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LUPIN MEAL UTILISATION IN AQUACULTURE FEEDS

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ABSTRACT

The paper reviews nutritional value and production of lupin meal and its uses in aquaculture feeds. Feed is the major cost variable in a aquaculture system representing up to 60% of total operating costs. The utilisation of cost effective feeds would improve profitability of a aquaculture business. Commercial aquaculture feeds have been traditionally based on fish meal as the main dietary animal protein source and soybean meal as the dietary plant protein source. Lupin meal as an alternative dietary protein source has a favorable amino acid profile as compared to soybean meal. Lupin meal is consistently available, cost effective, palatable and highly digestible to most species of fish. It has been demonstrated that lupin meal will replace a considerable amount of soybean meal with no loss in production and fish performance. Manganese and methionine levels must be considered when utilising high levels of lupin in aquaculture feeds. Lupin meal is comparable nutritionally with soybean meal; it is more cost effective.

Key words : lupin meal, *Lupinus spp.*, aquaculture feeds.

I. INTRODUCTION

The use of feeds in aquaculture systems has increased production and profits considerably. However, fish or shrimp feeds are expensive and can amount to over two-thirds of the variable cost a aquaculture operation.

Aquaculture feeds usually contain 25% to 50% protein. To obtain these protein levels in feeds, high protein feedstuffs are utilised extensively and comprise 50% to 70% of the feed formula. Fish feeds, for example, were developed on the concept of "fish eat fish", therefore fish meal is a major and traditional component of fish feeds.

Limited supplies and the high price of fish meal have forced aquatic nutritionists to consider alternative sources of protein. Plant protein feedstuffs are generally cheaper than animal protein feedstuffs. Of the plant protein feedstuffs, lupin seeds and lupin meal are increasingly being utilised in aquaculture feeds due to their nutritional quality, lower cost, and availability.

The basic nutritional principles are similar for all animal species, terrestrial and aquatic. It has long been realised that Lupin (*Lupinus* spp.) is regarded as one of the legumes with high potential, due to its high protein content (32-36% for the whole seed; 39% for the dehulled seed; Kyle, 1994;

Petterson and Mackintosh, 1994) and low market prices (Orr, 1994). It is also reported that lupin has lower levels of undesirable elements such as phytic acid, saponins, lectins and trypsin inhibitors than soybean meal (Kyle, 1994; Petterson and Mackintosh, 1994; Petterson and Fairbrother, 1996; Petterson *et al.*, 1997). The amino acid profile of lupin meal was found to be similar to that of soybean meal and should provide most essential amino acids (Hughes, 1988; Kyle, 1994), although deficient in methionine was shown in tests with rats (Schoeneberger *et al.*, 1982). Lupin meal was highly digestible in the diets for rainbow trout (Hughes, 1988) and black tiger shrimp, *Penaeus monodon* (Sudaryono and Ambariyanto, 1999; Sudaryono, 1999a; 1999b). Lupin (*Lupinus* spp.) seed meal is one of the promising sources of plant protein which has been suggested as an economical alternative to fish meal or soybean meal for compounded finfish diets (De la Higuera *et al.*, 1988; Hughes, 1988, 1991; Jenkins *et al.*, 1994; Morales *et al.*, 1994; Robaina *et al.*, 1995) *and P. monodon* diets (Sudaryono and Ambariyanto, 1999; Sudaryono, 1999a; Sudaryono *et al.*, 1999).

The purpose of this paper is to review the use of lupin meal in aquaculture feeds.

II. NUTRITIONAL VALUE OF LUPIN MEAL

2.1. Protein and Carbohydrate

The major protein components in lupin seed are the globulins. Three main storage glycosylated globulins have been characterised in lupins (*Lupinus albus*, *Lupinus luteus* and *Lupinus angustifolius*) - γ-conglutin (lectin-like), β-conglutin (vicilin-like), and α-conglutin (legumin-like) (Esnault *et al.*, 1991; Melo *et al.*, 1994; Duranti *et al.*, 1995). These proteins of the three *Lupinus* species have identical structure, composition, and physical properties as those of other legumes.

