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Lupins - An alternative protein source for aquaculture diets

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Abstract
To support fast-growing and sustainable aquaculture production, the reduction in fishmeal has proven to be a challenge for the development of aquafeeds, because the most important protein source in aquaculture, the fish meal, is a limited resource. A variety of plant proteins have been investigated as possible fish meal replacements for aquaculture diets such as lupins are one of the plant varieties which is non-starch leguminous seeds with high protein sources. Plant protein meals and fishmeal differ in their nutrient composition due to former contains varying levels of antinutritional factors. Antinutritional factors can be reduced during feed extrusion. Typically, lupin seeds have a crude protein (CP) content of between 31 and 42%, which is higher than the content of most other grain legumes. Therefore, we can look the lupin meal as a plant protein source for aquaculture diets.

Keywords: Aquaculture, Fish meal, Alternative protein/ Lupin, Growth.

1. Introduction
Fish meal is the major protein source in feeds for aquaculture industry because of its high biological estimate, but this is a limited food stock. To support fast-growing and sustainable aquaculture production, the reduction in fishmeal has proven to be a challenge for the development of aquafeeds (FAO, 2012) [9]. There has been considerable interest in the use of lupins as a partial or total replacement for fish meal in aquaculture feeds. A variety of plant meals have been tested as possible substitutes for fishmeal in a range of finfish and crustacean species (Tacon & Metian, 2008) [22]. Among plant protein sources, cultivated lupin-species (*Lupinus albus*.) have good potential due to their high protein content (30-40 g/100g). Plant protein meals and fishmeal, however, differ in their nutrient composition and because the former contains varying levels of antinutritional factors. A factor which could limit the acceptance of lupin seeds is the presence of toxic alkaloids; which can be reduced by subjecting the seed to heat treatment and rinsing with water. The quality of a particular dietary protein source depends both on its digestibility and amino acid profile (Kaushik and Cowey, 1991) [16]. Lupin *(Lupinus sp.*) is regarded as one of the legumes with high potential, due to its high protein content (30-50%) and low market prices. Fish feed constitutes between 50% and 70% of a commercial farmer's cost of production.
Replacement of fish meal with Lupins (*Lupinus* sp.) in aquaculture diets has been possible due to its nutritional value, availability and low price (Moyano *et al*., 1992, Yones, 2005) [17, 24]. Lupin seed meal (LSM) may be a good alternative vegetable protein of high nutritive quality when used at levels up to 30% or 40% in rainbow trout diets (De la Higuera *et al*., 1988; Hughes, 1988; Gomes and Kaushik, 1989) [7, 15, 13].

2. Fish Meal
Fishmeal is one of the most important ingredients in formulating aquafeeds. Its inclusion is primarily for its high quality protein, but has the additional benefit of its oil content and associated highly unsaturated fatty acids. Fish meal is mostly produced from whole pelagic (i.e., surface-dwelling fish not bottom-dwelling) fish (e.g., anchovy, herring, mackerel, menhaden, sardine, tuna) or seafood processing by products such as processing waste, viscera and other unused parts of fish (Hardy and Tacon, 2002; Yano *et al*., 2008) [14] that have little or no use for human consumption. Fish meal is generally light brown in colour and is produced by cooking, pressing, drying and milling fresh raw fish and fish trimmings. It can be sold as four types; high quality meal, which is usually used in small-scale aquaculture units such as trout farms or marine species, a low temperature meal which is highly

digestible and used in salmon production, prime meal and fair/ average quality meal which has lower protein content and is used for pig and poultry feeds.

