Processing and Fractionation

Summary

The transformation of Australian Lupin Bean into a variety of nutritious food ingredients and products is a multi-step process that begins with the maturing pods of the Australian Sweet Lupin crop. These pods are harvested to obtain whole beans, which are then cleaned, sized and dehulled to separate the hulls from the kernels.

The hulls (containing around 80% dietary fibre), often overlooked in the processing of other legumes, are not wasted in the case of lupin. They can be transformed into hull dietary fibre food ingredients. It's an excellent example of how lupin processing seeks to utilize every part of the seed.

The kernels are milled to flakes or more finely to flour which are both versatile ingredients that can be used in a wide range of food products. From bread and pastries to pasta and protein shakes, lupin kernel flour enhances the nutritional profile of these foods, adding a large amount of plant-based protein and soluble dietary fibre. The oil content of the Australian Lupin Bean is relatively low (7%) and is not typically removed from the milled flakes and flour. However, the oil is of good quality and is potentially recoverable.

The kernel flour can be further processed into three separate parts (or fractions): kernel fibre, protein concentrates, and an acid-soluble 'whey' waste stream. Each of these fractions have unique properties and potential uses in the food industry.

The kernel fibre (containing around 75% dietary fibre) can be used to increase the fibre content of various foods. This fibre has a benefit for digestive health and can be incorporated into foods like bread, pasta and snacks.

The protein concentrates (containing up to 75% protein), or isolates (up to 90% protein) can be produced from the lupin flour. This rich source of plant-based protein can be used in a variety of foods, from protein bars and shakes to plant-based meat and dairy alternatives.

Thirdly, the acid-soluble 'whey' stream, containing both valuable proteins and sugars, was previously discarded as waste but is now recognised for its potential value. This acid-soluble ‘whey’ contains bioactive peptides and prebiotic oligosaccharides, which can have various health benefits. All these components are currently being explored for their potential use as functional food ingredients.

Potential uses of the Australian Lupin Bean

Dry milled products

Australian Lupin Bean is manufactured into a range of mill products including hulls, split kernels, flakes, grits, and flour. Once separated from the pods, the seeds are cleaned and graded using a vibrating screen and then dehulled to give the split kernels and the hull (Villarino et al., 2015). The relatively thick hull of lupin (about 25% of the weight of the seed) compared to other pulses offers a challenge for efficient dehulling and the majority of lupin seeds are dehulled before further milling for human food (Clements et al., 2005).

Hull fibre

Lupin hull fibre is milled to a coarse powder before it is used as a food ingredient. It is composed mainly of insoluble cellulosic fibre with small amounts of protein and lipids, with some minerals, and phytochemicals such as polyphenols (Malekipoor et al., 2022) and the pharmacologically active triterpenoid lupeol (Pilkington, 2013).

There has been interest in processing methods such as high temperature high pressure extrusion cooking to increase the soluble fibre level of lupin hull and also increase the bioavailability of its minerals and antioxidants (Zhong et al., 2021). The hull is used to a small extent in high-fibre bread and to add bulk to meat products (Zhong et al., 2018) however, only a small proprotein is currently used in value added food applications.

Kernel splits

Australian Lupin Bean kernel splits do not cook rapidly like the splits of traditional pulses due to their virtual absence of starch. However, kernel splits can be used to replace soy in fermented foods, such as tofu (Jayasena et al., 2010), tempeh (Fudiyansyah et al., 1995) and shoyu (Worm and Beirao de Costa, 1990). In one evaluation, a Japanese expert panel found miso made from Australian Sweet Lupin more acceptable than soy miso for colour and overall appearance and as acceptable for flavour and texture (Coffey, 1989).

Kernel flour

Freshly ground kernel flour (particle size <150 to >600 µm) from the Australian Lupin Bean has a golden colour, a slightly nutty flavour and a slightly oily feel. It has a high water and oil holding capacity and good emulsification properties. Lupin proteins lack the structural strength of wheat gluten and therefore the inclusion of as little as 10 % lupin kernel flour in wheat-based pan breads can result in a lower loaf volume. This is however offset by higher water absorption, a longer shelf life and a more balanced amino acid profile (Petterson, 1998). Commercial usage has been more successful in noodles, pasta, flat breads, pizza bases, tortillas, cookies and cakes at up 40% replacement of wheat flour. These inclusions can increase dietary fibre levels by 106%-346% and protein content by 46%-352% (reviewed by Villarino et al., 2016).