Gladstone (1970), Waldroup and Smith (1989) and Kyle (1994) reviewed nutritional studies of lupins for animals and humans and concluded that the nutritional quality of lupin protein is equal to that of soybean and superior to that of other legume species. A comparison of the typical contents of the major nutrients in the various species of lupins is given in Table 1. Figures of the approximate composition of *L. albus* and *L. angustifolius* presented in Table 1 are comparable to those obtained by other workers (Yanez *et al.*, 1983; Halvorson *et al.*, 1984; Harris *et al.*, 1986).

Lupin is one of the richest sources of plant protein and although the protein content and amino acid profiles vary between species, intraspecies variability is low (Harris *et al.*, 1986; Petterson and Mackintosh, 1994; Petterson and Fairbrother, 1996; Petterson *et al.*, 1997). The protein content of the seed may range from 29 to 45%, depending on the cultivar, the extent of dehulling, and other factors. Dehulled lupin seeds contain higher protein levels (38–52%) than whole ones (32–36%) (Kyle, 1994; Petterson and Fairbrother, 1996). Like most legume proteins, lupin protein contains low amounts of the sulfur amino acids, methionine and cystine (King, 1981; Schoneberger *et al.*, 1982; Eggum *et al.*, 1993; Petterson *et al.*, 1997). In comparison to soybean protein, lupins also tend to be lower in lysine and tryptophan (Eggum *et al.*, 1993; Petterson *et al.*, 1997). However, the seeds are typically a rich source of arginine and contain a reasonably good balance of essential amino acids with a high degree of digestibility (Hughes, 1988; Rubio *et al.*, 1994; Brebaum and Boland, 1995; Lampartszczapa, 1996). Woo and Maeng (1992) reported that crude protein of lupin seed was more digestible than that of soybean meal in *in vitro* digestibility studies,.

Apart from the oligosaccharides, virtually all of the carbohydrate in lupins is present as cell wall polysaccharide in the cotyledons, about 39% of the total in *L. angustifolius*, and in the seed coat, about 90% of the total in *L.angustifolius* (Petterson and Mackintosh, 1994). Mohamed and Rayasduarte (1995) reported that *L. albus* was lower in starch (3%) than other common legumes. Lupin seeds had about twice as much non-starch polysaccharides than other legumes and higher insoluble dietary fibre (Donangelo *et al.*, 1995). Whole *L. albus* seed was reported to contain lower starch (3%) and higher fibre (34.2%) than soybean meal (Mohamed and Rayasduarte, 1995).

2.2. Lipid and Minerals

The lipid content of *L. albus* (7.6-11.8%), *L. angustifolius* (4.9-7.0%) and *L. luteus* (5.2-6.1%) is generally higher than in cereals and other pulse crops but much lower than in the oilseed crops (Harris *et al.*, 1986; Petterson, *et al.*, 1997). *L. albus* and *L. luteus* have a higher content of linolenic acid (n-6) (7.2–12.2% and 7.5–8.7% of lipid, respectively) than *L. angustifolius* (3.1–7.2% of lipid). However, *L. albus* contains lower linoleic acid (n-3) (13.0–25.0% of lipid) than *L. luteus* and *L. angustifolius* (46.8-47.7% and 31.3–47.12% of lipid, respectively).

Mineral content is low in lupins. Total calcium (0.15–0.22%), phosphorus (0.30–0.51%), copper (4.7–8.8 ppm), zinc (30–56 ppm), cobalt, and selenium values of various lupin species are low for animal requirements but this is readily corrected when using lupins in formulated feeds (Harris *et al.*, 1985; Petterson and Fair-brother, 1996). White lupins (*L. albus*) have been found to accumulate excessive levels of manganese, in the range of 767 g Mn/kg of seed (Hove *et al.*, 1978), while *L. angustifolius* seeds were reported to contain low manganese levels, in the range of 16.9 g Mn/kg of seed (Petterson and Fairbrother, 1996). It has been reported that high manganese contents can cause manganese toxicity, especially in pigs (King, 1981).

