinose and uronic acid. These complex compounds are referred to as non-starch polysaccharides and their structure is based on a backbone of rhamno-galacturonans. About 20 per cent of the non-starch polysaccharides are water-soluble, and are thought to have bio-active as well as textural properties due to their viscous nature and effect on intestinal transit time.



As in soy, arabino-galactanes are the dominant sugar chains of the cell wall material of the lupin cotyledon. Fermentation tests using lupin fibres and micro organisms of the human intestine indicate that extensive biodegradation of lupin fibre occurs in the human intestine, which enables the growth of beneficial bacteria such as bifidobacteria. Another important attribute of the cotyledon arabino-galactanes is their ability to hold large quantities of water, about eight-fold by weight for lupins, which helps to maintain normal gut motility.

Another rich source of nutrients for beneficial bifidobacteria in the colon are lupin oligosaccharides; a higher α -galactoside of sucrose. The oligosaccharide-fraction (5-12%) contains raffinose, stachyose, verbascose and ajugose. Raffinose has one galactose moiety linked to sucrose through an α 1,4 bond, while stachyose has two, verbascose three and ajugose four.



Australian Sweet Lupin
L. angustifolius

Seed coat (hull) - 25%

- Cellulose fibres (bran)

Kernel (cotyledons) - 75%

- Cell wall material - (30%) pectin-like dietary fibres
- Inside cells -
 - Protein bodies (40%)
 - Fat bodies (7%)
 - Oligosaccharides (6%)
 - Starch (<2%)
 - Phytic acid (1%)
 - H₂O (12%)

Protein

The protein content of the lupin kernel is very high and can constitute more than half the kernel's total weight. Most of the proteins consist of globulin type storage proteins called conglutins; these make up about 85 per cent of the total protein and have similar size and physical properties to the storage proteins of other grain legume species. The remaining 15 per cent of proteins are albumins, which are soluble at pH 5 and vary in size from about 6,000 to 117,000 daltons.

The digestibility and bioavailability of lupin kernel protein is comparable to soy protein. In both legumes, the sulphur-containing amino acids are the limiting amino acids, while the amino acid lysine is present in large quantities (Table 2).

Combining lupin and cereal proteins results in a higher nutritional value than either protein source alone - bringing it almost in line with animal protein.^{34,35}

Table 2 Typical amino acid profiles for the Australian sweet lupin (g/100g).

Amino acids	Australian sweet lupin
Alanine	1.04
Arginine	3.59
Aspartic acid	2.99
Cysteine	0.42
Glutamic acid	6.63
Glycine	1.29
Histidine	0.79
Isoleucine	1.22
Leucine	2.12
Lysine	1.46
Methionine	0.20
Phenylalanine	1.18
Proline	1.26
Serine	1.59
Threonine	1.09
Tryptophan	0.31
Tyrosine	1.13
Valine	1.17
Cyst+Meth	0.62
Tyr+Phen	2.33





Lipids

The lipid content of Australian sweet lupin is made up of triglycerides (71%), phospholipids (15%), free sterols (5%), glycolipids (3.5%) sterol and wax esters (0.5%), free alcohols (0.4%) and unidentified waxy material (4%). The sterols present in the non-saponifiable fraction of the oil are mainly sitosterol and campesterol with smaller amounts of stigmasterol and avenasterol.

The oils have high antioxidant capacities due in part to the presence of tocopherol (vitamin E). The total vitamin E content is about 2.3-4.6 mg/kg of oil. During germination, the concentration of gamma-tocopherol decreases as alpha-tocopherol is formed.