Grinding the kernel to flour exposes the lipids in the grain to oxygen and triggers an enzymatic reaction that can result in the development of 'beany' flavours that some consumers find unpalatable (Nasar-Abbas and Jayasena, 2012). Thus, good quality Australian Lupin Bean flour should be stored at low temperature and be consumed before the manufactures recommended use-by date.

Recently there has been interest in understanding the types of compounds related to off flavours generated when producing food products with pulses including lupin in order to find processing solutions to reduce their impact on consumer acceptability (Krause et al., 2022).

Lupin flour particle size can affect its performance in bread for which coarse flour/fine grits allowed a greater incorporation (up to 28% of wheat flour substituted by milled lupin kernels) while maintaining high consumer acceptability (Villarino et al. 2015). Compared to finely milled lupin flour, the coarse milled flour appears to absorb less moisture during dough formation and thus allows the wheat gluten to fully hydrate and form a good quality dough capable of leavening. However, if the lupin is too coarse it will be inadequately hydrated in the final bread giving an unacceptable gritty mouth feel.

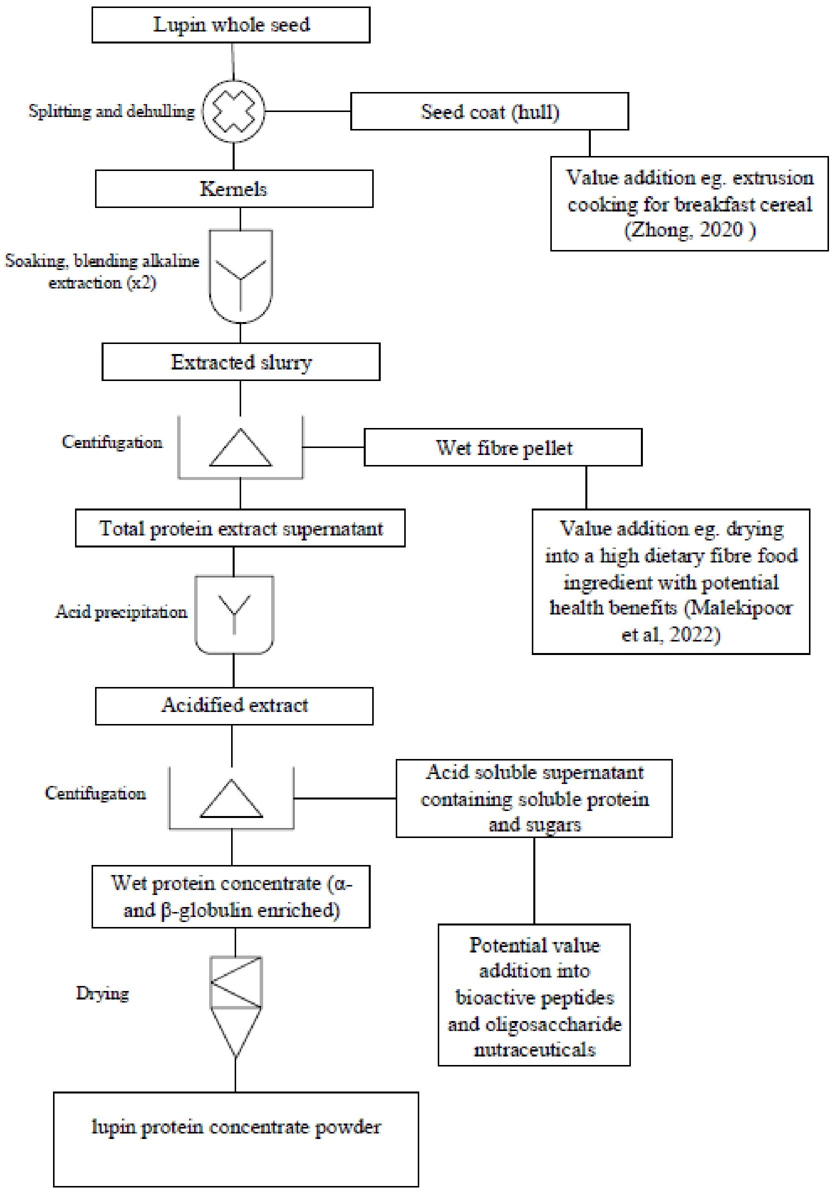
Kernel Flakes

Lupin flakes or grits are sheared to a particle size of approximately 1.5-3.0 mm in diameter. This allows the flakes to hydrate rapidly whilst reducing the risk of flavour profile change (Benjamin, 2017). Flakes have proven successful as a basis for a range of food applications that are typically made from the traditional pulses such as dhal, falafel and hummus as well as crumbing mixes. They can also form a basis for salads and have been successful substituting for kernel flour in cakes, cookies and bread. Notably, the inclusion of the lupin flake with ground red meat has been demonstrated to produce excellent burgers with a boost in protein and dietary fibre and lower fat content (Melia, 2014).

The yellow colour of the lupin kernel and its milled derivatives is a result of carotenoids (Wang et al., 2008) and has been used to an advantage in cakes and biscuits by acting as partial replacement of egg yolk and butter that usually impart this desirable colour (KohaJdoVa et al., 2011).

Protein concentrates and isolates

Kernel flakes or flour can be used as a raw material to produce protein concentrates (over 70% protein content) and isolates (over 90% protein content).



A flow diagram of a process for fractionation of lupin kernels into protein concentrates/isolates as well as kernel dietary fibre and an acid soluble stream.
