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Effectiveness of *Lathyrus sativus* L. grain as animal Feed

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Abstract
Lathyrus (*Lathyrussativus* L.) is an important legume crop with low cost and easy cultivation grown in India, Bangladesh, China, Ethiopia, Nepal, and Pakistan for human food and animal feed. Inherently *Lathyrus* possesses resistance to drought, excess moisture, salinity, diseases, and insect pests. As *Lathyrus* has an ambivalent reputation due to ODAP content in its plant parts, efforts are on to develop low or ODAP free *Lathyrus* varieties with high biomass for dual purpose for human food and animal feed. Older published animal feeding studies are of limited use, since the presence and role of ODAP was unknown until the 1960s. More recent feeding studies indicate that low ODAP lines of *L. sativus* can be safely incorporated at inclusion rates up to 40, 30 and 70% of the diet of poultry, pigs and sheep, respectively, without growth reductions (Hanbury, *et al*, 2000). *Lathyrus* is known as excellent feed and fodder crop for centuries as a main concentrate for horses (Anonymous, 1894). Livestock is a key component of farming systems in South Asia and in Africa, and most particularly with small and marginal farmers, estimated about 678 million, and indicates importance of livestock to their livelihoods (ILRI, 2000). *Lathyrus* is increasingly recognized as an important feed and fodder crop by the resource poor farmers of semi-arid and dry areas. Acceptability of low ODAP varieties by the farmers of non-traditional *Lathyrus* growing areas and high nutritional composition makes the *Lathyrus* a perfect dual purpose for crop securing food, feed and fodder security in the region. (Sarkar, *et al*., 2010). As world demand for legume feed protein is likely to increase, due to increasing demand for animal food products, *L. sativus* are crops that should be considered in regions with suitable environments (Hanbury, *et al*, 2016).

Keywords: *Lathyrus*, ODAP content, protein, antinutritional factors, lathyrism

Introduction
The *Lathyrussativus* L belongs to the Fabaceae family. *Lathyrussativus* L. not only has potential as an agriculturally important crop for animal feed and human food, it also can be useful for studies of plant drought resistance (Choudhary *et al*., 2016) [17]. The people known it under various names: dinner, dental peas, cicericula, Dentisor. It is a precious annual plant, which has a long history of culture. The species sativus is widely cultivated. *Lathyrussativus* is a valuable plant of culture, both using it and as a precursor. *Lathyrussativus* is cultivate on about 500 thousand ha the globe. The areas large occupy it crop in India, Spain, Portugal, Near East, North Africa. It is used in human nutrition and animal feeding. Flour from the *Lathyrussativus* is used (10%) for tasty bread. The berries are used up to mature, green and mature in the form of garner. It is use in animal feed as a green fodder, a fan, alone or mixed with cereals, and the grains are given as concentrated fodder. The *Lathyrussativus* are also used to obtain high-quality glues used in aviation, textile, veneering, etc. The stem is in the muscle, branched, but non-resistant to fall. The leaves par pinnate with two narrow, lance late leaves, end with branched circle. The flowers are of violet color, rarely pink, blue, placed in raceme 2-3.

Lathyrus sativus L.
Livestock plays an important role in Indian agriculture and rural economy. Rural population has major livelihood sources and income from livestock and poultry by selling milk, meat and egg. Livestock contrives 9% and 25% to National GDP and agricultural GDP respectively and contribution from livestock is about 15-20% to the farmers household income.

At present, the country faces a net deficit of 45.1% green fodder, 21.9% dry crop residues and 64% in terms of concentrated feeds (Hegde N.G, 2006) [35].

Fig 1: *Lathyrus sativus* L.

In India the available natural fodders are poor in quality with regards to energy, protein and minerals and vitamins which leads to reduces production which directly effects farmer's income. The farmers investing about 70% of total cost of milk production on feed, fodder and concentrates only, thus good quality of green fodder having sufficient nutritive value are the demand of the day due to more demand of milk. Although, green fodder, hay and silage contains good nutritional values, but there maintenance, ways of consumption and presence of some toxic material also alarm us. Among the different quality controlling aspects anti quality materials/substances are also of prime importance (Wadhwan V.M, 2014) [81].

