LUPIN PRODUCTS – CONCEPTS AND REALITY

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ABSTRACT

Australian Sweet Lupin (ASL) (*Lupinus angustifolius*) is now a major crop in Western Australia. Until recently virtually all of the grain has been sold for use in intensive animal industries, with ~15,000 tonnes being used for human consumption (Fletcher, 2006). There are case examples from around the world where separate initiatives have been taken to introduce varying types of foods using lupin grain. The success of any such initiative will depend on many factors, some particular to the venture itself, others particular to the industry or country in which they operate. It is appropriate for participants in the lupin industry to appreciate the dimension and fabric of the challenges that await the launch of new lupin uses.

The early introduction of soy flours and grits to the USA food processors many years ago was not successful. Smith and Circle (1972) believed this to be for a number of reasons:

- **There was a mistaken assumption that a need calls for a Market.**
- **They failed to precisely define the market segment where the product had greatest value.**
- **They had inadequate information about the buying process and the patterns of influence on the decision makers.**
- **They failed to anticipate the demands that the new product would make on the customer's technical and operational skills.**
- **They failed to consider the amount of new investment required by the customer and the extent to which the present technology is rendered obsolete.**
- **They had insufficient knowledge about the 'results area' of the users business, that is how profits are generated.**

The successful introduction of lupin derived food into the human food market should not be expected to occur overnight. It will depend on the positive outcome from the ever dynamic relationship between the processing technologies, each individual market demand, the price of the raw grain and the processors ability to add value to the derived products.

KEYWORDS

Processing, kernels, hulls, food, protein isolates, protein concentrates, oil, dietary fibre, cosmetics, aquaculture

INTRODUCTION

The lupin grain is high in protein (30%-40%) and dietary fibre (30%) low in fat (6%) and has minimal starch giving it a very low Glycaemic Index (GI).

There has been increasing interest from the food industry, as evidence from research clearly indicates that lupin has great potential as a food ingredient (Petterson and Crosbie, 1990; Kyle, 1994; Petterson, 1998; Jayasena and Quail, 2004). Lupin ingredients have been included in a range of highly palatable breads, baked goods, meat products and beverages (Schneider *et al.* 2005).

However the most exciting story to emerge is lupin's amazing attributes in terms of health benefits, particularly in relation to a number of conditions now known as 'metabolic syndrome' which includes a cluster of factors such as, obesity, high blood pressure, insulin resistance and elevated blood cholesterol (Arnoldi, 2005).

Lupin enriched foods have the potential to:

- Beneficially influence satiety (appetite suppression) and energy balance (Archer *et al.* 2004, Lee *et al.* 2006).
- Beneficially influence glycaemic control (Magni *et al.* 2004, Hall *et al.* 2005a).
- Improve blood lipids (Martins *et al.* 2005, Hall *et al.* 2005, Nowicka *et al.* 2006, Spielmann *et al.* 2007).
- Improve hypertension ((Pilvi *et al.* 2006).
- Improve bowel health (Johnson *et al.* 2006, Smith *et al.* 2006).

Lupins also contain moderate amounts of carotenoids: beta carotene, lutein and zeaxanthin, (Ghezlou, 2000, El-Difrawi and Hudson, 1979), tocopherols (Hansen and Czochanska, 1974, Lampart-Szczapa *et al.* 2003), and other bioactive components showing exciting potential (Duranti, 2008). An interesting minor component of the lupin lipid fraction is lupeol (Hamama and Bhardwaj, 2004), a triterpene alcohol shown to improve epidermal tissue reconstitution (Nikiema *et al.* 2001, Miska *et al.* 2006),

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as well as induce differentiation and inhibit the cell growth of melanoma cells (Hata *et al.* 2003, Saleem *et al.* 2004).

PRODUCTS OF LUPIN PROCESSING

The lupin seed has to be processed before it is suitable for use as a food ingredient. There are many processing options and technical approaches that have been considered (Knauf *et al.* 2007). A business plan for The Baltic Protein & Prebiotic Products PPP (BASAN, 2002) has been developed in keeping with the processing schema outlined in this document (Fig. 1). It includes information on markets and the pricing of competitive ingredients. Whilst the plan was designed for a Northern European scenario and is to an extent dated, much of the information is still relevant and provides a useful analytical framework. A similar analysis was conducted by Kingwell (2003).

There is an opportunity for progressive processing of the lupin to increase its value. In the first instance it is likely to be associated with the development of a ‘whole bean food’ as well as dehulling for feed/food or similar milling activity. Fig. 1 presents some potential applications, some of which are already a commercial reality.