2.3. Anti-nutritional factors

Unlike soybeans and other legumes (e.g., chickpeas, lentils), lupins do not contain lectins and protease inhibitors such as trypsin inhibitors (Hove *et al.*, 1978; Hove and King, 1979; Eggum *et al.*, 1993; Grant *et al.*, 1993). Thus, raw lupins do not need extensive processing facilities to inactivate the lectins and trypsin inhibitors and can be readily incorporated into feeds (Woo and Maeng, 1992; Brebaum and Boland, 1995). A number of other anti-nutritional factors and a comparison of the contents of trypsin inhibitor in various legume seeds is presented in Table 2. Nutritionally, lupin seeds could offer some advantages as an alternative to soybeans due to lupin seeds having a lower content of antinutritional factors such as trypsin inhibitors, phytic acid, tannins, saponins and lectins.

III. THE STATUS OF LUPIN PRODUCTION AND ITS USES

The term lupins is commonly used to describe the whole seed (grain) of various *Lupinus* species. Australia is the largest producer and the only significant exporter of lupins in the world (Kyle, 1994) with annual total exports of almost 1 million tonnes in 1995/96 and 1996/97 (ABARE, 1997). Other major lupin-producing countries are

Europe, South Africa, Chile, New Zealand, and the former USSR as well as the USA (Waldroup and Smith, 1989). The production of lupin seeds in Australia in 1996/97 was about 1.56 million tonnes and Western Australia alone contributed around 1.31 million tonnes (ABARE, 1997). In the past 7 years (1990/91 - 1996/97 period), Australia has been producing around 1.2 million tonnes of lupin seeds per annum and 80-85% of the production was consistently produced by Western Australia, with between 60 and 70% of the annual crop being exported. *L. angustifolius* is now a major crop in Western Australia with an annual production (since 1994/95) of about 1 million tonnes and about 30% of the production comes from other states of Australia (Petterson *et al.*, 1997). Other commercial species of lupin which grow well in Australia are *L. albus* and *L. luteus*. Their annual production is expected to reach 200,000 tonnes within a few years.

Up to now only 4 of the 300 *Lupinus* species have been domesticated. Three of them (the white lupin, *L. albus*; the yellow lupin, *L. luteus*; the blue lupin, *L. angustifolius*) have their origin in the Mediterranean region, whereas the fourth, *Lupinus mutabilis* is derived from South America (Gladstone, 1970). Waldroup and Smith (1989), however, reported that only *L. albus*, *L. luteus* and *L. angustifolius* have significant nutritional value for livestock feeding. Lupin seeds which are commercially available and currently extensively used for humans and livestock are 'sweet' (low-alkaloid) varieties of *L. luteus, L. angustifolius* and *L. albus* (Ruiz, 1978; Waldroup and Smith, 1989; Nelson and Delane, 1990). The German scientist, von Sengbusch, early this century developed these lupin species to have low alkaloid content. This pioneering work was further developed in Western Australia to produce modern commercial cultivars of the narrow-leafed mediterranean lupin, *L. angustifolius* and the broad-leafed *L. albus* with low alkaloid content of 0.01–0.02% (Gladstone, 1972). Ruiz (1978) showed that the cultivars of *L. luteus* (Weiko III), *L. albus* (Keivskii mutant, Ultra, Ultra-Aust.), and *L. Angustifolius* (Unicrop, Astra, Uniharvest) contain low levels of alkaloid (0.006%, 0.007–0.022%, and 0.008–0.010, respectively). Demonstration of the low alkaloid content (<0.02%) of these lupin species is in agreement with results of other workers (Pearson and Carr, 1977; Harris *et al.*, 1986; Petterson *et al.*, 1997).