The genus *Lathyrus* is a large one, comprising 189 species and sub-species according to Allkin *et al.* (1985) [5], and approximately 150 species according to Kupicha (1983) [41]. Of these only a small number are cultivated. Erskine *et al.* (1994) [22] suggest that *L. sativus* was originally domesticated as a secondary crop as a result of being a weed of lentil (Lens culinaris) crops. It has been demonstrated in recent studies that the Lathyrus spp. (*L. sativus* L.) have considerable potential as grain legume crops on fine textured, neutral to alkaline, soil types in southern Australian Mediterranean-type environments (Hanbury *et al*., 1995; Siddique *et al*., 1996, Siddique and Hanbury, 1998) [30, 69, 70]. This species being evaluated as low input, multi-purpose crops for green manuring, animal feed and fodder. In Australia, animal feed is seen as the primary use of the grain of these species, both on and off farm. Animal feeding with this species has a long history and is still practised in some parts of the world. However, published studies are scattered and frequently difficult to access. This review aims to summarise the animal feeding literature and demonstrate the potential for this species as animal feed.

Soybean (*Glycine max*) meal is used widely as a source of protein for animal feeds, and the price of most other protein meals and grain legumes are set relative to this commodity. In Europe there has been increasing emphasis on local production of legumes for animal feed in order to supply some of this protein demand (Gatel, 1994) [27], rather than relying on imported soybean meal. Subsidies have resulted in increasing production of, particularly, Field peas (*Pisumsativum*) and faba beans (*Viciafaba*). This expansion has been partly at the expense of previously grown legume crops, such as Lathyrus spp., which do not have subsidies (Franco Jubete, 1991) [25].

The use of legumes as sources of protein for the animal feed industry is expected to increase further in the near future. Rising incomes in the Asian region are increasing the demand for meat products, and hence the requirement for animal feeds. There have been changes in public perception and some unfortunate developments, such as the consequences of `mad cow' disease (i.e. bovine spongiform encephalopathy or BSE) in UK. This has resulted in many feed compounders either choosing to, or being banned from, using animal by-products as a source of protein (Farrell, 1997) [23].

Fig 2: Seeds dried

Lathyrus sativus L. seeds dried

The amino acid requirement of animals often differ with species and bodyweight, hence no single source of plant protein will provide the exact amino acids required for all animals. It is, therefore, preferable to include a range of protein sources in diet formulations, each complementing the other. For these reasons, the demand for grain legumes, such as Lathyrus spp., by the feed industry is expected to increase. Any feedstuff is likely to be used in diets for animals if it supplies the required nutrients, if it is cost competitive with other available ingredients, and if the user is confident it will produce the desired result.

Lathyrism

Lathyrus species, particularly L. sativus, have been known since classical times to be implicated in a paralysis of humans and animals (Hugon *et al*., 2000) [37] known as ``lathyrism" or more specifically ``neurolathyrism". Both ruminants and monogastric species can be affected, some literature indicates that monogastrics can be more affected. It was only in the later half of the 20th century that the compound responsible was identified (Murti *et al*., 1964; Rao *et al*., 1964) [53, 62]. Neurolathyrism is the term used to describe the symptoms shown after heavy consumption of several different *Lathyrus* species and some Vicia species. The symptoms are weakness of the hind limbs and paralysis or rigidity of the muscles. The form of neurolathyrism most pertinent to this discussion is that caused by the non-protein amino acid 3-(-N-oxalyl)-L-2,3-diamino propionic acid (ODAP, also referred to as b-N-oxalylamino-L-alanine or BOAA; Fig. 3): which has been recorded in humans and animals following consumption of L.

sativus, L. cicera, L. ochrus and L. clymenum (Barrow *et al*., 1974; Padmanaban, 1980; Franco Jubete, 1991) [8, 56, 25]. The seed of a number of other uncultivated Lathyrus species have been found to contain ODAP (Bell, 1962, 1964) [13]. Historically the consumption of L. sativus has been most often linked with lathyrism in humans and animals, primarily because of all *Lathyrus* species it is the most widely utilised as grain and fodder. Lathyrism is the term mostly used to refer to neurolathyrism caused by ODAP.