WHOLE SEED

Whole ASL seed is a widely accepted supplement feed for ruminants as they are high in available energy (carbohydrate fraction), protein and have advantages in handling, storing and feeding. ASL in particular, is used to feed sheep in times of pasture shortage, but is also widely used in pig and poultry nutrition, mainly as kernels (Table 1) where it is valued for its consistent quality and low content of anti-nutritional factors (Petterson, 2001).

Table 1. Historical usage of ASL (*L. angustifolius*) produced in Western Australia.

Markets	Portion of WA crop	Important parameter	Component of lupin valued
Ruminant	60%	Energy	Whole seed
Pigs	25%	Energy and Protein	Kernel
Poultry	10%	Energy and Protein	Kernel
Fish	5%	Protein	Kernel
Humans	minor	Protein and Dietary Fibre	Kernel

BEAN SPROUTS

Sprouting of legume grains has many nutritional benefits. The content of bioactive antinutritional factors such as alkaloids, oligosaccharides and phytate is reduced while that of beneficial isoflavones and phytosterols and some vitamins is increased (Dagnia *et al.* 1992; Trugo, 1993; Lee, 1986; Katigiri *et al.* 2000). Literature reports indicate a faster growth of lupin sprouts (36% greater yield) than for soy and mung bean, and that the crispier lupin sprouts have a high acceptability rating compared to soy sprouts (Yu, 1988).

LUPIN HULLS

Pure Lupin hulls (LH) contain mostly cellulose and hemicellulose, with ~ 4-6% crude protein, some lignin and minerals (ash) (Rowe and Hargreave, 1988; Evans, 1994).

STOCKFEED

Most commercial dehulling operations attain a protein content of approximately 12% in their hull fraction as a certain amount of kernel kibble ends up in the hull material (Bailey, 1992). This makes for an extremely useful supplement to ruminant diets - the hulls are highly fermentable in the rumen (Bailey, 1992; Rowe and Hargreave, 1988).

FOOD USES

The hulls can also be milled/ground into coarse bran suitable for use as (crude or bulk) fibre enrichment of bread, currently used in Australia and in Europe. A patent has been granted for the concept product of a high fibre cereal similar to Kellogg’s All-Bran (Tucek, 2006), based on lupin hull fibre. Of note is the fact that most fibre enrichment ingredients are based on wheat fibre, and there are very few options available for the ‘coeliac market’ in terms of a gluten free ‘all-bran’ type cereal. Lupin hull fibre can fulfil this ‘niche’ market.