Petterson and Fairbrother (1996) have reviewed the use of lupins (*L. Angustifolius, L. albus, L. luteus*) as potential alternatives to soybeans for human foods and animal feeds. The results indicate that lupins have as high a nutritive value as soybeans in human foods such as tempe, miso, traditional soy sources, tofu, bread, cakes and pasta. The use of lupins in aquaculture feeds is discussed below.

IV. LUPIN INCLUSION IN AQUACULTURE FEEDS

Lupins are a useful ingredient in the diet for several aquaculture species such as rainbow trout, snapper, gilthead seabream (De la Higuera *et al.*, 1988; Hughes; 1988, 1991; Gomes and Kaushik, 1989; Moyano *et al.*, 1992; ; Jenkins *et al.*, 1994; Morales *et al.*, 1994; Robaina *et al.*, 1995). For example, De la Higuera *et al.* (1988) reported that increasing inclusion levels of *L. albus* meal in diets up to 32% did not affect growth and feed intake of rainbow trout and lupin meal protein could replace the dietary protein from fish meal up to 30%. Heat treatment of lupin seeds did not improve nutritional quality of lupin-based diets for rainbow trout (De la Higuera *et al.*, 1988). In another study, Moyano *et al.*

(1992) reported that no adverse effects on feed efficiency and protein retention efficiency of rainbow trout were found when they were fed with diets containing substitution levels of dietary fish meal protein of up to 70% by lupin meal protein. Hughes (1988) using similar species reported that *L. albus* meal can replace up to deparate 76% of fish meal protein and totally replace full-fat soybean meal (FFSM) protein in diets without any reduction on growth. He concluded that *L. albus* as a protein source for rainbow trout can be included in practical diets at a maximum level of 40%. Similarly, Hughes (1991) has also successfully demonstrated the use of either whole or dehulled *L. albus* meal as an alternative to FFSM at an inclusion level of 40% in diets for rainbow trout. Including 43% dietary lupin meal to replace 40% of a fish meal protein diet improved the growth performance, feed intake, and feed efficiency in rainbow trout (Morales *et al.*, 1994). Furthermore, Morales *et al.* (1994) pointed out that the fish-meal-based diet containing lupin meal was a significantly better performer than the control diet (no lupin seed meal) and the diets containing cottonseed meal or corn gluten meal. Overall, in rainbow trout, lupin meal has shown consistently good results as a potential alternative dietary protein source to soybean meal, fish meal and other protein sources.

The success of lupin meal use in diets for other finfish species has been recently reported by several authors. Lupin (*L. angustifolius*) meal can be included into the juvenile snapper (*Pagrus auratus*) diets up to 28% to totally substitute the protein of soybean meal with no reduced performance in growth and feed efficiency (Jenkins *et al.*, 1994). Robaina *et al.* (1995) reported that substitution of up to 30% dietary fish meal protein by lupin (*L. angustifolius*) meal did not significantly decrease the performance of the diets for juvenile gilthead seabream (*Sparus aurata*) in terms of growth and protein efficiency ratio. Lupin meal in these fish diets was included approximately up to 35%. Increasing the fibre content of diets with increasing inclusion levels of dietary lupin meal is one of the considerations for limited use of lupin meal in fish diets. Based on the above studies, generally lupin meal regardless of lupin species can be included in finfish diets at levels approximately up to 40% without any detrimental effects on growth performance and feed utilisation. Sudaryono *et al.* (1995) have tested a diet containing approximately 70% of whole lupin (*L. angustifolius*) meal as a sole plant protein source for juvenile *P. monodon*. This diet was very poorly utilised by shrimp compared with other diets. The high fibre content of this diet was likely to be responsible for the poor growth performance and water stability.

