# THE NUTRITIVE VALUE OF LUPINS IN SOLE CROPPING SYSTEMS AND MIXED INTERCROPPING WITH SPRING CEREALS FOR GRAIN PRODUCTION

Andreas Berk[1], Andreas Bramm[2], Herwart Böhm[3], Karen Aulrich[3] and Gerhard Rühl[2]

[1]Institute of Animal Nutrition, Friedrich Loeffler Institut (FLI)
[2]Institute for Crop and Soil Science, Julius Kuehn Institut (JKI)
[3]Institute of Organic Farming, Johann Heinrich von Thuenen Institut (vTI), Germany

Corresponding author's email: andreas.berk@fli.bund.de

## ABSTRACT

**In total 572 experimental plots were established at two sites during three years with different grain legume species, such as lupins, field beans and peas as well as mixed intercropping of different legumes or legumes with spring cereals for grain production. From all plots yield as well as quality and energy parameters of grains were analysed and the feed values calculated. Compared to soy bean meal yellow lupins have an adequate protein content but a low yield. While the energy content of lupins as feed for pigs, cattle and milking cows was only slightly higher than of soybean meal, its feed energy for poultry was nearly comparable. In the case of mixed intercropping with spring cereals the feed energy content for pigs and cattle by using spring wheat or barley as partner was higher than a comparable mixture of wheat and soy bean meal. The lowest feed energy contents were achieved with mixtures of legumes and oats. From the view of animal nutrition the proportion of lupins in the mixed intercropping grains should be higher in relation to spring cereals especially to increase the protein content.**

## KEYWORDS

*Lupinus angustifolius*, grain legumes, intercropping, feed value, protein content, feed energy

## INTRODUCTION

In Europe the protein supply for animal feeding largely depends on imported soy beans, which increasingly comprise genetically modified (GM) cultivars. This creates a problem particularly for organic farms and brand named meat producers, which are not allowed to utilise GM soybeans. The conflict can be solved by home-grown high-protein forages. Suitable legumes for grain production in central Europe are field beans (*Vicia faba*), peas (*Pisum sativum*) and lupins (*Lupinus angustifolius*, *L. albus* and *L. luteus*). Within these crop species lupins have the highest protein and the lowest starch content. The necessary starch proportion in feed mixtures is provided by mixing cereals to legumes. Beans, peas and lupins are adapted to the central European climate, have a high value in rotation systems and are suitable as protein feed for cattle, pigs and poultry. In complete feeds (compound feed) for animals it is usual to mix cereals, to enrich the feed with starch for feed energy, and legumes, firstly to enrich protein or amino acids. In this context the production system 'mixed intercropping' of legumes and spring cereals is of special significance, having advantages (Aufhammer, 1999). The production of different but qualitative complementary dry matters is important for aspects of the feeding values.

## MATERIALS AND METHODS

Field experiments were conducted at two institutions in Northern Germany, the Institute of Crop and Soil Science, located at Braunschweig and the Institute of Organic Farming, at Trenthorst near Hamburg. The grain legume species, lupins, field beans and peas were tested in sole cropping using recommended seed densities. Special attention was paid to mixed intercropping of lupins and spring cereals for grain production.

At Braunschweig generally 40 kg N $ha^{-1}$ and 4 l $ha^{-1}$ of the herbicide Stomp (equivalent to 1600 g a.i. $ha^{-1}$ of Pendimethalin) have been applied after sowing. The organic farming system was managed according to its special guidelines. The seeding ratio for mixed intercropping (blue lupins and spring cereals) was varied from 50:50 f that used for the pure stands to 63:37, 75:25 and 85:15. Branched (indeterminant) as well as single stem (determinant) cultivars of the blue lupin were used.