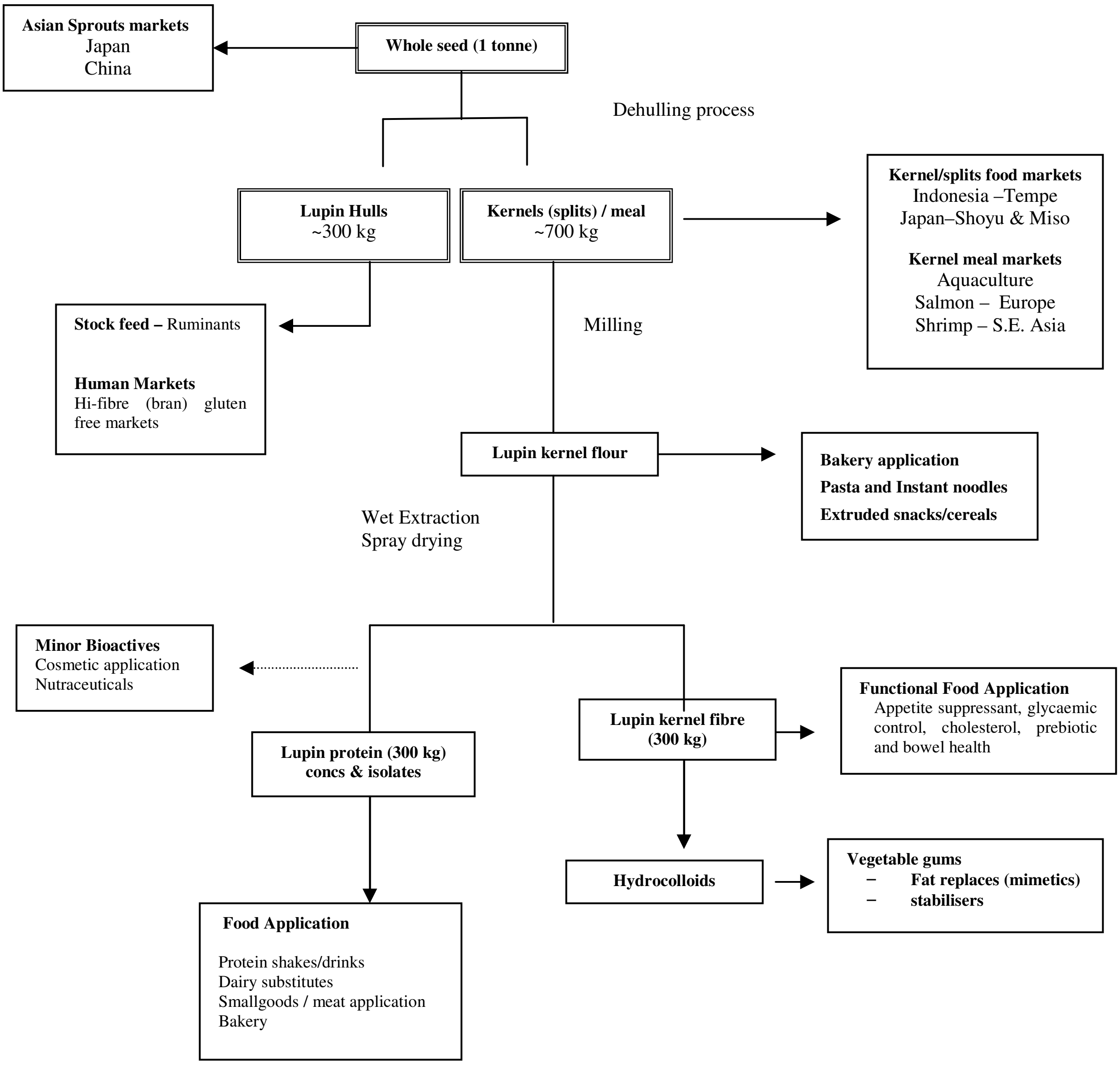

Fig. 1. Schema of Potential Processing streams and Product applications for ASL.

LUPIN KERNELS

Potential uses for lupin kernels (LK) are as a base for producing flour and fractionation into LK fibre and protein isolates, with pigments and other constituents as valuable by-products.

Monogastric and Aquaculture Feeds

LK are widely used in compounded feeds for pigs and poultry, and more recently in aquaculture. The higher energy, protein and digestibility aspects of lupin kernels are fully appreciated by commercial pig producers and feed millers and the majority of lupins used by the large Australian piggeries are dehulled (Edwards and van Barneveld, 1998). The additional processing of lupins is also highly beneficial for poultry. Hammer or cutter milling of kernels is generally used to provide a meal suitable for inclusion in the compound feeds.

Lupin kernel meal can be used in both high performance (high protein and oil content) and low performance (low protein and oil content) diets for finfish (Glencross, 2005). The feed utilisation and protein conversion rates are comparable to or slightly better than equivalent formulations containing soybean meals as the main vegetable protein source, provided the lysine and methionine contents are correctly balanced. Lupin kernel meals are used commercially in diets for freshwater, estuarine and ocean finfish as well as crustaceans. The latter use lupin kernel meals as effectively as they do soybean meals (Smith, 2005).

Asian fermented foods

Lupin kernels have been used to make tempe (Kidby *et al.* 1977; Hung *et al.* 1990; Coorey, 1996), miso a well-known Japanese condiment and soup base

(Cunha *et al.* 1990; Coffey, 1989) and lupin shoyu (comparable to Japanese soy sauce). (Worm and Beira da Costa, 1990; Hung, 1990; Lee *et al.* 1982). Lupin grain was sold into Indonesia for tempe manufacture from about 1985 to 1995, however trade was abandoned during the tumultuous years of political change and the Indonesia monetary crisis. There has been renewed interest in the use of lupin for tempe (Jayasena and Quail, 2004).

Lupin kernel flour

Lupin Kernel Flour (LKF) has a golden yellow colour, has a slightly nutty flavour and a slightly oily feel. It is generally coarser than wheat flour, even when ground to pass through a 150 μm screen (Corre-Gammere, 1993). The flour has a high water holding capacity, and oil holding capacity, and good emulsification properties (Leterme and Fenart, 1997).

Lupin proteins lack the structural strength of wheat gluten. Therefore the inclusion of as little as 10% LKF in wheat-based breads results in a lower loaf volume.

