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 an aquaculture system representing up to 60% of total operating costs. The utilisation of cost effective feeds would improve profitability of an 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 Ambriyanto, 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 Ambriyanto, 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 (vicia-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; Schoeneberger 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; Brebaun 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 Fairbrother, 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 anti-nutritional 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-leaved mediterranean lupin, *L. angustifolius* and the broad-leaved *L. albus* with low alkaloid content of 0.01-0.02% (Gladstone, 1972). Ruiz (1978) showed that the cultivars of *L. luteus* (Weiwo III), *L. albus* (Kievskii 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 temppe, 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 depurate 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 (Pomatomus saltator) 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. (1993) 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%.
ACKNOWLEDGEMENTS

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REFERENCES


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

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

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 *)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Unit</th>
<th>L. albus</th>
<th>L. angustifolius</th>
<th>L. luteus</th>
<th>G. max (soybean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaloids</td>
<td>%</td>
<td>&lt;0.01</td>
<td>0.02</td>
<td>0.04</td>
<td>-</td>
</tr>
<tr>
<td>Phytate</td>
<td>%</td>
<td>0.57</td>
<td>0.50</td>
<td>0.93</td>
<td>1.59</td>
</tr>
<tr>
<td>Saponins</td>
<td>ppm</td>
<td>n.d.</td>
<td>573</td>
<td>-</td>
<td>3500</td>
</tr>
<tr>
<td>Tannins</td>
<td>%</td>
<td>0.40</td>
<td>0.29</td>
<td>0.30</td>
<td>0.57</td>
</tr>
<tr>
<td>Lectins</td>
<td>dilut</td>
<td>n.d.</td>
<td>n.d.</td>
<td>-</td>
<td>&gt;4</td>
</tr>
<tr>
<td>Trypsin</td>
<td>(µg T.I./mg protein)</td>
<td>0.08</td>
<td>0.12</td>
<td>-</td>
<td>16.5-29*</td>
</tr>
</tbody>
</table>

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