Currently, only few reports are available on protein digestibility studies of lupin diets by finfish. Apparent protein digestibility coefficients (APDC) of the diets containing up to 40% lupin meal was generally high, ranging from 81.4 to 85.3% for rainbow trout (De la Higuera *et al.*, 1988; Hughes, 1988; Morales *et al.*, 1994) and from 87.5 to 93% for gilthead seabream (Robaina *et al.*, 1995). APDC of *L. albus* diets was similar to that of fish meal diets in rainbow trout (De la Higuera *et al.*, 1988; Morales *et al.*, 1994). Robaina *et al.* (1995) reported a similarity in APDC among *L. angustifolius*, fish meal, and soybean diets in gilthead seabream. Variations in apparent digestibility coefficients of lupin diets are closely related to differences in diet composition, juvenile size, and animal species tested. Based on the above studies, it can be concluded that lupin meal, regardless of lupin species, can be included in finfish diets at levels up to approximately 40%.

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REFERENCES

ABARE, 1997. Australian Commodity Statistics. ABARE, pp. 166-189.

Brebaum, S. & Boland, G.J., 1995. Sweet white lupin - a potential crop for Ontario. Canadian Journal of Plant Science, 75: 841-849.

Collins, J.L. and Sanders, G.G., 1976. Changes in TI activity in some soybean varieties during maturation and germination. Journal of Food Science, 41: 169-172.

De la Higuera, M., Garcia-Gallego, M., Sanz, A., Cardenete, G. Suarez, M.D. and Moyano, F.J., 1988. Evaluation of lupin seed meal as an alternative protein source in feeding of rainbow trout (*Salmo gairdneri*). Aquaculture 71:37-50.

Donangelo, C.M., Trugo, L.C., Trugo, N.M.F. and Eggum, B.O., 1995. Effect of germination of legume seeds on chemical composition and on protein and energy utilization in rats. Food Chemistry, 53: 23-27.

Duranti, M., Gius, C. and Scarafoni, A., 1995. Lectin-like activity of lupin seed conglutin γ, a glycoprotein previously referred to as a storage protein. Journal of Experimental Botany,, 46: 725-728.

Eggum, B.O., Tomes, G., Beames, R.M. and Datta, F.U., 1993. Protein and energy evaluation with rats of seed from 11 lupin cultivars. Animal Feed Science and Technology, 43: 109-119.

Esnault, M.A., Merceur, A. and Cithard, J., 1991. Characterization of globulins of yellow lupin seeds. Plant Physiology and Biochemistry, 29: 573-583.

Gladstone, J.S., 1970. Lupins in Western Australia. Department of Agriculture, Western Australia, Perth, W.A. Bulletin 3834, pp. 3-37.

Gladstone, J.S., 1972. Lupins in Western Australia. Department of Agriculture, Western Australia, Perth, WA. Bulletin 3834: 3-37.

Halvorson, J.C., Waibel, P.E. and Shehata, M.A., 1984. The effects of white lupin on the growth feed efficiency, and taste characteristics of turkeys. Minnesota Turkey Research, University Minnesota Reports, 30: 23-31.

Harris, D.J., Spadek, Z.E. and Baseden, S., 1986. Chemical Evaluation of Lupin Seed as a Feed Grain. Agricultural Chemistry Laboratory, Feb. 1986, Western Australia, 42 pp.

Hove, E.L. and King, S., 1979. Trypsin inhibitor contents of lupin seeds and other grain legumes. New Zealand Journal of Agricultural Research, 22:41-42.

Hove, E.L., King, S. and Hill, G.D., 1978. Composition, protein quality, and toxins of seeds of the grain legumes *Glycine max*, *Lupinus* spp., *Phaseolus* spp., *Pisum sativum* and *Vicia faba*. New Zealand Journal of Agricultural Research, 21:457-462.

Hughes, S.G., 1988. Assessment of lupin flour as a diet ingredient for rainbow trout (*Salmo gairdneri*). Aquaculture, 71: 379-385.