Table 3 Fatty acid profiles for Australian sweet lupin (% of oil)

Fatty acid profile	Australian sweet lupin
Myristic C14:0	0.15
Palmitic C16:0	10.98
Palmitoleic C16:1	0.11
Stearic C18:0	3.75
Elaidic C18:1(9)t	3.97
Oleic C18:1(9)c	33.50
Vaccenic C18:1(7)	0.71
Linoleic C18:2 (ω 6)	37.10
Linolenic C18:3 (ω 3)	5.29
Arachidic C20:0	0.90
Eicosenoic C20:1(9)	0.29
Gadoleic C20:1(11)	0.30
Arachidonic C20:4	0.01
Behenic C22:0	1.90
Erucic C 22:1	<0.01
Lignoceric C24:0	0.39
Sterols	2.20
Eicosadienoic C20:2	---





Minerals and trace elements

The mineral (ash) content of Australian sweet lupin varieties fluctuates between 3.2 and 4.6g/100g dry matter. Typical mineral contents in mg/g are: calcium between 15 and 29; magnesium 11 - 20; sodium 3 - 11 and; potassium 66 - 90. Typical trace element contents in mg/kg are: iron 31 - 150; zinc 24 - 45 and; copper 2.5 - 6.8. Australian sweet lupin features a higher calcium and phosphate content than cereals. Trace element content varies with the mineral content of the soil.

Anti-nutritional or bio-actives?

Legume grains contain a range of compounds, traditionally known as anti-nutritional factors or anti-nutrients, which when consumed can cause negative effects. However, while some anti-nutritional factors have a negative effect on feed use efficiency of livestock, in humans the same factors can provide beneficial effects such as preventing the development of some forms of cancer and osteoporosis.

Unlike most legume grains, lupins do not require heating to denature their proteinaceous anti-nutritional factors and render them safe for consumption by

humans and animals. Australian sweet lupin has a very low content of proteinaceous anti-nutritional factors. Typically, trypsin inhibitor activity is < 0.1 mg/kg, and chymotrypsin inhibitor activity < 0.1 mg/kg. Lectin activity is virtually non-existent in Australian sweet lupin.

Phytate (inositol hexaphosphate and lower substituted homologues and their salts) contributes about one-half of the total phosphorus content in Australian sweet lupin. Phytate can form insoluble complexes with divalent cations, particularly Ca^{++} and Zn^{++} , making them less available for absorption and utilisation. Foods based on Australian sweet lupin have similar rates of phosphorus absorption to soy-based products, according to human nutritional studies.

Saponins are plant glycosides in which the non-sugar moiety is a steroid or a triterpenoid compound. The saponin content of Australian sweet lupin ranges from 55 to 730 mg/kg, which is lower than many other legume species. Saponins are generally harmless to humans; with some even claimed to be beneficial in terms of lowering blood cholesterol levels and protecting against coronary heart disease.

Isoflavones are generally regarded as anti-nutritional factors because of their negative effects on the fertility of ruminants grazing medic and subterranean pastures. However,

they are now recognised as preventative agents against some forms of cancer and osteoporosis in women. Isoflavones are present in lupin in the green leaf material and in the hypocotyls of germinating seeds (sprouts).

Lupin alkaloids are usually bicyclic, tricyclic or tetracyclic derivatives of quinolizidine. The quinolizidine alkaloids are mild toxins but have a short half-life in humans; they are usually excreted largely unchanged in the urine of more than 90 per cent of humans. The grain of modern domesticated Australian sweet lupin cultivars typically contains less than 200 mg/kg alkaloids. In contrast, grain from ‘bitter’ wild lupin types can contain from 5,000 to 40,000 mg/kg alkaloids.

Mycotoxins associated with lupins are from the family of phomopsins, a group of linear hexapeptides with an anti-microtubule effect that is most pronounced in the

liver and kidney. The most recent varieties of Australian sweet lupin are resistant to invasion by the responsible fungus (*Diaporthe toxica*), which coupled with the dry Western Australian climate, makes the risk of phomopsin contamination extremely low. Grain containing phomopsins can easily be removed from unaffected harvested grain by grading, using screens, gravity tables and aspirators. A rapid enzyme-linked immunosorbent assay for the phomopsins is readily available to the food industry.



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For more information on Australian sweet lupin
please contact:

Ms Sofia Sipsas

Manager Lupin Product Development

Email : ssipsas@agric.wa.gov.au

Department of Agriculture and Food
Western Australia

Government of Western Australia