# Maximising the Efficiency of Lupin Use in Pig Diets

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## Introduction

Lupins have an excellent potential for use in Australian pig diets due to their favourable chemical composition, and cost-competitiveness with a wide range of other protein sources. To date, however, they are frequently associated with variable pig production responses, and their nutritive value in terms of amino acid availability and digestible energy has proved very difficult to define. In addition, lupin species such as *L. albus,* despite having desirable chemical characteristics, reduce the feed intake of pigs when they are included in diets and the reasons for this phenomenon have so far eluded researchers. Other factors, such as the influence of non-starch polysaccharides from lupins on their nutritive value, are also largely unknown. For these reasons, the use of lupins in pig diets to date may not be as high as their potential

The objectives of this paper are to 1) discuss the potential for lupin use in pig diets, 2) examine the chemical composition and characteristics of lupin species available for use in Australian pig diets, 3) examine some of the variable production responses that have been shown when lupins are included in pig diets and discuss some of the possible reasons for these responses and 4) discuss research that will improve the efficiency of lupin use in pig diets.

## Potential for Lupin Use in Pig Diets

Lupins are extremely well suited to the mediterranean environment of southern Australia. Apart from a sensitivity to soil conditions with a preference for coarse textured, usually acidic soils, and an intolerance of alkaline soils (Perry *et al.* 1994), lupins are a highly adapted crop plant and now represent a significant proportion of Australia's total grain legume production.

Edwards (1994) estimated the current potential domestic consumption of grain legumes by the Australian stockfeed industry to be in the order of 1.36 million tonnes. Of this, 350 000 tonnes of lupins could be used in pig diets. A major limitation to the achievement of this potential, however, is a distinct asynchrony of supply and demand. For example, the Queensland pig industry could consume some 78 000 tonnes of lupins in pig diets, but the growing regions are well beyond their economic transport boundaries. In contrast, West Australia (which accounts for 84% of Australia's total lupin production) has a gross excess of lupins relative to modest consumption. The competitiveness of lupins as a stockfeed ingredient would be considerably enhanced if they could be produced within reasonable proximity to the current livestock industry (Edwards, 1994).

## Chemical Composition of Lupins

In Australia, *L. angustifolius* and *L.albus are* the predominant lupin species available for use in pig diets. A comparison of their gross chemical composition (Table 1) reveals that *L.albus* is clearly the superior cultivar in terms of crude protein, amino acid, fat and gross energy content. In addition, L.albus has lower levels of crude fibre and alkaloids, while levels of other anti-nutritional factors are similar for both species. Despite this, *L. angustifolius* (also known as the Australian sweet lupin) is preferred for use in pig diets. Bamett and Batterham (198 1) replaced soybean meal in wheat-based diets (equal energy and lysine content) with *L. angustifolius* and found that weaner pigs (6-20 kg) could tolerate up to 43% lupin-seed meal without adversely effecting growth. Pearson and Carr (1976) included *L. angustifolius* at levels up to 37% at the expense of more conventional protein concentrates without detrimental effects on the growth of grower/finisher pigs. Similar responses to *L. angustifolius* have been reported by Taverner (1975) and Batterham (1979). *L. albus* is NOT recommended for use in pig diets. Commercial nutritionists formulating diets for large Australian piggeries state categorically that it is uneconomical to include *L. albus* in pig diets due to resulting depressions in growth rates. The main reason for reduced pig growth when *L. albus* is included in diets is reduced feed intake, suggesting a palatability problem with this species. Poor acceptance and growth occurs at inclusion levels of *L. albus* above 15% (SCA, 1987).

Petterson and Mackintosh (1994) reported a variation in the protein content of *L. angustifolius* of 272 to 376 g/kg (air-dry basis, n=3351). Similar variation was reported for L. albus (291-403 g/kg). Not only will variation of this magnitude effect price, but as many home-mixers do not analyse the protein content of the legumes used in their diets, production losses or highly inefficient production may result. Less variation in protein content will also improve confidence in lupin quality resulting in increased security of use by producers. Lupins have a comparable amino acid profile to other legumes such as peas and soybean. A notable exception is low levels of methionine (0.59-0.87 g/16gN). As a consequence, pig and poultry diets containing lupins will frequently need supplements of synthetic methionine. Liebholz (1984) showed a growth response in pigs (2 1-35 kg) to additional methionine when lupin-seed meal was used as the sole supplement to a cereal based diet.