There are two forms of lathyrism, neurolathyrism and osteolathyrism. Osteolathyrism is characterized by skeletal deformities and can be caused by consumption of the species *L. odoratus* (sweet pea), *L. hirsutus, L. pusillus and L. roseus* (Roy, 1981) [64]. Osteolathyrism has been recorded experimentally in a wide range of animals (Barrow *et al*., 1974) [8]. The principal compound responsible was found to be b-aminopropionitrile (BAPN; Fig. 3), although the related nitriles aminoacetonitrile (AAN) and methylene aminoacetonitrile (MAAN) also have some osteolathyritic activity (Barrow *et al*., 1974) [8]. Although BAPN is not found in either L. sativus or L. cicera (Bell, 1962, 1964) [13], there is evidence that a BAPN precursor (2-cyanoethyl-isoxazolin-5-one) is present in L. sativus seedlings but not in seed (Lambein *et al*., 1993) [44]. Consumption of *L. sativus* seedlings and shoots as vegetables has been blamed as the cause of osteolathyritic symptoms found in a small proportion of people with chronic neurolathyrism (Haque *et al*., 1997) [34]. Incidents of osteolathyrism from feeding of L. sativus have not been reported in animal studies, either under natural grazing or experimental conditions.

Lathyrism in humans has received more attention than that in animals, due to the social cost. Symptoms in humans are most often initial painful spasms in the muscles of the lower limbs with accompanying weakness, followed by chronic spastic paraplegia of various degrees (Spencer *et al*., 1986) [74], and can lead to total loss of use of the legs (Attal *et al*., 1978) [7]. The paralysis is rarely reversible (and then only in early stages of the symptoms; Hugon *et al*., 2000) [37] and the consequences for poor communities who depend upon *L. sativus* as a primary food source at times of food scarcity can be devastating. Lathyrism still occurs, with a 1997 outbreak during food shortages in Ethiopia crippling 2000 people (Getahun *et al*., 1999) [29]. Lathyrism is endemic to the areas of the world which have significant areas of L. sativus cultivation; India, Bangladesh, Ethiopia and Nepal. However, in the 20th century outbreaks were also reported in Afghanistan, Algeria, China, France, Germany, Italy, Pakistan, Romania, Russia, Spain and Syria (Trabaud and MouhaÈrram, 1932; Barrow *et al*., 1974; Roy and Spencer, 1989; Hugon *et al*., 2000) [79, 8, 37]. Boiling has been found to reduce ODAP levels in several cases, however, there are mixed reports on other forms of cooking (TekleHaimanot *et al*., 1993; Akalu *et al*., 1998) [65, 3]. Padmajaprasad *et al*. (1997) [57] reported that boiling grain and discarding the water reduced ODAP levels by up to 90%.

ODAP toxicity

Following its isolation and identification (Murti *et al*., 1964; Rao *et al*., 1964) [53, 62] the neurolathyritic action of ODAP was soon demonstrated in adult monkeys (Rao *et al*., 1967) [63]. Cheema *et al*. (1969) [16] administered ODAP intraperitoneally to rats. Young rats showed lathyrism symptoms and had 0.11 mmol gÿ1 ODAP in the brain, adult rats showing trace or nil ODAP and no symptoms. Olney *et al*. (1976) found some indication of exclusion of ODAP by the blood-brain barrier in mice. Padmanaban (1980) [56] suggested that the hypothesis of less ODAP exclusion by the blood-brain barrier in young animals should be re-examined, as greater excretion of ODAP by older animals may be an important factor. Spencer *et al*. (1986) [74] showed unequivocally that ODAP, either naturally present in L. sativus or when added to other food sources, was the cause of corticospinal dysfunction in monkeys (Macacafascicularis), with symptoms of hind limb motor difficulties. ODAP acts as a glutamate (Fig. 3) analogue in the nervous system and probably acts by binding strongly to a-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid (AMPA)- type glutamate receptors. Permanent damage probably occurs with excitotoxic degeneration of neurons, although there are other possible neurotoxic effects. The ultimate fate of ODAP and the distribution in the brain and spinal cord is not known (Hugon *et al*., 2000) [37]. ODAP was not detected in pig loin tissue following feeding for an extended period (Castell *et al*., 1994) [15].