This is however offset by higher water absorption, a longer shelf life, a more balanced amino acid profile, and the technical advantage of better dough mixing (Petterson, 1998; Knauf *et al.* 2007). In terms of commercial reality LKF has been successfully included in pizza bases, biscuit and cake flours and the traditional breads of many countries particularly in Europe. It is estimated that 500,000 tonnes of food consumed in Europe contain lupin (Fletcher, 2006). There are several companies in Europe selling LKF as well as an Australian company for use in bakery and patisserie lines (www.lupins.org). Listed are some of the companies working in this space:

- NaProFoods (www.naprofood.de). Producer of functional lupin proteins and gluten free lupin flour. Food ingredients from lupins are used in meat and bakery products, in sweets, ice cream, sauces.
- Terrena Ingredients (www.lupin.fr, Lup'ingredients) Producer of lupin flours and concentrates for application in meat and bakery products, in sweets, ice cream, sauces.
- Fa. L.I.FRANK (www.lifrank.nl) Producer of lupin flours and concentrates for application in meat and bakery products, in sweets, ice cream, sauces.
- Irwin Valley (www.lupinflour.com) Producer of lupin flours for application in bakery products.

LUPIN PROTEINS

Protein concentrates

Protein concentrates can be made from lupin kernel flours using standard soybean industry processes (Manrique, 1977). ASL kernel flour with starting protein content of 46% crude protein (CP) (N x 6.25) achieved a protein content of 52% CP after washing with a 70% ethanol solution (10:1) v/w. The yellow lupin (*L. luteus*) kernel flour with starting protein content of 52% CP achieved a protein content of 72% CP (Sipsas, 2004) after the same concentration process. The fraction of the flour which is removed by washing is predominantly oligosaccharides which make up 8% of the *L. angustifolius* kernel flour and 14% of the *L. luteus* kernel flour.

Yellow lupin flour reached the 65% benchmark set by the soy industry for protein concentrates. Pre-heat treatment of the lupin kernel flours makes the lupin proteins less soluble in the aqueous medium allowing for the oligosaccharides to be removed with water without the need for ethanol.

Lupin protein isolates

Lupin protein isolates can be prepared by solubilisation at pH 9 of the lupin kernel flour, removing the insoluble residue (Fibre) and then acid precipitation (pH 4.5) of the protein curd to yield a high protein fraction of 80-92% purity (Sipsas, 2004; Manrique, 1977). Particle size of the kernel flour can influence the amount of protein yield and purity of the protein and fibre fractions. While lupin proteins appear not to have the high level of cross-linking of soy proteins they have other desirable attributes (King *et al.* 1983; Vasilakis and Doxastakis, 1999; Alamanou *et al.* 1996; Holley *et al.* 2001; Tomoskozi *et al.* 2001, Washe *et al.* 2001). The proteins that do not precipitate out in the process described above have a high foaming and whipping capacity and could be used in various mixes to replace egg white products. These proteins could be recovered by ultrafiltration (and possibly a precipitation or coagulation step) and drying. The yield is likely to be ~ 5% of LK weight (Holley *et al.* 2001). Some of the applications for protein isolates are:

- Dairy substitutes.
- Fillings for barbecue sausages, cooking sausages, pates.
- Dispersion for compounded ham products.
- Water/Oil and Oil/Water emulsions for salad dressings, other dressings, fat/oil containing bread spreads and frostings.
- Vegetarian, meat or sausage products as a functional ingredient depending on the required applicable concentration.
- Cakes, roulades, cookies, biscuits.
- Baby food, diet products.
- Scent and taste transporters.

Lupin milk, ice creams and yoghurts are they still a concept?

In 2002 the global market for dairy alternatives was estimated at more that $2 billion. Soy milk dominates the market with almost 80 percent of sales and has a significant presence in many of the world's developed markets. Rice, oat and almond varieties of non-dairy milk are not as widely distributed as soy milk and are not available in most countries. ASL kernels or the protein extract from kernels can be used to make milk. Like soy milk, lupin milk is healthy balanced plant-based beverage, without the saturated fat found in dairy milk. Lupin milk can then be used to make excellent yoghurt and pro-biotics (Han *et al.* 1985; Lee *et al.* 1986; Camacho *et al.* 1988; Jimenes-Martines *et al.* 2003). Currently there seems to be no commercial lupin milk, yoghurt or pro-biotics products.

Products vs concepts

However researchers from the Fraunhofer Institute for Process Engineering and Packaging IVV in Freising have made an ice cream exclusively from ASL proteins and canola oil (Eisner *et al*. 2008). The lupin protein that is present in the ice-cream is easy to process and has excellent sensory properties. It was expected that the 'Lupin ice cream' made by Eiscremewerke Demin GmbH was to be available in German shops by December 2006 (Fraunhofer Magazine, 2006). Another product 'Lupin Bean Mayonnaise' made by Sacksmania LDA a Portuguese company, is available for purchasing over the internet www.tradekey.com.