Crude nutrients (according to the official methods of the VDLUFA, Naumann and Bassler, 1997) were scanned and predicted by near infrared reflectance spectroscopy (NIRS). NIRS analysis on organically grown legumes was carried out on the ground samples using the Fourier-Transform NIR spectrometer (NIRLab N-200, Fa. Büchi, Essen) in the spectral range from 1000 to 2500 nm with a step of 1 nm. Each sample was scanned three times and the spectra were averaged. Spectral data were exported to the NIRCal software (Fa. Büchi, Essen). Calibration equations developed for each

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constituent separately by partial least square regression technique (PLS) were used for prediction of the crude nutrients (Aulrich & Böhm, 2008). The conventionally grown samples were analysed with the NIRSystems 6500 spectrophotometer (FOSS) in the spectral range from 400-2500 nm. The spectral data were treated by ISI software. The feed energy values were calculated according to the equations of the Society of Nutrition Physiology (GfE, 2001, 2006), in case of pigs and cattle or the WPSA (1984) in case of poultry (Table 1). In total 572 data sets from the field trials at the 2 sites were evaluated for 3 years (2005–2007). These represent 166 data sets from pure crops and 406 from mixed intercropping (Table 2).

The calculated feed energy contents are shown in Table 5. The starch content of blue lupins showed a higher variability. The lowest value was 81 g kg$^{-1}$ DM (cultivar 'Boltensia') and the highest 140 g kg$^{-1}$ DM (cultivar 'Sonet'). Compared to soybean meal, the main protein feed in the world, the energy values of lupins are clearly higher with the exception of AMEN (soy bean meal: ME(pigs) 14.80 MJ, AMEN11.70 MJ, ME(cattle) 13.70 MJ and NEL 8.60 MJ). Therefore, the energy value of lupins will not restrict its use in complete feeds.

Seed yield and protein content of white lupins are negatively correlated, those of yellow and blue lupins positively correlated (Table 6). In case of white and yellow lupins and partly in case of field beans and peas the correlation between yield and feed value data are moderate. The yield of blue lupins has a low or no correlation to the feed value data.

In the case of mixed intercropping of lupins and spring cereals the latter contribute more to the total yield (Table 7).

To rate the feed value for mixed intercropping it should be compared with a virtual mix of 80% winter wheat and 20% soy bean meal representing a common complete feed. Table 8 compares legumes and intercroppings in respect to protein and starch content and Table 9 in respect to energy contents.

The protein content of mixed intercropping grains with lupins is, irrespective of the cereal species, only marginally less compared to the reference wheat – soybean meal mix. Additionally the starch content of lupin/spring wheat or oats-mixtures is nearly the same as that of the chosen reference.

## RESULTS AND DISCUSSION

The yield of the pure crops is shown in Table 3. Field beans and peas have a higher yield compared to lupins. Protein content and starch content are shown in Table 4.

The protein content of the blue (*L. angustifolius*) and yellow lupins (*L. luteus*) corresponds to the DLG-feed table values (349 g kg$^{-1}$ respectively 439 g kg$^{-1}$ DM) whereas the protein content of white lupins (*L. albus*) is more than 40 g lower compared to the DLG-table (376 g kg$^{-1}$ DM). The highest protein content was determined in yellow lupins (up to 441 g kg$^{-1}$ DM, cultivar 'Bornal'). In the case of blue lupins the protein content ranged from 294 g kg$^{-1}$ (cultivar 'Boruta') up to 380 g kg$^{-1}$ DM (cultivar 'Borlana').

In the case of intercropping mixtures of lupins and spring wheat or spring barley the feed energy content is higher for pigs and cattle and lower for poultry and milking cows. Oats as intercrop partner decreases the energy content for all compared animals and categories. The high percentages of spring cereals in the mixed intercropping grains (81.4% up to 81.6%, Table 7) lead to a relatively low content of protein and feed energy for cattle. The correlation between protein content and the yield percentage of lupins is between 0.55 and 0.92 (Table 10). That is the reason why the increase of the lupin proportion in the mixed intercropping grains is desired.