In human populations young men are widely reported as the most susceptible to lathyrism (McCarrison, 1926; Shourie, 1945; Attal *et al*., 1978; Hamid *et al*., 1986; Getahun and TekleHaimanot, 1997) [57, 76, 32, 28], although the reasons for this are not understood (Hugon *et al*., 2000) [37]. The production and susceptibility to ODAP may be linked to Zn deficiency in plants and humans, respectively (Lambein *et al*., 1994; Lambein and Kuo, 1997). ODAP has also been found to inhibit growth of some insects and yeasts (Rao *et al*., 1964; Mehta *et al*., 1972) [62, 52], and so may have a plant protective role.

Anti-nutritional factors

Chemical substances present in the diet which by themselves or their metabolic products arising in the system interfere with the feed utilization, reduce production or affects the health of the animal. They are also called as toxic factors or incriminating factors. Anti-nutritional factors present in various feed/fodder are given in Table 1. Toxic substances of natural origin can be classified based on their chemical properties and on the basis of their effect on utilization of nutrients.

Table 1: Anti-Nutritional factor in forage crops

S. No.	Antinutritional/ Toxic substances	Fodder crops
1	Nitrate	Sudan Grass Pearl millet
2	Oxalates	Paddy straw,Guinea Grass, Bajra and Hybrid Napier, Setaria Grass, Kikyu&Buffel grass
3	Saponins	Lucerne
4	Tannins	Fodder tree/Shrubs
5	Cynogens	Sorghum, Sudan grass, Jhonson grass
6	Glucosinolates (Goitrogens)	Cabbage, Turnips, Rapeseed and Mustard green
7	Mimosine	Subabul
8	β-N-oxalyl-L-α, β-diamino propionic acid (β-ODAP or BOAA)	Lathyrus

In common with all grain legumes there are a range of antinutritional factors (ANFs) found in *L. sativus* grain. The ANFs commonly found in grain legumes include: tannins, phytic acid, oligosaccharides, protease inhibitors (trypsin and chymotrypsin inhibitors), amylase inhibitors and lectins (Liener, 1989). ODAP is also an ANF and is almost unique to the Lathyrusgenus. There are only a small number of published studies of levels and activities of ANFs, other than ODAP, in *L. sativus* (Latif *et al*., 1975; Deshpande and Campbell, 1992; Aletor *et al*., 1994; Urga *et al*., 1995; Srivastava and Khokhar, 1996; Wang *et al*., 1998) [43, 19, 6, 80, 71, 82].

Proteinaceous ANFs

The proteinaceous ANFs are (i) trypsin and chymotrypsin inhibitors (both protease inhibitors), respectively measured as trypsin inhibitor activity (TIA) and chymotrypsin inhibitor activity (CTIA), (ii) amylase inhibitors and (iii) lectins. ODAP will also be included under this heading, although ODAP is a non-protein amino acid and not strictly a proteinaceous ANF.

ODAP

Until recent times animal feeding studies with L. sativus have been performed with no knowledge of the role of ODAP in lathyrism. Therefore, in all older studies of animal feeding (i.e. pre 1960s) the concentration of ODAP is unknown. Recent studies have shown that ODAP concentrations can vary widely both within and between the these species, however, environmental conditions are not as important as genotype (Hanbury *et al*., 1999) [35]. Nonetheless, stresses such as salinity and drought (Hussain *et al*., 1997) [36] have been found to increase ODAP concentrations but are little understood. Concentrations of ODAP in the seed can be particularly high in *L. sativus*land races, up to 1.50% (Table 2).

Table 2: ODAP content (% as received) mean and range of a number of lines of *L. sativus* grown at various locations.