Hughes, S.G., 1991. Use of lupin flour as a replacement for full-fat soy in diets for rainbow trout (*Oncorhynchus mykiss*). Aquaculture, 93:57-62.

Jenkins, G.I., Waters, S.P. Hoxey, M.J. and Petterson, D.S., 1994. Lupin seed (*Lupinus angustifolius*) as an alternative to soybean meal in diet of juvenile snapper (*Pagrus auratus*). In: M. Dracup and J. Palta (Editors), Proceedings of the First Australian Lupin Technical Symposium, 17-21 October 1994, Perth, Western Australia, Department of Agriculture, WA., pp. 74-78.

Kyle, W. S. A. 1994. The current and potential uses of lupins for human food. In: Lupin Update Meetings for Advisers and Consultant "Consolidation", Jerramungup, 8th and 9th February 1994, Department of Agriculture, Western Australia, pp. 89-92.

King, R.H. 1981. Lupin-seed meal (*Lupinus albus* CV. Hamburg) as a source of protein for growing pigs. Animal Feed Science and Technology, 6:285-296.

Lampartszczapa, E., 1996. Preparation of protein from lupin seeds. Nahrung, 40: 71-74.

Mohamed, A.A. and Rayasduarte, P., 1995. Composition of *Lupinus albus*. Cereal Chemistry, 72: 643-647.

Morales, A.E., Cardenete, G., De la Higuera, M. and Sanz, A., 1994. Effects of dietary protein source on growth, feed conversion and energy utilization in rainbow trout, *Oncorhynchus mykiss*. Aquaculture, 124: 117-126.

Moyano, F.J., Cardenete, G. and De-la-Higuera, M., 1992. Nutritive value of diets containing a high percentage of vegetable proteins for trout, *Oncorhynchus mykiss*. Aquatic Living Resource, 5: 23-29.

Nelson, P. and Delane, R., 1990. Producing lupins in Western Australia, E. Lawson (Editor). Bulletin of Department of Agriculture, Western Australia, 4179: 85 p.

Orr, J., 1994. Implications of CAP and GATT reforms on lupin marketing. In: P. Nelson (Editor), Lupin Update Meetings for Advisers and Consultatants "Consolidation", pp. 142-151.

Petterson, D.S. and Fairbrother, A.H., 1996. Lupins as a raw material for human foods and animal feeds. Indonesian Food and Nutrition Progress, 3: 35-41.

Petterson, D.S. and Mackintosh, J.B., 1994. The chemical composition of lupin seed grown in Australia. In: , M. Dracup and J. Palta (Editors), Proceedings of the First Australian Lupin Technical Symp. Perth, Western Australia 17-21 October 1994. Department of Agriculture, WA., pp. 39-48.

Petterson, D.S., Sipsas, S., Mackintosh, J.B., 1997. The Chemical Composition and Nutritive Value of Australian Pulses (2nd Edition). Grains research and Development Corporation, Canberra. 65 pp.

Pearson, G. and Carr, J.R., 1977. A comparison between meals prepared from the seeds of different varieties of lupin as protein supplements to barley-based diets for growing pigs. Animal Feed Science and Technology, 2: 49-58.

Robaina, L., Izquierdo, M.S., Moyano, F.J., Socorro, J., Vergara, J.M., Montero, D. and Fernandez-Palacios, H., 1995. Soybean and lupin sead meals as protein sources in diets for gilthead seabream (*Sparus aurata*): nutritional and histological implications. Aquaculture, 130: 219-233.

Rubio, L.A., Grant, G., Caballe, C., Martinezaragon, A. and Pusztai, A., 1994. High in-vivo (rat) digestibility of faba bean (*Vicia faba*), lupin (*Lupinus angustifolius*) and soya bean (*Glycine max*) soluble globulins.

Ruiz, L.P., Jr., 1978. Alkaloid analysis of 'sweet' lupin seed by GLC. New Zealand Journal of. Agricultural Reserach, 21: 241-242.