Several lines of a third lupin species, L.luteus (Yellow lupin), are being introduced into West Australia and prospects for commercial release of seed for some areas of the State are promising (Petterson and Mackintosh, 1994). Based on their chemical composition (Table 1), this species has great potential as a protein source for pig diets. Extensive nutritional evaluation of this species for pigs, however, is required before this will become a reality.

## Production Responses to Lupins

Despite *L. angustifolius* supporting similar growth rates to pigs fed more traditional protein sources, such as soybean meal, the production response to lupins can be highly variable. Some possible reasons for variable production responses may be:

### *1. Interactions With Other Diet Ingredients.*

Hansen *et al.* (199 1) reported that soluble dietary fibre causes interactions to occur between certain dietary mixtures. This could result in a reduction in the digestibility of amino acids and energy in the small intestine. As lupins have comparatively high levels of soluble non-starch polysaccharides, these interactions may be highly likely to occur when they are included in pig diets.

Highly variable responses have been shown to occur when various lupin cultivars are fed to pigs in either a sugar- or wheat-base. Batterham (unpublished) showed that three cultivars of *L.albus* promoted similar growth rates and lysine utilisation than soybean meal with either a sugar- or wheat-base when diets were formulated to contain equal levels of ileal digestible lysine (Table 2).

**Table 1** Gross chemical composition (g/kg) of *L. angustifolius*, *L. albus* and *L. luteus*

| Nutrient | *L.angustifolius* | *L.albus* | *L.luteus* |
|---|---|---|---|
| Crude protein | 321 | 361 | 379 |
| Fat 58 | 91 | 50 | |
| Crude fibre | 149 | 103 | 163 |
| Gross energy (MJ/kg) | 18.3 | 18.6 | NA |
| Amino acids (g/kg)* | | | |
| Arginine | 36.5 | 46.8 | 44.9 |
| Cystine | 4.6 | 5.0 | 9.1 |
| Histidine | 7.6 | 6.5 | 10.9 |
| Isoleucine | 12.3 | 14.1 | 15.9 |
| Leucine | 20.8 | 23.0 | 27.6 |
| Lysine | 14.3 | 15.7 | 20.2 |
| Methionine | 2.2 | 2.4 | 2.8 |
| Phenylalanine | 11.2 | 12.3 | 16.0 |
| Threonine | 10.4 | 11.9 | 14.5 |
| Tryptophan | 3.2 | 3.7 | NA |
| Tyrosine | 10.7 | 17.1 | 10.8 |
| Valine | 11.8 | 13.6 | 14.8 |
| Antinutritional factors (%) | | | |
| Alkaloids | 0.02 | <0.01 | NA |
| Tannins (total) | 0.32 | 0.37 | 0.32 |
| Tannins (condensed) | <0.01 | 0.01 | 0.02 |
| Saponins (mg/kg) | 573 | NA | NA |

* Amino acid profile of *L.luteus* supplied courtesy of the Grain Pool of WA.
NA, not analysed
(*From Petterson and Mackintosh, 1994*)

**Table 2** Empty-body-weight gain (g/d) and retention (g/g) of ileal digestible lysine in pigs fed *L.albus* in either a sugar- or wheat-base

| | ***L.albus*** Hamburg | | ***L.albus*** Kiev mutant | | ***L.albus*** Ultra | | Soybean | |
|---|---|---|---|---|---|---|---|---|
| | Sugar | Wheat | Sugar | Wheat | Sugar | Wheat | Sugar | Wheat |
| ID lysine (g/MJ DE) | 0.36 | 0.56 | 0.36 | 0.57 | 0.36 | 0.57 | 0.36 | 0.58 |
| EBW gain (g/d) | 522 | 717 | 510 | 670 | 490 | 666 | 517 | 814 |
| Lysine retained: ID lysine intake | 0.82 | 0.65 | 0.92 | 0.54 | 0.77 | 0.49 | 0.73 | 0.54 |