**Table 1.** Equations for calculating feed energy values (MJ kg$^{-1}$ DM).

| Animal/-category | Energy | Formula |
|---|---|---|
| Pigs | ME | 0,0205*g DXP+0,0398*g DXL+0,0173*g S+0,0160*g Z +0,0147* g (DOS – DXP – DXL – S – Z) |
| Poultry | $AME_N$ | 0,01551*g XP+0,03431*g XL+0,01669*g XS+0,01301* g XZ |
| Cattle | ME | 0,0312*g DXL+0,0136*g DXF+0,0147*g (DOS-DXL-DXF)+0,00234*g XP |
| Dairy cows | NEL | 0,6*(1+0,004*[q-57])* ME (MJ) |

ME = metabolisable energy; AMEN = apparent ME, N = corrected; NEL = net energy lactation; D = digestible; X = crude; P = protein; L = lipid; F = fibre; OS = organic substance; q = ME/gross energy.

**Table 2.** Data evaluation.

| Pure crops | | Mixed intercropping | |
|---|---|---|---|
| Species | n | Partners | n |
| Field beans | 15 | Field beans / peas | 16 |
| Peas | 23 | F. beans or peas / lupins | 106 |
| White lupins | 17 | Field beans / oats | 12 |
| Yellow lupins | 7 | Peas / spring wheat | 4 |
| Blue lupins | 59 | Peas / spring barley | 28 |
| Spring wheat | 15 | Peas / oats | 4 |
| Spring barley | 15 | Lupins / spring wheat | 105 |
| Oats | 15 | Lupins / spring barley | 105 |
| | | Lupins / oats | 26 |

**Table 3.** Yield (t $ha^{-1}$ DM) with standard deviation of lupins, field beans and peas.

| | n | Mean | s |
|---|---|---|---|
| Blue lupins | 59 | 1.85 | 0.41 |
| White lupins | 17 | 2.39 | 0.75 |
| Yellow lupins | 7 | 1.29 | 0.22 |
| Field beans | 14 | 3.10 | 0.73 |
| Peas | 23 | 3.73 | 0.82 |

**Table 4.** Mean protein and starch content of lupins, field beans and peas (g $kg^{-1}$ DM).

| | n | Protein | Starch |
|---|---|---|---|
| Blue lupins | 59 | 347.6 ± 23.6 | 121.7 ± 87.5 |
| White lupins | 17 | 332.6 ± 41.1 | 83.7 ± 21.8 |
| Yellow lupins | 7 | 422.0 ± 11.1 | 35.3 ± 3.0 |
| Field beans | 14 | 302.4 ± 17.6 | 432.0 ± 21.7 |
| Peas | 23 | 222.8 ± 15.0 | 521.9 ± 15.2 |

**Table 5.** Mean feed energy contents of lupins, field beans and peas (MJ $kg^{-1}$ DM).

| | n | ME (pigs) | AMEN | ME (cattle) | NEL |
|---|---|---|---|---|---|
| Blue lupins | 59 | 16.46 ± 1.03 | 10.83 ± 0.86 | 14.44 ± 0.25 | 9.07 ± 0.15 |
| White lupins | 17 | 16.81 ± 1.27 | 12.39 ± 0.21 | 15.41 ± 0.07 | 9.11 ± 1.09 |
| Yellow lupins | 7 | 16.09 ± 1.33 | 11.15 ± 0.34 | 14.66 ± 0.13 | 9.18 ± 0.07 |
| Field beans | 14 | 15.22 ± 0.54 | 13.25 ± 0.50 | 13.76 ± 0.06 | 8.55 ± 0.61 |
| Peas | 23 | 16.50 ± 0.41 | 13.99 ± 0.14 | 13.56 ± 0.07 | 8.60 ± 0.04 |