Schoeneberger, H., Gross, R., Cremer, H.D. and Elmadfa, I., 1982. Composition and protein quality of *Lupinus mutabilis*. Journal of Nutrition, 112: 70-76.

Sudaryono, A., 1999a. The Apparent Digestibility of Dry Matter and Protein from Prepared Diets by Juvenile *Penaeus monodon* : Replacement of Soybean Meal with Lupin Meal. (In Press). Jurnal Kelautan Maret 99.

Sudaryono, A., 1999b. Influence of Different Legume Meals Inclusion on Diet Digestibility in Juvenile *Penaeus monodon* (Fabricius) (In Press). Jurnal Cosdev Juni 99.

Sudaryono, A., Hoxey, M.J., Kailis, S. G. and Evans, L. H., 1995. Investigation of alternative protein sources in practical diets for juvenile shrimp *Penaeus monodon*. Aquaculture, 134: 313-323.

Sudaryono, A., Tsvetnenko, E. and Evans, L.H., 1999. Replacement of soybean meal by lupin meal in practical diets for juvenile *Penaeus monodon*. Journal of the World Aquaculture Society, 30: 46-57.

Sudaryono, A. and Ambariyanto, 1999. Apparent digestibility of practical diets for *Penaeus monodon* : replacement of fish meal with lupin meal. Jurnal Ilmu Kelautan, 13: 19-26.

Waldroup, P.W. and Smith, K.J., 1989. Animal feed uses of legumes. In: , R.H. Mattews (Editor), Legumes Chemistry, Technology and Human Nutrition. Marcel Dekker, Inc., pp. 271-283.

Woo, K.C. and Maeng, W.J., 1992. Effect of heat treatment of lupin seed on protein solubility, urease activity and protein digestibility in vitro. Korean Journal of Animal Nutrition and Feedstuffs, 16: 136-141.

Yanez, E., Ivanovic, D., Owen, D.F. and Ballestra, D., 1983. Chemical and nutritional evaluation of sweet lupines. Ann. Nutr. Metab., 27: 513-520.

Table 1. Approximate composition of whole lupin seed of various species (range, g/100 g as received) (After Petterson *et al.*, 1997).

Index	*L. albus*	*L. angustifolius*	*L. cosentinii*	*L. luteus*
Dry matter	90-92	90-93	90-94	91-92
Crude protein (N x 6.25)	29-40	27-37	23-38	36-41
Crude lipid	8-12	5-7	3-4	5-6
Ash	3-4	3	2-4	3-4
Crude fibre	9-13	12-24	15-24	14-21
ADF	12-21	16-24	-	20-28
NDF	14-23	20-29	-	28-38
Lignin	0.4-1.8	0.4-1.9	-	0.7-0.8
Linoleic*	13-25	31-47	-	47-48
Linolenic*	7-12	3-7	-	8-9
Calcium	0.1-0.3	0.2-0.3	0.1-0.4	0.2-0.3
Phosphorus	0.3-0.9	0.2-0.4	0.2-0.5	0.3-0.6
Manganese**	23-3772	7-76	8-326	25-50

ADF = acid detergent fibre; NDF = neutral detergent fibre; % in lipid; ** mg/kg

Table 2. Anti-nutritional factors in various legume seeds (After Petterson *et al.*, 1997; Petterson and Mackintosh, 1994; Hove and King, 1978 [a])

Factor	Unit	*L. albus*	*L. angustifolius*	*L. luteus*	*G. max* (soybean)
Alkaloids	%	<0.01	0.02	0.04	-
Phytate	%	0.57	0.50	0.93	1.59
Saponins	ppm	n.d.	573	-	3500
Tannins	%	0.40	0.29	0.30	0.57
Lectins	dilut	n.d.	n.d.	-	>4
Trypsin mg protein	(μg T.I./	0.08	0.12	-	16.5-29[a]