Lupin kernel fibre

Lupin kernel fibre is virtually colourless, odourless, and an 8-fold water holding capacity. It has been shown to have cholesterol lowering properties, stool bulking properties and transit time reduction effect in humans as well as a marked reduction in blood glucose levels in non-insulin diabetics (Hall *et al.* 2005; Hall *et al.* 2005a; Smith *et al.* 2006; Johnson *et al.* 2006). Within the kernel fibre there is a hydrocolloid fraction (George Weston Foods, 2005) reported to have properties similar to that of pectins. Hydrocolloids are a particular type of complex carbohydrate that can serve two functions: They can be used as fat replacers in a wide range of food products, mimicking the creamy texture and mouth feel without adding calories to the product. In frozen desserts they have an added function of slowing the rate of ice crystallisation. Hydrocolloids are also used as carriers of flavours and other high value, low concentration ingredients of formulated foods. Their purpose is to enable a uniform distribution of the special ingredient throughout the finished product (Danisco website www.danisco.com).

Bioactives and cosmetic application of lupin

Recently two products, Alpha-lupaline and Collageneer (both by Expanscience Laboratories www.expanscience.fr), have attracted a lot of interest from the cosmetic industry. Both are variants of a combination of cold-press lupin oil and a carrier oil. Various laboratory tests have shown free radical scavenging and antioxidant activity as well as anti-elastase activity (Miska *et al.* 2000; Miska *et al.* 2006). Expanscience promotes Alpha-lupaline as an active ingredient in anti-wrinkle, sunscreen, and skin protection products and Collegeneer as a restructuring ingredient. Lupin extracts are appearing in several cosmetic lines including many high end lines such as Givenchy, Clarins, Decleor, Sothys, Murad, Jan Marini and Lancome.

A study by Closs and Paufique (1999) indicated that lupin peptides also have positive attributes in relation to skin care. Recently peptide extracts of lupin has been shown to have metalloprotease inhibiting activity, in particular collagenase and gelatinase (Miska *et al.* 2006; Watson, 2008).

'Boots the UK's leading retailer of beauty products, launched their full No. 7 Protect and Perfect range as a result of the phenomenal success of the No. 7 Protect & Perfect Beauty Serum in 2007. No. 7 Protect and Perfect Beauty Serum shot to fame in the summer of 2007 after a television documentary (BBC) found it to be a skincare product proven scientifically to repair photo-aged skin and improve the fine lines associated with photo-ageing (lupin peptides are an active ingredient in the formula). Sales of the wonder cream increased by nearly 2000% the day after the TV program, with 13 being sold every minute. At the height of the public's frenzy for the serum, Boots' production facilities were working around-the-clock to meet the target of 1,000 bottles an hour. (Boots Press release March 01, 2008)'

CONCLUSION

The existing volumes of lupin products for human consumption are at present fairly modest. Despite this, the market has significant economic potential at both the domestic and international levels. Lupin protein can compete against soybean, wheat and pea protein as ingredients in food production. Lupin hull fibre can compete against other coarse fibre ingredients such as wheat, oats and barley bran in the production of baked goods and breakfast cereals while lupin dietary fibre and hydrocolloids can compete with other refined dietary fibres and vegetable gums. Concomitantly growing evidence of lupins positive attributes towards 'western diseases' would be expected to create a fair degree of consumer demand.

Limited research has been conducted to examine the economic feasibility of producing lupin-based ingredients for the food and feed industry. The commercial viability of processing of lupin grain into protein and fibre may depend on the ability to extract the minor 'bio-actives' to supply the 'natural' dietary supplements markets.

LITERATURE CITED

Alamanou, S., J.G. Bloukas, E.D. Paneras and G. Doxastakis. 1996. Influences of protein isolate from lupin seeds (*Lupinus albus* ssp. Graecus) on processing and quality characteristics of frankfurters. Meat Science 42: 79-93.

Archer, B.J., S.K. Johnson, H.M. Devereux and A.L. Baxter. 2004. Effect of fat replacement by insulin or lupin-kernel fibre on sausage patty acceptability, post-meal perceptions of satiety and food intake in men. British Journal Nutrition 91: 591-599.

Arnoldi, A. (Ed). 2005. Optimised processes for preparing healthy and added value food ingredients from lupin kernels, the European protein-rich grain legume. Proceedings of the Final Conference of the European Project. Milan, November 9-10, 2005. Aracne pp. 202.

Bailey, A.N. 1992. Lupin Pellets for the Live Sheep Export Industry. Masters thesis, University of Western Australia.

BASAN − The Baltic Protein & Prebiotic Products (PPP). 2002. The Baltic Sea Agri-Industrial Network www.baltic-network.de.

Camacho, L., E. Banados, E. Fernandez. 1989. Canned 'humitas' prepared from opaque-2 maize with sweet lupin (*Lupinus albus* var. Multolupa), nutritional and quality changes. Archivos Lantinoamericanos de Nutricion 39: 185-199.