**Table 6.** Correlation (R) between yield and feed value data.

| | n | Protein | Starch | ME (pigs) | $AME_N$ | ME (cattle) | NEL |
|---|---|---|---|---|---|---|---|
| Blue lupins | 59 | 0.19 | 0.09 | 0.03 | 0.27 | 0.12 | 0.13 |
| White lupins | 17 | -0.18 | 0.23 | -0.64 | 0.09 | 0.13 | 0.34 |
| Yellow lupins | 7 | 0.66 | 0.20 | 0.38 | 0.60 | 0.48 | 0.50 |
| Field beans | 15 | -0.48 | -0.20 | 0.10 | -0.32 | -0.02 | 0.25 |
| Peas | 23 | -0.13 | 0.30 | 0.41 | 0.03 | 0.17 | 0.10 |

**Table 7.** Yield (t $ha^{-1}$ DM) and yield percentage of different mixed cropping systems differentiated to the partners.

| Mixed cropping system partner 1 / partner 2 | n | Yield [t $ha^{-1}$ DM] | Yield percentage [%] |
|---|---|---|---|
| F. beans or peas / lupins | 106 | 1.793 / 0.681 | 69.8 / 30.2 |
| Peas / spring barley | 28 | 1.700 / 2.203 | 43.4 / 56.6 |
| Lupins / spring wheat | 105 | 0.600 / 2.704 | 18.5 / 81.5 |
| Lupins / spring barley | 105 | 0.558 / 2.606 | 18.4 / 81.6 |
| Lupins / oats | 26 | 0.585 / 2.769 | 18.6 / 81.4 |

**Table 8.** Mean protein and starch contents of mixed intercropping grains (g $kg^{-1}$ DM).

| | n | Protein | Starch |
|---|---|---|---|
| F. beans or peas / lupins | 106 | 277.0 ± 33.4 | 374.8 ± 71.7 |
| Peas / spring barley | 28 | 168.8 ± 18.8 | 574.0 ± 32.4 |
| Lupins / spring wheat | 105 | 172.1 ± 30.0 | 535.0 ± 52.8 |
| Lupins / spring barley | 105 | 152.6 ± 27.3 | 400.9 ± 40.8 |
| Lupins / oats | 26 | 164.6 ± 25.4 | 530.6 ± 69.7 |
| Wheat / soy bean meal | - | 213.0 | 555.0 |

**Table 9.** Mean feed energy contents of mixed intercropping grains (MJ $kg^{-1}$ DM).

| | n | ME (pigs) | $AME_N$ | ME (cattle) | NEL |
|---|---|---|---|---|---|
| F. beans or peas / lupins | 106 | 15.99 ± 0.87 | 12.83 ± 0.56 | 13.80 ± 0.21 | 8.89 ± 0.59 |
| Peas / spring barley | 28 | 15.62 ± 0.41 | 13.80 ± 0.33 | 13.32 ± 0.11 | 8.66 ± 0.27 |
| Lupins / spring wheat | 105 | 16.09 ± 0.50 | 13.81 ± 0.46 | 13.65 ± 0.14 | 7.73 ± 0.98 |
| Lupins / spring barley | 105 | 15.04 ± 0.44 | 13.16 ± 0.37 | 13.27 ± 0.19 | 7.90 ± 0.52 |
| Lupins / oats | 26 | 13.78 ± 0.46 | 11.61 ± 0.32 | 12.14 ± 0.28 | 7.43 ± 0.19 |
| Wheat / soy bean meal | - | 15.30 | 14.00 | 13.40 | 8.50 |

**Table 10.** Correlation (R) between part of yield of lupins and feed value data.

| | n | Protein | Starch | ME (pigs) | $AME_N$ | ME (cattle) | NEL |
|---|---|---|---|---|---|---|---|
| Lupins / spring wheat | 105 | 0.55 | -0.84 | -0.15 | -0.79 | -0.53 | 0.01 |
| Lupins / spring barley | 105 | 0.60 | -0.69 | -0.03 | -0.62 | -0.31 | 0.06 |
| Lupins / oats | 26 | 0.92 | -0.89 | 0.90 | -0.31 | -0.98 | 0.98 |

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