(Provided by Dr Stuart Johnson)

The lupin kernels are wet milled, or flour is used (either defatted or non-defatted) and the protein is extracted by using water at alkaline pH. Centrifugation is then used to separate the protein solution from the insoluble dietary fibre residue. The protein solution is adjusted to acidic pH, which leads to the precipitation of the major protein forms (alpha- and beta-conglutins). The precipitated solution is then centrifuged to give the protein paste which is dried (eg. spray drying) to give a shelf-stable protein food ingredient and an acid-soluble dilute liquid "whey fraction".

The protein fraction has good digestibility and bioavailability but is somewhat deficient in the sulphur amino acids cysteine/methionine meaning more lupin needs to be consumed that for instance casein (milk protein) for the same nutritional benefit (Chew et al., 2003). Protein content of lupin and other plant protein sources is commonly determined by the assessment of its organic nitrogen content and multiplication by a conversion factor to give protein content. The true conversion factor for lupin 5.5 (Mosse, 1990), however the food industry conventionally uses 6.25 (that for meat protein) which may slightly overestimate the protein content of foods containing lupin.

Lupin protein concentrate/isolate has good solubility and excellent emulsifying properties for use as a food ingredient (Sironi et al., 2005). However, it has low viscosity and gelation ability, therefore it has limited application in foods requiring thickened or gel-like texture for instance in plant based dairy and meat or gluten-free noodles/pasta. To overcome this limitation a protein modification technology has recently been developed to give a lupin protein concentrate with high viscosity and good gelling properties that make it highly suitable for more widespread use in plant-based and gluten-free applications (Al-Ali, 2020).

Air classification of Australian Lupin Bean flour can produce modest yields of a 59% protein fraction. This is arguably a more sustainable route than conventional wet extraction processes and delivers a protein concentrate with native functional properties (Pelgrom *et al*., 2014).

Kernel dietary fibre

A dietary fibre from the Australian Lupin Bean is made by drying the fibre residue from the alkaline extraction of protein from the kernels. Spray drying can be used to make a shelf-stable powdered food ingredient. This fibre is made up of fragments of the thickened cell walls of the kernel. It consists of a mixture of both insoluble and soluble dietary fibre made up of a mixture of different non-starch polysaccharides (Malekipor et al., 2022).