Camacho, L. and C. Sierra. 1988. Lupin processing for the obtainment of a tofu-like product. *In:* T. Twardowski (Ed.). Proceedings of the 5th International Lupin Conference. Poznan: July 1988. 682-685. International Lupin Association. Poznan.

Closs, B., J. Paufique. 1999. White Sweet Lupine extract as a skin restructuring agent. Cosmetics and Toiletries 114: No. 8 pp. 75-82.

Coorey, R. 1996. An evaluation of the pilot scale production and shelf-life of lupin tempe. MSc Thesis, Curtin University of Technology, Perth, Australia.

Corre-Gammere, V. 1993. The production of micronised sweet white lupin flour for use as a human food. Advances in lupin research 7: pp. 482-491.

Dagnia, S.G., D.S. Petterson, R.R. Bell and F.V. Flanagan. 1992. Germination alters the nutritional value of lupin seed. Journal of the Science of Food and Agriculture 60: pp. 419-423.

Danisco Company. www.danisco.com.

Duranti M. 2008. Modern approaches and recent achievements in studying the impact of white lupin seed proteins on human nutrition and health. Proceedings of the 12th International Lupin Conference.

Edwards, A. and R. van Barneveld. 1998. Lupins for Livestock and Fish. *IN:* Lupins as Crop Plants: Biology, Production and Utilisation (Eds) J.S. Gladstones, C.A. Atkins and J. Hamblin. CAB International. pp. 385-409.

Eisner, P., K. Muller, U. Knauf, G. Kloth. 2008. Method for producing a vegetable protein ingredient for ice cream and ice cream containing said protein ingredient. Patent USPTO Application #: 20080089990 − Class: 426565000 (USPTO).

El-Difrawi, A.E. and B.J.F. Hudson. 1979. Identification and estimation of carotenoids in the seed of four lupin species. J. Sci. Food Agric. 30: pp. 1168-1170.

Evans, A.J. 1994. The carbohydrates of lupins, composition and uses. *In:* M. Dracup and J. Palta (Eds). Proceedings of the First Australian Lupin Technical Symposium. Western Australian Department of Agriculture, South Perth. Pp. 110-114.

Fletcher, A. 2006. Lupin sector defends safety of its ingredient. Food Navigator/Europe www.foodnavigator.com (News on Food & Beverage Development).

Fraunhofer Magazine. 2006. Vegetable 'ice cream'. A publication of Fraunhofer Gesellschaft. ISN 1615-7028. www.fraunhofer.de/magazine.

George Weston Foods Limited. 2005. Process for the production of lupin extracts. Patent: WO/2005/002355, International Application No PCT/AU2004/000877, IPC: A23J 3/14 (2006.01), A23L 1/20 (2006.01).

Ghezlou, K. 2000. Extraction, Identification and Estimation of Carotenoids in Australian Lupin Seed. MSc Thesis, Curtin University of Technology, Perth, Australia.

Glencross B.D. (Ed.). 2005. Seeding a Future for Grains in Aquaculture Feeds − Part III. Proceedings of a Workshop, 14th April 2005 Fremantle, Western Australia. 54 p.

Hamama, A.A. and H.L. Bhardwaj. 2004. Phytosterols, triterpene alcohols, and phospholipids in seed oil from white lupin, Journal of the American Oil Chemists' Society 81: pp. 1039-1044.

Han, O., W.T. Tae, Y.W. Kim, J.K. Lee and C.H. Lee. 1985. Lactic acid fermentation of lupinseed milk. Korean journal of Applied Microbiology and Bioengineering 3: pp. 191-198.

Hall, R.S., S.K. Johnson, A.L. Baxter and M.J. Ball. 2005. Lupin kernel fibre-enriched foods beneficially modify serum lipids in men. European Journal of Clinical Nutrition 59: pp. 325-33.

Hall, R.S., S.J. Thomas and S.K. Johnson. 2005. Australian sweet lupin flour addition reduced the glycaemic index of a white bread breakfast without affecting palatability in healthy human volunteers. Asia Pacific J. Clinical Nutrition 14: pp. 91-97.

Hansen, R.P. and Z. Czochanska. 1974. Composition of the Lipids of Lupin Seed (*Lupinus angustifolius* L. var. Uniwhite). Journal of the Science of Food and Agriculture 25: pp. 409-415.

Hata, K., K. Hori and S. Takahashi. 2003. Role of p. 38 MAPK in Lupeol-induced B16 2F2 mouse melanoma cell differentiation. J. Biochem. 134: pp. 441-445.

Holley, W., T. Luck, K. Muller, C. Schafer and A. Wasche. 2001. Properties and applications of lupin protein Isolates and Joint-products. *IN:* Proceedings of the 4th European Conference on Grain Legumes, Cracow, Poland, pp. 402-403.