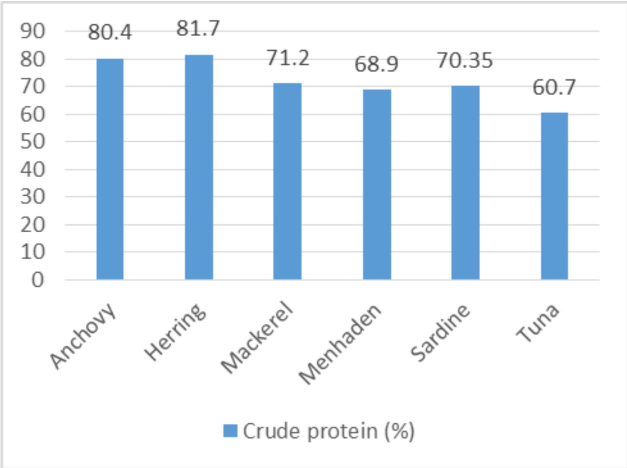


Fig 1: Fish meal use in Aquafeeds

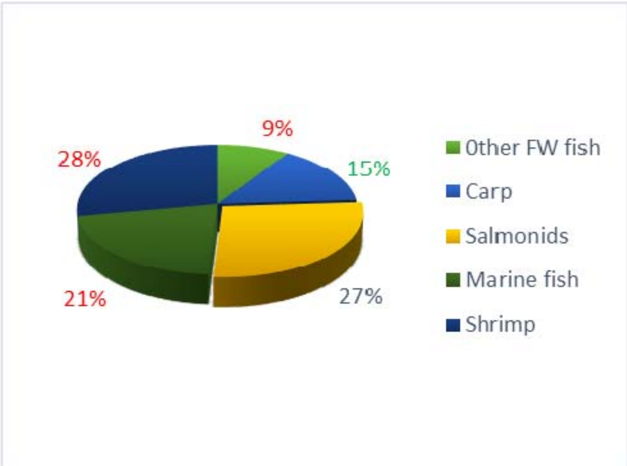


Fig 2: Proximate composition of various fish meals (%, dB) *

(Source: Ferouz Y. Ayadi *et al*., 2012)

Fig 3: Essential amino acid profiles for various fish meals (%, db)

(Source: Ferouz Y. Ayadi *et al*., 2012)

3. Lupin Seed Meal (LSM)

Lupin are used as ingredients in livestock feeds. The main species commonly used in fish feeds are *Lupinus angustifolius*, *Lupinus albus* and *Lupinus luteus* (De la higuera *et al*., 1988; Burel *et al*., 1998; Glencross *et al*., 2005) [7, 3, 20]. Lupins are non-starch leguminous seeds with high protein sources. It is a leguminous plant within the genus Lupinus, a group within the bean and pea family, the Fabaceae. The lupin products that have been evaluated in aquaculture diets are meal prepared from both whole seed and dehulled seed (Lupin kernel meal). The lupin kernel meal is produced by removal of the indigestible seed coat i.e. dehulling. Western Australia has now become the largest grower, producing more than 85% of world's lupin crop and exports most of it as animal feed.

Whole LSM contains approximately 16% (db) crude fiber, whereas dehulled LSM has only around 3.7% (db) (Chien and Chiu, 2003). Depending on the species, CP of dehulled extruded LSM is approximately 42-55% (db), compared to 32-38% (db) for whole LSM (Burel *et al*., 2000; Chien; Chiu 2003 and Glencross *et al.* 2005) [2, 5, 20]. Lysine and methionine content for dehulled and whole lupin is similar. Disadvantages of whole LSM are high fiber contents and antinutrients such as a- galactosides, trypsin inhibitor and inositol phosphates.

4. Antinutritional Factors

ANFs are mainly alkaloids that effect palatability and can be washed out using water. Dehulling increases the nutritive value of LSM by reducing the fiber content (Davis *et al*., 2002; Chien Chiu, 2003) [6, 20], increasing the CP content and decreasing the amount of carbohydrates without affecting the lipid level. Other antinutritional factors present in lupin include oligosaccharides, phytate, saponin and protease inhibitors (Chhorn Lim *et al*., 2008) [4]. The mode of action of these ANF also varies, with some affecting palatability, others digestion and some interfering with metabolic rate (Francis *et al*., 2001) [11].

Table 1: Antinutritional factors in the whole seed (g/kg DM) of various lupin species.

Antinutrient	*Lupinus angustifolius*	*Lupinus albus*	*Lupinus luteus*
Trypsin inhibitor	0.13	0.09	0.18
Alkaloids	<0.20	<0.10	<0.50
Oligosaccharides	46	73	99
Phytate	5.6	6.3	10.3
Saponin	0.63	0	0
Tannins	0.10	0.20	0.30

5. Chemical composition of Lupin meals

There is considerable variability in the composition of lupin meals depending on both lupin species and whether they are in a whole-seed or kernel form (Table 2). Protein content of lupins is significantly increased by the production of a kernel (seed coat removed/dehulled) form. Typically, lupin seeds have a crude protein (CP) content of between 31 and 42%, which is higher than the content of most other grain legumes. Protein content of lupins is highest in the kernel meals of *L. luteus* and *L. mutabilis* varieties, which both exceed 50% protein in the kernel meal form. Fat content is highest in the *L. mutabilis* and *L. albus* varieties. The composition of *L. mutabilis* is similar to that of soybeans. Lupins are notable in that they possess negligible starch levels within their carbohydrate component. Lignin is also present in very low quantities.