As a food ingredient the fibre has a pale colour and very little flavour or odour. It also has a smooth texture with high water-binding and also oil binding properties. As such it can be easily incorporated into a wide range of food product types to allow high fibre labelling claims without significantly reducing their consumer acceptability. Examples include its use as a replacer in sausage patties (Archer et al., 2004) and 10% replacement of durum flour in pasta (Clark and Johnson, 2002).

Other potentially valuable fractions

The acid soluble waste stream from the earlier described protein fractionation contains potentially valuable proteins and oligosaccharides.

One of these proteins is gamma-conglutin a glycoprotein of which there is mounting evidence that its hydrolysed peptides have insulin mimetic and antidiabetic properties (Tapadia et al., 2021). Also in this stream are albumins which can form stable foams and thus may be a vegan egg white replacer (Wong et al., 2013).

Oligosaccharides of the raffinose family have prebiotic and positive impacts on gut health.

References

Al-Ali, HAA. 2021. Increasing the gelling functionality of lupin protein using ultrasound treatment. PhD Thesis, Curtin University, Western Australia.

Archer, BJ., Johnson, SK., Devereux, HM., Baxter, AL. 2004. Effect of fat replacement by inulin or lupin-kernel fibre on sausage patty acceptability, post-meal perceptions of satiety and food intake in men. Brit. J. Nutr., 91, 591-599.

Benjamin C (2017). Pulse Pod Emagazine. www.pulseaus.com.au

Chew, PG. Casey, A. Johnson, SK. 2003. Protein quality and physico-functionality of Australian sweet lupin (Lupinus angustifolius cv. Gungurru) protein concentrates prepared by isoelectric precipitation or ultrafiltration. Food Chem., 83, 575-583.

Clark, RL., Johnson, SK., 2002. Sensory acceptability of foods with added lupin (Lupinus angustifolius) kernel fibre using pre-set criteria. J. Food Sci., 67, 356–362.

Clements, JC., Dracup, M., Buirchell, BJ., Smith, CG., 2005. Variation for hull and pod wall percentage and other traits in a germplasm collection and historical cultivars of lupins. Aust. J. Agric. Res., 56, 75–83.

Coffey RS, 1989. Lupins as an energy-rich protein source for feed and food. In: T.H. Applewhite (Ed.). Proceedings of the World Congress on Vegetable Protein Utilisation in Human Foods and Animal Feedstuffs. American Oil Chemists' Society, Champaign, Illinois. pp. 410-414.

Fechner, A. Kiehntopf, M. Jahreis, G. 2014. The formation of short-chain fatty acids is positively associated with the blood lipid–lowering effect of lupin kernel fiber in moderately hypercholesterolemic adults. J. Nutr., 144, 599–607.

Fudiyansyah, N., Petterson, DS., Bell, RR., Fairbrother, AH., 1995. A nutritional, chemical and sensory evaluation of lupin (L. angustifolius) tempe. Int. J. Food Sci. Technol., 30, 297–305.

Jayasena, V., Khu, WS., Nasar-Abbas, SM., 2010. The development and sensory acceptability of lupin-based tofu. J. Food Qual., 33, 85–97.

Johnson, SK., Clements, J., Villarino, CB. J., Coorey, R. 2017. Chapter 9. Lupins: Their unique nutritional and health-promoting attributes. In The Gluten-free Ancient Grains: Cereals, Pseudocereals and Legumes- Sustainable, Nutritious and Health-promoting Foods for the 21st Century, eds J. R. N. Taylor and J. M. Awika. Elsevier, Amsterdam.

KohaJdoVá, Z., Karovicova, J., Schmidt, S., 2011. Lupin composition and possible use in bakery: a review. Czech J. Food Sci., 29, 203–211.

Krause, S., Keller, S., Hashemi, A., Descharles, N., Bonazzi, C., Rega, B. 2022. From flours to cakes: Reactivity potential of pulse ingredients to generate volatile compounds impacting the quality of processed foods. Food Chem., 371, 131379.

Malekipoor, R., Johnson, SK., Bhattarai, RR 2022. Lupin kernel fibre: nutritional composition, processing methods, physicochemical properties, consumer acceptability and health effects of its enriched products. Nutrients, 14, 2845.