L. sativus		**Location**	**Source**
Mean (Range)	No.		
0.20 (0.16±0.25)	10	Spain	Franco Jubete (1991) [25].
0.49 (0.07±0.75)	70	Syria	Abd El-Moneim (1994) [2]
0.49 (0.33±0.59)	36	Syria	Aletor *et al*. (1994) [6]
0.39 (0.04±0.76)	407	Australia	Hanbury *et al*. (1999) [35]
0.88 (0.45±1.40)	172	Bangladesh	Kaul *et al*. (1982) [40]
0.72 (0.37±1.04)	10	Ethiopia	TekleHaimanot *et al*. (1993) [65]
0.44 (0.28±1.50)	1187	India	Pandey *et al*. (1995) [58]
0.32 (0.18±0.52)	76	Chile	Tay *et al*. (2000) [78]
NA (0.08±0.99)	73	China	Chen cited by Campbell (1997) [12]
0.46			Grand mean

Amylase inhibitor activity

Amylase is the enzyme primarily involved in starch digestion in mammals. Amylase inhibitors are thought to reduce amylase activity, but the extent to which they are important is debated (Deshpande and Damodaran, 1990) [20]. Deshpande and Campbell (1992) [20] found in 100 lines of *L. sativus* that the range of amylase inhibitor activity (AIA) was 3.6±91.4 units gÿ1 DM, substantially lower than the 330± 675 units gÿ1 DM found in P. vulgaris cultivars (Deshpande *et al*., 1982).

Tannins

Tannins are polyphenolic compounds of two classes: low molecular weight hydrolysable and higher molecular weight non-hydrolysable (or condensed). It is postulated that condensed tannins bind to proteins in the digestive tract and form complexes which are frequently indigestible (Marquardt, 1989) [50]. The hydrolysable tannins are often found to have little effect on digestibility. Tannins in faba beans and field peas are frequently localised in the seed coat (Marquardt, 1989; Gatel and Grosjean, 1990) [50, 26], with high tannin levels in darker seed coats than lighter ones. Similarly, Deshpande and Campbell (1992) [20] found that white or cream coloured seeds of *L. sativus* were associated with low tannin levels (both condensed and total), whereas seed with darker seed coats generally had high tannin levels. Similar observations regarding L. sativus were made by Urga *et al*. (1995) [80] and Wang *et al*. (1998) [82]. In *L. sativus* lighter seeds are associated with white flower colour (Jackson and Yunus, 1984) [39], consequently the selection of white flower colour could be used to reduce tannin contents. There is considerable scope for improvement of varieties with negligible condensed tannin levels. In the case of *L. sativus*, much suitable germplasm is already identified.

Protein content and quality

The mean protein content in L. cicera and L. sativus is 25 and 27%, respectively, from samples across a wide range of locations (Table 4). These are higher than protein contents in ®eld pea (23%) or faba bean (24%), but lower than in lupin (32%) (Petterson *et al*., 1997) [60] or soybean (42%; Ravindran and Blair, 1992) [55]. Chandna and Matta (1994) found the composition of seed protein in L. sativus to be: albumins (14%), globulins (66%), glutelins (15%) and prolamins (5%); similarly; Duke (1981) [21] also quotes values of 26, 53, 15 and 6%, respectively.

Table 3: Protein concentrations (as received) reported in *L. sativus* L.

Mean protein (%)	**No. lines**	**Location**	**Source**
24	114	Bangladesh	Kaul*et al*. (1982) [40]
28	76	Chile	Tay *et al*. (2000) [78]
29	41	-	Petterson *et al*. (1997) [60]
26	40	Australia	Laurence (1979) [45]
31	36	Syria	Aletor *et al*. (1994) [6]
25	25	Ethiopia	Urga *et al*. (1995) [80]
30	15	India	Ramanujam *et al*. (1980) [61]
25	12	Australia	Hanbury (unpublished)
25	10	Spain	Franco Jubete (1991) [25]
27	3	Canada	Rotter *et al*. (1991) [66].
29	3	India	Shobhana *et al*. (1976) [75]