EBW, empty-body-weight; ID, ileal digestible (*From Batterham, unpublished)*

In contrast, Wigan (1995) and Femandez and Batterham (1992) showed that lupin seed meal and lupin kernels promoted superior growth rates and lysine retention superior to soybean meal when diets were sugar based, while soybean meal was superior in wheat-based diets (Table 3). The results of Batterham (unpublished) are also in contrast to those of King (198 1) who showed depressed intake when pigs were fed L.albus at levels above 15% in the diet. Apart from inaccurate determination of ileal digestible lysine or digestible energy, it is difficult to explain these results apart from varying polysaccharide interactions between L.angustifolius or L.albus and sugar and wheat respectively. More importantly, results of this nature support the hypothesis that the nutritive value of feed ingredients may not always be additive when mixed diets are prepared. There is a need to improve our understanding of how the chemical and physical composition of lupins relates to specific physiological effects in the pig.

### *2 Poor Definition of Nutritive Value*

A high degree of variation in the estimates of both lysine availability and digestible energy suggests that there is either a large variation in these parameters between lupin samples (influenced by their growing environment and cultivar), or there are variations in the experimental technique used to measure these parameters, or both.

To date, the availability of amino acids in lupins for pigs has proved difficult to define. There is a large difference between the ileal digestibility of lysine in lupin seed meal (0.86-0.93; SCA, 1987) and lysine availability, and it has been suggested that lysine from lupins may be absorbed in a form that is inefficiently utilised by the pig. To further confound the issue, the current recommended value for lysine availability in lupins for pigs of 0.55 (SCA, 1987) is not supported by results achieved commercially. Industry experience has revealed that values of 0.70 and 0.80 can be applied as the availability of lysine in lupin-seed meal and lupin kernels respectively, while maintaining excellent pig growth. These values are supported by Godfrey and Payne (1987) who suggested the availability of lysine in lupin kernel meal. (L. angustifolius) exceeds 0.70. One explanation for the above differences may be inadequacies in the slope-ratio assay when defining amino acid availability in lupins. Alternatively, there may be a significant difference between the availability of lysine in older lupin cultivars such as Uniharvest (used in lysine availability experiments by Batterham et al. 1984) and new cultivars such as Gungurru that dominate current commercial use.

An accurate lupin energy value for pigs has also proved very difficult to defme. Wigan *et al.* (1994) summarised recent estimates of the DE content of lupins for pigs. Estimates ranged from 12.3-15.3 MJ/kg for lupin seed meal and 15.4-16.6 for lupin kernels. Reasons for this wide range in energy values may include 1) the use of wheat or sugar as a base for the experimental diets, or 2) the degree of crushing/grinding of the lupins prior to inclusion in the experimental diets. Sugar-based diets may promote the preferential absorption and utilisation of monosaccharides from the small intestine, decreasing the reliance on hind-gut microbial degradation of energy and absorption of volatile fatty acids as an energy source. This is supported by Wigan (1995) who showed a highly significant difference in the digestibility of energy in lupin kernels fed to pigs in either a sugar (0.36) or wheat base (0.77).

As well as decreasing the accuracy of diet formulations, this range in DE estimates can have a considerable bearing on the price of lupins. For example, differences in DE of 2 MJ/kg could be worth up to $30.00/tonne.

When dealing with lupins, one must also ask whether DE is the most appropriate measure of available energy content for pigs. This is due to the fact that a large proportion of lupin dry matter and energy is digested in the hind-gut compared with other legumes (Taverner et al., 1983). In addition, low DMD in the small intestine when high levels of lupins are fed can have significant impact on the dressing percentage of pigs. King (1990) reported that dressing percentage of pigs decreases by 0.8 to 1.4 percentage units for every 10% increment of dietary lupin-seed meal when lupins are given to pigs over the entire grower/finisher phase.