Melia, K., 2014. Value-added red meat with inclusion of lupin. Meat and Livestock Australia. mla.com.au/contentassets/f92c7239a2e44ae697c2ef562e4534d7/p.psh.0707_final_report.pdf

Mosse, J. 1990. Nitrogen to protein conversion factor for ten cereals and six legumes or oilseeds. A reappraisal of its definition and determination. Variation according to species and to seed proteincontent. J. Agric. Food Chem., 38, 18–24.

Nasar-Abbas, S.M., Jayasena, V., 2012. Effect of lupin flour incorporation on the physical and sensory properties of muffins. Quality Assur. Safety Crops Foods, 4, 41–49.

Pelgrom JAM., Berghout, AM., van der Goot, AJ., Boom RM., Schutyser, MAI. and Pascalle JM. 2014. Preparation of functional lupine protein fractions by dry separation. Food Science and Technology 59, 680-688.

Petterson D, 1998. Composition and food uses of lupins. In: Gladstones JS, Atkins C, Hamblin J (eds.). Lupins as Crop Plants; Biology, Production and Utilization. CAB International, Wallingford, UK. 353–384.

Pilkington, MJ (2013). Characterisation of lupin derived lupeol with a metabolomics study of the impact and potential neuroprotection of lupeol. Honors Thesis. Murdoch University, Western Australia.

Sironi, E., Sessa, F., Duranti, M., 2005. A simple procedure of lupin seed protein fractionation for selective food applications. Eur. Food Res. Technol., 221, 145–150.

Tapadia, M., Johnson, S., Utikar, R., Newsholme, P., Carlessi, R. 2021. Antidiabetic effects and mechanisms of action of γ-conglutin from lupin seeds. J. Func. Foods., 87, 104786.

Villarino, C., Jayasena, V., Coorey, R., Chakrabarti-Bell, S., Johnson, S., 2015. The effects of lupin (Lupinus angustifolius) addition to wheat bread on its nutritional, phytochemical and bioactive composition and protein quality. Food Res. Int., 76, 58–65.

Villarino, CBJ., Jayasena, V., Coorey, R., Chakrabarti-Bell, S., Johnson, S. K., 2016. Nutritional, health and technological functionality of lupin flour addition to bread and other baked products: Benefits and challenges. Crit. Rev. Food Sci. Nutr., 26, 835–857.

Wang, S., Errington, S., Yap, H.H., 2008. Studies on carotenoids from lupin seeds. In: Palta, J.A., Berger, J.B. (Eds.), Lupins for Health, Wealth, Proceedings of the 12th International Lupin Conference, 14–18, Sept 2008, , Fremantle, Australia.

Wong, A., Pitts, K., Jayasena, V., Johnson, S., 2013. Isolation and foaming functionality of acid-soluble protein from lupin (Lupinus angustifolius) kernels. J. Sci. Food Agric., 93, 3755–3762.

Worm, MA and Beirao de Costa, ML 1990. Lupin as a raw material for shoyu production. In: D. von Baer (Ed.) Proceedings 6th International Lupin Conference, Temuco-Pucon, November 1990, 60-67. Associacion Chilena del Lupino,Temuco.

Zhong, L., Ali, H., Fang, Z., Wahlqvist, ML., Hodgson, JM., Johnson, SK. 2020. Lupin seed coat as a promising food ingredient: physicochemical, nutritional, antioxidant properties, and effect of genotype and environment. Int. J. Food Sci. Technol., 55, 1816-1824.

Zhong, L., Fang, Z., Wahlqvist, ML., Hodgson, JM., Johnson, SK. 2021. Multi-response surface optimisation of extrusion cooking to increase soluble dietary fibre and polyphenols in lupin seed coat. LWT, 140, 110767.

Zhong, L., Fang, Z., Wahlqvist, ML., Wu, G., Hodgson, JM., Johnson, SK. 2018. Seed coats of pulses as a food ingredient: Characterisation, processing, and applications. Trends Food Sci. Technol., 80, 35–42.