Jayasena, V. and K. Quail. 2004. Lupin: a legume with a future. Food and Beverage Asia, December 2004: pp. 16-21.

Jimenez Martinez, C., H. Hernandez Sanchez and G. Davila Ortiz. 2003. Production of a yogurt-like product from *Lupinus campestris* seeds. Journal of the Science of Food and Agriculture 83: pp. 515-522.

Johnson S.K., V. Chua, R.S. Hall and A.L. Baxter. 2006. Lupin kernel fibre foods improve bowel function and beneficially modify some putative faecal risk factors for colon cancer in men. *British Journal of Nutrition* 95 (2): pp .372-378.

King. J., C. Aguirre and S. de Pablo. 1983. Functional Properties of Lupin Protein Isolates (*Lupinus albus* cv. Multolupa) *Journal of Food Science* 50: pp. 82–87.

Kingwell, R. 2003. Economic considerations for Lupin Protein Concentrate production. *In:* Seeding a Future fir Grains in Aquaculture Feeds (B.D. Glencross, Ed). Department of Fisheries, North Beach, WA Australia pp. 82.

Knauf, U., A. Seger, C. Bagger and J. Bez. 2005. Lupin food ingredients and lupin-based food products. *Grain legumes* 43: pp. 16-17. European Grain Legume Association.

Kyle, W.S.A. 1994. The current and potential uses of lupins as food. IN Proceedings of the 1st Lupin Technical Symposium (Eds) M. Dracup, and J. Palta, Department of Agriculture, Western Australia. pp. 89-97.

Lampart-szczapa, E., J. Korczak, M. Nogala-Kalucka and R. Zawirska-Wojtaskiak. 2003. Antioxidant properties of lupin seed products. *Food chemistry* 83: pp. 279-285.

Lee, C.H. 1986. Lupin seed for human consumption. *In:* Proceedings of the 4th International Lupin conference. Geraldton, Western Australia, pp. 64-76.

Lee, Y.P., T. Mori, S. Sipsas, A. Barden, I. Puddey, V. Burke, R. Hall and J. Hodgson. 2006. Lupin-enriched bread increases satiety and reduces energy intake acutely. *American J. Clinical Nutrition* 84: pp. 975-980.

Leterme, P. and E. Fenart. 1997. New outlets in the food industry. Grain legumes 15: pp. 24. European Grain Legume Association. Lupins.org: www.lupins.org – Information Resource Portal for lupins. Provided by Pulse Western Australia.

Petterson, D.S. 2000. The use of lupins in feeding systems – review. Asian-Australian *Journal of Animal Science* 13: pp. 861-882.

Petterson, D.S. 1998. Composition and food uses of lupins. *In:* J.S. Gladstones, C. Atkins, and J. Hamblin (eds.). Lupins as crop plants: biology, production and utilisation. pp. 353-384 CABI, Oxon.

Petterson, D.S. and G.B. Crosbie. 1990. Potential of lupins as food for humans. *Food Australia* 42: pp. 266-8.

Pilvi, T.K., T. Jauhiainen, Z.J. Cheng, E.M. Mervaala, H. Vapaatalo and R. Korpela. 2006. Lupin protein attenuates the development of hypertension and normalises the vascular function of NaCl-loaded Goto-Kakizaki rats. *J. Physiological Pharmacology* 57: pp. 167-176.

Magni, C., F. Sessa, E. Accardo, M. Vanoni, P. Morazzoni, A. Scarafoni and M. Duranti. 2004. Conglutin γ, a lupin seed protein, binds insulin in vitro and reduces plasma glucose levels of hyperglycemic rats. *J. Nutr. Biochem.* 15: 646-650.

Manrique, J. 1977. The influence of isolation procedures on the yield and functional properties of protein from Lupinus Leguminosae. PhD The University of New South Wales.

Marchesi, M., C. Parolini, E. Diani, E. Rigamonti, L. Cornelli, A. Arnoldi, C.R. Sirtori and G. Chiesa. 2007. Hypolipidemic and anti- atherosclerotic effects of lupin proteins in a rabbit model. Brit J Nutr. Published online by Cambridge University Press 04 Mar 2008.

Martins, J.M., M. Riottot, M.C. de Abreu, A.M. Viegas-Crespo, M.J. Lança, J.A. Almeida, J.B. Freire and O.P. Bento. 2005. Cholesterol-lowering effects of dietary blue lupin (*Lupinus angustifolius* L.) in intact and ileorectal anastomosed pigs. *J Lipid Res.* 46: 1539-1547.