**Table** 3 Empty-body-weight gain (g/d) and retention (g/g) of ileal digestible lysine in pigs fed *L.angustifolius* in either a sugar- or wheat-base

| | Sugar | | | Wheat | | |
|---|---|---|---|---|---|---|
| | Lupins | Kernels | Soybean | Lupins | Kernels | Soybean |
| EBW gain | 579 | 560 | 543 | 779 | 739 | 808 |
| Lysine retained: | | | | | | |
| ID lysine intake | 0.83 | 0.82 | 0.67 | 0.57 | 0.58 | 0.67 |

(From Wigan, 1995)

### *3 Presence of Oligosaccharides*

It has been suggested that the variable energy contribution from lupins is due to high levels of oligosaccharides. The argument is that higher oligosaccharides are largely indigestible in the small intestine of the pig, so they are highly fermented in the hind-gut. This results in the production of volatile fatty acids by the intestinal bacteria which are subsequently used as energy by the pig. Gas is another by-product from this fermentation. Wigan et al. (1994) suggested that wide variation in oligosaccharide concentration both within and between species of lupin may be influencing nutritive value and the highly variable performance of lupins.

Oligosaccharides are very difficult to define. When 2-10 monosaccharides are joined by glycosidic linkages the resulting polymer is referred to as an oligosaccharide. The most common oligosaccharide in nature is sucrose, which is cleaved by the enzyme sucrase and absorbed in the small intestine. Higher oligosaccharides such as raffinose, stachyose and verbascose (which are commonly found in legumes) are not digested in the small intestine, and hence are considered as dietary fibre. The levels of these oligosaccharides in lupins are not dissimilar to those contained in soybean meal (Table 4). For this reason, it is difficult to single out oligosaccharides as the primary cause of the variable nutritive value of lupins. Lupins have a very high level of dietary fibre, of which the oligosaccharides form a part, but the overall composition of this dietary fibre and the associated physiological effects is of far greater importance.

**Table 4** Raffinose, stachyose and verbascose content (% DM) of lupins and soybean meal.

| | Legume | |
|---|---|---|
| Oligosaccharide | Soybean meal | Lupins |
| Raffinose | 1.0 | 1.0 |
| Stachyose | 4.7 | 5.3 |
| Verbascose | 0.3 | 1.4 |

Collectively, raffinose, stachyose and verbascose are non-reducing a-galactosides derived from sucrose. The role of a-galactosides in gas production has already been investigated in rats and humans for several legume seeds. From these studies it appears that stachyose may be responsible for half or more of the gas produced from the fermentation of legume seeds. From Table 4, however, we can see that stachyose levels in lupins are only marginally higher than levels in soybean meal, so one would not expect a major difference in gas produced between animals fed lupins or soybean meal. In addition, no difference in the production of methane between pigs fed diets containing lupin meal, lupin fibre, a combination of the two, and a control diet containing cellulose has been shown (M.Champ, pers comm).

A contrasting view is that some oligosaccharides may have the potential to reduce mortality and protect health by influencing the microbial balance in the animals intestine. As higher oligosaccharides (fructo-oligosaccharides) are not digested in the small intestine, they are available for fermentation in the hind-gut, thus providing a selective substrate that can promote the growth of desirable bacteria yet interfere with potential pathogens.

It appears oligosaccharides play only a small role in the variable nutritive value of lupins. The problem is likely to be far more complex involving interactions between a combination of lupin components and other diet ingredients.

## Improving the Efficiency of Lupin Use in Pig Diets

Lupins have an excellent potential to increase in value as a pig feed. The Australian pig industry has a firm commitment to improving our understanding of the nutritive value of lupins. Based on the above characteristics of lupins and resulting pig production responses, research programs have been designed to investigate or clarify the following aspects pertaining to the nutritive value of lupins:

*I. The availability of lysine in lupins for pigs using production responses to varying levels of amino acid intake and subsequent carcass analysis.*

The availability of amino acids, particularly lysine, in lupins needs to be clarified to improve the accuracy of diet formulations and the efficiency of pig production. Definition of the availability of amino acids in lupins will also have a strong bearing on the price and use of lupins in pig diets.

*2. The productive energy contribution from lupins for pigs.*

Net energy (NE) is defined as ME minus heat production. Heat production is the amount of heat released due to the energy cost of the digestion processes and nutrient metabolism. Thus losses of energy as heat production vary with feedstuff composition and type of production. NE represents the best estimate of the “true” energy value of a diet and has been proposed by Noblet and Henry (199 1) as the preferred system of assessing the energy value of raw materials. NE estimates may be obtained from either calorimetry studies or energy retention by the comparative slaughter technique. Using the comparative slaughter technique the net energy of diets can be assessed by determining the amounts of energy deposited in growing pigs fed at increasing energy intakes. A reliable estimate of the true productive energy in lupins relative to other common protein sources is essential for accurate commercial diet formulation.