Table 2: Gross chemical composition (%) of whole seed and kernel of two species of lupins and fish meal.

Species	*L. angustifolius*		*L. luteus*		Fishmeal
	Seed	***kernel***	***Seed***	***kernel***	
Moisture	9	12	9	12	9
Seed coat	24	-	27	-	-
Protein	32	41	38	52	67
Fat	6	7	5	7	11
Ash	3	3	3	4	13
Lignin	1	1	1	1	-
Polysaccharides	22	28	8	12	-
Oligosaccharides	4	6	9	12	-
NFE*	51	36	43	30	-

Nitrogen free extractives = Seed coat + lignin + polysaccharides + oligosaccharides

(Source: Sipsas, 2003)

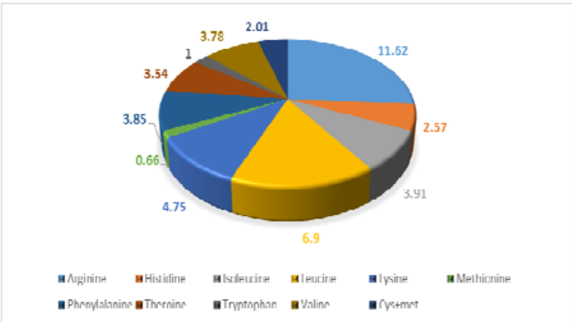


Fig 4: Essential amino acid profile of Australian sweet lupin (g/16g N)

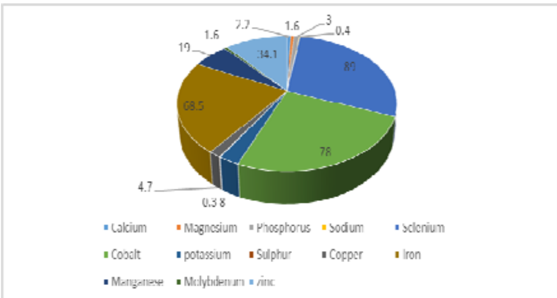
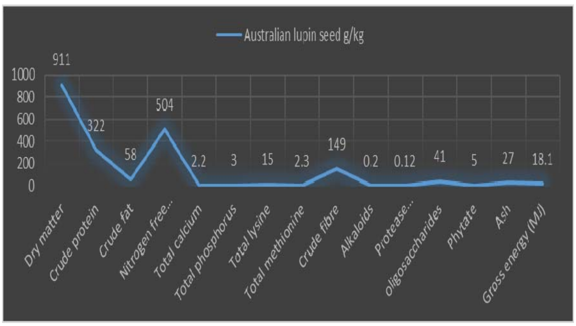
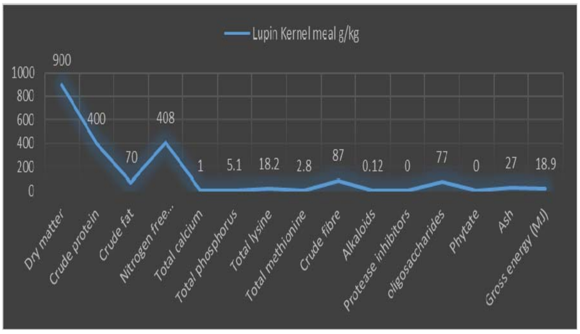


Fig 5: Mineral profile of Australian sweet lupin (per/kg as received)

6. Nutrient comparison between Australian lupin seed and kernel meal



A. Australian sweet lupin seed



B. Australian lupin Kernel meal

(Source: http://www.coorowseeds.com.au)

Table 3: Essential amino acid profile of lupin kernel meal (% on dry matter basis)

Essential amino acids	lupin kernel meal
Arginine	2.98
Histidine	1.34
Isoleucine	1.64
Leucine	2.28
Lysine	1.82
Methionine	0.34
Cystine	0.69
Phenylalanine	1.51
Tyrosine	1.12
Tryptophan	0.43
Valine	1.32

(Source: Abdel-Moneim A. M. Yones. 2010).