Animal feeding studies

As for human food there are many historical references to the use of Lathyrus spp. as animal feed or fodder, principally *L. sativus, L. cicera, L. ochrus and L. clymenum.* Use of *L. sativus* is referred to by Columella in the first century A.D. (PenÄaChocarro and Zapata PenÄa, 1999) [59]. Because of concerns of human lathyrism there has been an emphasis in many countries to develop *L. sativus* cultivars with lower ODAP levels (Roy *et al*., 1993; Campbell *et al*., 1994) [77] with some success. Consequently, recent animal feeding studies have been able to both quantify the amount of ODAP in the diet and provide a low ODAP intake at higher inclusion rates of *L. sativus.* Due to the possible high variability in ODAP content in the lines used in older studies their results should be interpreted cautiously. Lathyrism can occur in both monogastrics and ruminants. Whether this can be avoided in low ODAP Lathyrus spp. lines and what constitutes a safe dose of ODAP in any species of animal is not certain. Observations on the effects on different animal species when fed on Lathyrus spp. of unknown ODAP content differ. There is some evidence that rumen micro-organisms may be able to degrade ODAP Horses are noted as being very susceptible to lathyrism with symptoms of paralysis of the hind limbs and sometimes dying, following heavy grazing or feeding on Lathyrus spp. seed (Stockman, 1932; Steyn, 1933; LoÂpezBellido, 1994) [73, 72, 48]. There is anecdotal evidence of pigs, sheep and cattle having died due to lathyrism after being turned into Lathyrus spp. ®elds (Stockman, 1932) [73]. He also claims that pigs may thrive on a pure diet of Lathyrus spp. seed, despite developing weakness in the hind legs. Monkeys can be affected similarly to humans by consumption of L. sativus and death sometimes results (Rao *et al*., 1967) [63]. It is reported that many species of birds are readily affected by lathyrism when consuming Lathyrus spp. seed (Stockman, 1932) [73], although Franco Jubete (1991) [25]. reported that in Spain doves fed avidly on L. cicera with no obvious ill-effects. Lewis *et al*. (1948) [46] fed *L. sativus* to young rats at 50% of food intake for 7±21 weeks and did not induce any lathyritic symptoms, growth rates were similar to those fed a diet based on field peas. Basu *et al*. (1937) [9] found no lathyrism symptoms in rats fed 15% L. sativus for 8 weeks, growth rates were lower than those fed field peas.

Although levels of ODAP were not reported in the above mentioned studies, evidence exists indicating that rumen microflora adapt to ODAP and break it down. Bacteria have been isolated from soil sludge which can use ODAP as their sole carbon and nitrogen source (Yadav *et al*., 1992) [83]. In sheep, tolerance to L. sylvestris in their diet seems due to changes in the rumen contents (Rasmussen *et al*., 1992) [67], presumably increasing breakdown of DABA, a neurotoxin chemically similar to ODAP (Fig. 3). Fermenting L. sativus seeds with Aspergillusoryzae and Rhizopusoligosporus for 48 h each has been shown to reduce ODAP concentration by >90% (Kuo *et al*., 1995) [42]. Farhangi (1996) [24] incubated *L. sativus* and *L. cicera* grain in sheep rumen fluid and reported a rapid disappearance of ODAP (>90% in 4 h), supporting the idea that certain rumen microorganisms can destroy the toxin. Using *L. sativus* lines of seed with a ODAP content of 0.08%, no symptoms of lathyrism were observed in donkeys, pigs or sheep when fed as 50±80% of daily intake for 180±250 days (Chen referred by Campbell, 1997); details are not available

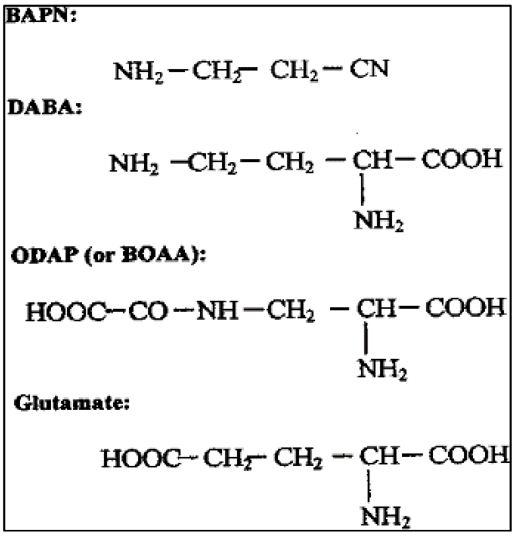

Fig 3: Chemical diagrams of b-aminopropionitrile (BAPN), L-2,4-diaminobutyric acid (DABA), 3-(-N-oxalyl)L-2,3-diamino propionic acid (ODAP or BOAA) and glutamate.