***The effects of lupin inclusion levels on voluntary feed intake by pigs.***

Reasons for the reduction in voluntary feed intake (VFI) when lupins are fed are still unclear but possibilities include high manganese levels, high alkaloid levels, low methionine levels, saponins, tannins and high fibre contents.

When lupins replace other protein sources in the diet there is generally a reduction in VFI and ADG when the level of inclusion rises above 10%. While feed:gain is often not affected by dietary lupin, dressing % can be reduced and hence feed:carcass gain is a more valuable measure of productive efficiency. The reduction in VFI is greater for *L. albus* than for *L. angustifolius* and it would appear that the factor reducing VFI is associated with the kernel. Although responses are somewhat variable, VFI appears to be reduced at lower lupin inclusion rates in starter pigs as compared to grower or finisher pigs. For example Donovan *et al.* (1993) found that there was a linear decrease in VFI and performance in starter pigs fed diets containing greater than 12 and up to 32% *L. albus* seeds. VFI was not affected in grower or finisher pigs although maximum inclusion rates of *L. albus* seeds were only 19 and 14%, respectively. Both ADG and feed:gain were reduced in grower pigs whereas only feed:gain was reduced in the finisher pigs. Likewise, researchers at Washington State University found a linear decrease in VFI in starter pigs but not in grower-finisher pigs diets containing up to *28% L. albus* seed (Muirhead, 1989).The available evidence suggests that the likely potential causes of reduced VFI during lupin feeding are NSP or oligosaccharides, saponins or some unidentified antinutritional factor. This factor(s) should be more prevalent in *L. albus* and concentrated in the kernel. Increased hindgut fermentation and delayed transit time could be the cause of the reduction in VFI. It is suggested that digestibility studies involving the measurement of colonic retention time (measured using a combination of solid and liquid phase markers) be used to determine whether retention time is increased in pigs receiving diets containing lupins.

***The role of anti-nuttitionalfactots in the variable production tesponses to lupins, particularly saponins.***

The main anti-nutritional factors in lupins are alkaloids, saponins, tannins and a-galactosides. Alkaloids, in particular, are often cited as the reason for reduced acceptance of *L. albus* by pigs (Hill and Pastuszewska, 1993). *L. angustifolius*, however, has similar levels of alkaloids to *L. albus* but is readily accepted by pigs. For this reason, it has been suggested that other anti-nutritional factors such as condensed tannins and saponins have a more prominent role in the poor acceptance of *L. albus*. As the amount of alkaloid in a pig diet increases above about 0.03% there is a decrease in intake, which in turn reduces liveweight gain (Hill and Pastuszewska, 1993). This level, however, is seldom exceeded in pig diets containing lupins. Apart from alkaloid levels in *L.angustifolius* and *L.albus* and the concentration of tannins in *L.angustifolius*, the available data on these ANF's is far from comprehensive. For example, limited samples of *L.albus* and very few samples of *L.angustifolius* have been analysed for saponins. It is also not clear why there is a poor acceptance of *L.albus* by pigs and it is important that any role of ANF's in this problem can be identified.

***5. The anti-nuttitive role of lupin non-starch polysaccharides in pigs.***

Graded inclusion levels and NSP isolates from lupins will be used to assess the effects of NSP on protein and energy digestion, protein x energy interactions in the hind-gut and the effects of NSP on endogenous losses. In addition, lupin oligosaccharides can be easily removed by soaking ground, de-hulled lupins in 80% ethanol for 16 hours. Following soaking and removal of the ethanol, the residue could be dried and fed to growing pigs. This would allow direct measurement of the effects of oligosaccharides from lupins on pig performance.

***6. The interactions between lupins and othet diet components.***

By characterising the digestibility of nutrients in a range of cereals and lupins,diets can be formulated to contain equal levels of ileal digestible amino acids. If interactions occur between the lupins and various feed ingredients, production responses to these diets will differ.

## Conclusions

Lupins represent a valuable protein resource to the Australian pig industry. A coordinated research program will clearly define the nutritive value of lupins for pigs increasing their value as a crop, improving their efficiency of use in pig diets and increasing their attractiveness as a crop for export markets.

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