Msika, P., A. Piccirilli and F. Paul. 2006. Peptide extract of lupine and pharmaceutical or cosmetic or nutritional composition comprising the same. US Patent #7029713.

Msika, P., A. Piccirilli and N. Piccardi. 2006. Use of a cosmetic of pharmaceutical composition, comprising a lupeol-rich extract as an active ingredient for stimulating the synthesis of heat shock proteins. Patent USPTO #: 20060216249 – Class: 424058000.

Msika, P., Rancurel, M.G. Montaudoin. 2000. Antioxidant and/or antielastase composition based on lupine oil. US Patent # 6146616.

Nikiema, J.B., R. Vanhaelen-Fastre, M. Vanhaelen, J. Fontaine, C. DeGraef and M. Heenen. 2001 Effects of anti-inflammatory triterpenes isolated from *Leptadenia hastate* latex on Keratinocyte proliferation. *Phytotherapy Research* 15: pp. 131-134.

Nowicka, G., L. Klosiewicz-Latoszek, C.R. Sirtori, A. Arnoldi and M. Naruszewicz. 2006. Lupin proteins in the treatment of hypercholesterolemia. *Atherosclerosis Supplements* 7: pp. 477-477.

Rowe, J.B. and G.T. Hargreave. 1988. Nutritive value of lupin hulls. Proceedings-of-the-Australian-Society-of-Animal-Production. 17: pp. 463.

Saleem, M., F. Afaq, V. M. Adhami and H. Mukhtar. 2004. Lupeol modulates NF-kB and P13K/Akt pathways and inhibits skin cancer in CD-1 mice. Oncogene 23: pp. 5203-5214.

Schneider, A., K. Crepon and E. Fenart. 2005. The perception of lupin in the European Food Industry. Pp. 9-20, In A. Arnoldi (Ed). Optimised processes for preparing healthy and added value food ingredients from lupin kernels, the European protein-rich grain legume. Proceedings of the Final Conference of the European Project. Milan, November 9-10, 2005.

Sipsas, S. 2004. New Lupin Products. Report for the Grains Research and Development Corporation. GRDC Project Number DAW 00069.

Smith, D. 2005. Adapting lupins for use in prawn diets – Benefits and constraints. *In:* Seeding a Future fir Grains in Aquaculture Feeds (B.D. Glencross, Ed). Department of Fisheries, North Beach, WA, Australia 34 p.

Smith S.C., R. Choy, S.K. Johnson, R.S. Hall, A.C.M. Wildeboer-Veloo and G. W. Welling. 2006. Lupin kernel fibre consumption modifies fecal microbiota in healthy men as determined by rRNA gene fluorescent in situ hybridization. *European J. Nutrition* 45: 335-41.

Smith, A.K. and S.J. Circle. 1972. Soybeans: Chemistry & Technology. 1-Proteins. (editors) AVI Publishing Co. USA.

Spielmann, J., A. Shukla, C. Brandsch, F. Hirche, G.I. Stangl and K. Eder. 2007. Dietary lupin protein lowers triglyceride concentrations in liver and plasma in rats by reducing hepatic gene expression of sterol regulatory element-binding protein-1c. *Ann. Nutr. Metab.* 51: 387-392.

Tomoskozi, S., R. Lasztity and S. Dudek. 2001. The functional potential of legume proteins for production of food ingredients. Grain legumes 33: pp. 16-18. European Grain Legume Association.

Tucek, M. 2006. Use of lupin bran in high-fibre food products. Patent No. WO/2006/133492.

PCT/AU2006/000821. IPC A23L 1/20 (2006.01), A23J 1/12 (2006.01), A23K 1/14 (2006.01), B02B 3/14 (2006.01).

Vasilakis, K. and G. Doxastakis. 1999. The rheology of lupin seed (*Lupinus albus* ssp. graecus) protein isolate films at the corn oil–water interface. Colloids and Surfaces B: Biointerfaces 12: pp. 331-337.

Wasche A., K Muller and U. Knauf. 2001. New processing of lupin protein isolates and functional properties. *Nahrung/Food* 45; pp. 393-395.

Watson, R.E.B. S.P. Long, J.J. Bowden, J.Y. Bastrilles, S.P. Barton and C.E.M. Griffiths. 2008. Repair of photoaged dermal matrix by topical application of a cosmetic 'antiageing' product *British Journal of Dermatology* 15: pp. 472-477.

Yu, R. 1988. Incorporation of lupin into human foods. *In:* Proceedings of the Food Conference '88. Ed. Saipin Maneepur, Pivan Varangoon and Budan Phithakpol. Bangkok, Institute of Food Research and Product Development, Kaselsart University, Thailand. Pp. 24-26.