7. Digestibility

Defined as that portion which is not excreted in the feces and which is assumed to be absorbed by the fish. Ingredients of the diet must be digested and absorbed by the fish before the nutrients can be used for growth, reproduction and other aspects of metabolism. Digestibility differs among species of fish raised under different environmental conditions. An important consideration in formulating feed is to maximize the efficient digestion and utilization of the component ingredient.

$$\% \text{ ME} = \frac{\text{intake energy} - (\text{energy lost in feces, urine, gills}) \times 100}{\text{Feed energy}}$$

Table 4: Digestibility (%) of *L. angustifolius and L. luteus* (whole and kernel meal) in silver Perch

Digestibility of Nutrient (%)	*L. angustifolius*		*L. luteus*	
	Whole seed	kernel	Whole seed	kernel
Dry matter	50.3	67.6	64.7	77.8
Nitrogen	96.6	100.3	96.1	101.4
Energy	59.4	74.0	72.7	85.2
Phosphorus	71.8	80.1	77.5	73.8

(Source: Peter white *et al*., 2008)

8. Factors affecting digestibility
There are a number of factors that affect digestibility in fish such as-
- Feed composition
- Ration composition
- Feed preparation
- Enzyme supplementation in feed
- Fish species (animal factors)
- Level of feeding
- Temperature of water
- Salinity of water

9. Benefits of lupin kernel meal in fish diet
- A cheaper source of protein
- High protein digestibility
- Increase in pellet sink rates with higher inclusion rates
- Increase in hardness and durability
- High phosphorus retention
- Does not cause enteritis in salmon compared to soy
- Proteins not damaged by heat processing

10. Use of lupin meal in aquaculture diets
Smith (2002) [21] investigated the effect of including up to 60% lupin kernel (*Lupinus angustifolius*) in *P. monodon* diets. The researchers conclude that when lupin was included up to 40% in the diets, weight gain was equal to and digestibility was higher than the diet using full fat SBM as the primary protein source. Other studies on rainbow trout diets likewise reported that heating LSM (*Lupinus albus*) did not improve nutritional quality of the diets. Supplemented with lysine and methionine, crude LSM at 44% inclusion level replaced fish meal, partially (up to 3%) in a 45% CP diet without detrimental effects on weight gain, protein efficiency or digestibility (DE la Higuera *et al*., 1988) [7]. Examining dehulled LSM (*Lupinus angustifolius*) at 40% inclusion levels in 44% CP diets for juvenile rainbow trout showed that 49% of the fishmeal could be replaced without significantly affecting growth performance or nutrient utilization. Burel *et al*., (1998) [3] concluded that depending on the crop between 50 and 70% extracted lupin (*Lupinus albus*) could be incorporated in 40 and 44% CP diets, replacing >50 and 76% of the fish meal, respectively without significant differences in growth performance. In 56% CP diets for juvenile gilthead sea bream, LSM (*Lupinus angustifolius*) was included up to 30% without compromising weight gain, feed efficiency or protein, However, the researchers concluded that LSM level should not exceed 20% of total protein to avoid liver lipid deposition (Robaina *et al*., 1995) [19]. Smith (2002) [21] found that the growth rate of shrimp was not affected by the inclusion of *L. angustifolius* cv. Gungurru kernel meal in feeds at levels up to 200 g/kg. However, at inclusion levels >200 g/kg the growth rate decreased with increasing kernel meal content of the feed.

11. Conclusion
As lupin meals are included in aquaculture diets primarily as a protein source, high protein content and low levels of NSP are favourable characteristics of the kernel meal. Plant protein is well digested by fish and crustaceans (Eusebio, P.S., 1991) [8]. Digestibility of diets and feed ingredients are important as they directly measure how much has been digested and metabolized. Solid waste water pollution in aquaculture has its origin in the feedstuff used, either as wasted feed or excretion from the fish. The wasted feed is due to overfeeding, while the solid excretion is mainly due to the indigestibility of the feed. But plant meals lack the essential fatty acids EPA and DHA and are deficient in amino acids required by tropical marine species. This means that formulated diets based on plant meal usually have to be supplemented with some fish oil or fish meal.

Alternative protein sources have been found which provide suitable sources of protein and fatty acids for tropical freshwater species, however, there are still no real alternatives to fish oil, which is critical in supplying the fatty acids EPA and DHA essentially required by marine species.

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