Low *et al*. (1990) found that inclusion of low ODAP *L. sativus* grain at 82% of the diet for up to 4 weeks (commenced at age 7 days) did not induce any symptoms of lathyrism in chickens. Control chickens fed a wheat/soybean based diet grew more rapidly. The ODAP concentration in the seed used was not measured, although the line was known to have low levels (mean 0.13%), low variation within a line is consistent in this L. sativus (30%; Hanbury *et al*., 1999) [31]. Rotter *et al*. (1991) [66] fed high (0.27%), medium (0.22%) and low (0.13%) ODAP lines of L. sativus to chickens at 20±80% of the diet. They found that an increased proportion of *L. sativus* seed in the diet of young chickens decreased weight gain, feed intake and efficiencies of feed conversion (feeding commenced at age 7 days). At 20 and 40% proportions there were minor or no differences to a wheat/soybean diet. However, using 0.27% ODAP seed generally resulted in decreased weight gain, feed intake and efficiencies of feed conversion, compared to lower ODAP seed. Since increasing the proportion of *L. sativus* above 40% (irrespective of ODAP concentration) also affected the chickens it can be concluded that there were ANFs in the seed (other than ODAP) which were not characterized.

Castell *et al*., 1994 [15] indicated that the pig feeding with ODAP concentration (0.09%) reduced growth rates using L. sativus. Poultry seem able to tolerate up to 40% of their diet of *L. sativus* of moderate ODAP concentrations (0.27%) with minor reductions in growth. Above 40% there appears to be significant effects of ANFs other than ODAP. (C.D. Hanbury *et al*., 2000) [33].

Both pigs and poultry showed depressed performance when high ODAP (0.27%) L. sativusline were fed. Whether this was due to ODAP or other ANFs in the Canadian varieties used is unclear. Further characterisation of the ANFs in both L. sativus and L. cicera is necessary to separate the effects of ODAP from those of other ANFs. Until this is performed higher ODAP lines (0.15% or higher) should be avoided.

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The serious consequences of lathyrism for animals means that caution must be exercised in feeding recommendations. There is sufficient evidence to justify the conclusion that safe feeding levels over extended periods are possible with the reduced ODAP levels of cultivars and germplasm now available. However, reduction in animal growth rates due to both ODAP and other ANFs have been recorded. Similarly to other commonly used grain legumes, the heating *L. sativus* will reduce the level and activities of the proteinaceous ANFs, which are particularly important for the monogastric species, also with possible reductions in ODAP content (Hanbury *et al*., 2000) [33]. Little improvement in ANFs (other than ODAP) has been attempted in breeding of *L. sativus*. The improvement of cultivars is possible in a short time frame, given the variation already recorded and available to breeding programs, particularly in *L. sativus*. Experience with other species of grain legumes indicates that variation in the known ANFs will be present in the germplasm. The germplasm for Lathyrus species is large, to date relatively unutilised and this *L. sativus*, are highly variable. Compositions of *L. sativus* are generally similar to field pea; apart from the presence of

ODAP, and their generally higher protein and ANF levels. Feeding data already shows that current cultivars can perform as well as industry standard ingredients. This indicates that rapid exploitation of these species in the feed industry is possible given experimentally established feeding recommendations. Since *L. sativus* are well adapted to large areas of southern Australia and other Mediterranean-type environments, the effectiveness of a rapidly developed market for grain would be one incentive for growers in these areas to adopt these crop options, particularly for those attempting to replace pasture legume rotations with low input grain legume crops.

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