Chemical composition, true metabolisable energy content and amino acid availability of grain legumes for poultry

T.S. Brand[1, 2,3#], D.A. Brandt[1, 2,4] and C.W. Cruywagen[2]
[1]Elsenburg Agricultural Research Centre, Private Bag X1, Elsenburg 7607, South Africa
[2]Department of Animal Science, University of Stellenbosch, Stellenbosch 7600, South Africa
[3]Dept. of Anatomy and Physiology, Faculty of Veterinary Science, University of Pretoria, Pretoria 0002, South Africa
[4]AFGRI Feeds, P.O. Box 135, Isando 1600, South Africa

Abstract

Samples of sweet yellow lupins (*Lupinus luteus*; n = 4), broad leaf lupins (*Lupinus albus*; n = 12), narrow leaf lupins (*Lupinus angustifolius*; n = 8), faba beans (*Vicia faba*; n = 2), field peas (*Pisum sativum; n* = 4) and narbon beans (*Vicia narbonensis*; n = 2) were collected over a two-year period. The physical characteristics (thousand seed and hectolitre mass), chemical composition (dry matter, ash, crude protein (CP), ether extract, acid detergent fibre, neutral detergent fibre and mineral content), energy values (nitrogen corrected true metabolisable energy content (TMEn for roosters)) as well as the lysine and methionine availability (with roosters) of the samples were determined. *Lupinus albus* had the highest TMEn (12.49 MJ/kg), followed by field peas (11.35 MJ/kg) and narbon beans (11.25 MJ/kg), faba beans (10.90 MJ/kg), *L. angustifolius* (10.46 MJ/kg) and *L. luteus* (10.20 MJ/kg). *Lupinus luteus* had the highest CP concentration (393.6 g/kg) followed by *L. albus* (381.9 g/kg), *L. angustifolius* (338.9 g/kg), faba beans (260.0 g/kg), field peas (247.4 g/kg) and narbon beans (237.6 g/kg) (values on a dry matter basis). *Lupinus luteus* had the highest lysine concentration (22.2 g/kg), followed by *L. albus* (19.6 g/kg), field peas (19.3 g/kg), *L. angustifolius* (18.6 g/kg), narbon beans (17.5 g/kg) and faba beans (17.0 g/kg).

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[#]Corresponding author. E-mail: tersb@elsenburg.com

Introduction

The need for protein in human and animal diets is increasing all over the world. Protein, especially for use in animal feed, is becoming scarcer and more expensive. This is particularly relevant as far as traditional protein sources, such as fish meal and meat and bone meal are concerned. Throughout the world today there is also a growing resistance against the use of animal protein sources in animal feeding (Brand, 2002). It is desirable, therefore, that the nutritional potential of alternative plant protein feeds, such as grain legumes is fully exploited.

Grain legumes contain moderately high levels of protein and amino acids and are promising alternatives (Wiseman, 1987; Brand *et al.*, 1995). Grain legumes that are cultivated in the Mediterranean rainfall area of South Africa include lupins (*Lupinus* spp), faba beans (*Vicia faba*), field peas (*Pisum sativum*) and narbon beans (*Vicia narbonensis*). Among these lupins normally contain the highest concentration of protein (299–357 g/kg; May *et al.*, 1993), followed by faba beans (234–388 g/kg; Garrido *et al.*, 1991), peas (145–285 g/kg; Reichert & MacKenzie, 1982) and narbon beans (210–228 g/kg; Eason *et al.*, 1990). However, comparative studies on the composition and nutritive value of the different types of lupins (*L. luteus*, *L. albus* and *L. angustifolius*), faba beans and narbon beans for monogastric animals are limited.

This study was conducted to determine and compare the physical characteristics, chemical composition and energy values for poultry of these locally produced legume grains.

Materials and Methods

Samples of *L. luteus* (2 cultivars), *L. albus* (6 cultivars), *L. angustifolius* (4 cultivars), faba beans (1 cultivar), peas (1 cultivar) and narbon beans (1 cultivar) cultivated in the Western Cape area of South Africa were collected over a two-year period.

The hectolitre mass (HLM) of the samples was determined by using the upper level of a two level funnel (South African Wheat Board 1986), while the thousand seed mass (TSM) of the samples was determined with an automatic seed counter. Samples were analysed for dry matter (DM), ash, crude protein (CP), ether extract (EE) and minerals by standard AOAC methods (AOAC 1984). Acid detergent fibre (ADF) and neutral detergent fibre (NDF) fractions were determined according to procedures described by

Van Soest (1963) and Van Soest & Wine (1967). The non-structural carbohydrate (NSC) content of the samples was calculated according to Smith (1995) as: NSC = 100 – (NDF + CP + EE + Ash). Amino acid analysis, after acid hydrolysis in a sealed tube, was done on a Beckmann Model 6300 amino acid analyser. The nitrogen corrected true metabolisable energy (TMEn) content of the samples was determined with poultry as described by McNab & Blair (1988). Six replicates per sample were used in a metabolism trial with adult roosters. The amino acid availability (lysine and methionine) in the samples, corrected for endogenous amino acid losses was also determined *in vivo*. Samples collected during the different years from the different cultivars were pooled for each grain legume type for statistical comparison by analysis of variance (Snedecor & Cochran, 1980).

Results

The chemical composition, physical characteristics and mineral composition of the different grain legumes are presented in Table 1. No significant differences in CP concentration were observed between *L. luteus* and *L. albus*, while *L. angustifolius* had a lower ($P \leq 0.05$) CP level than the other lupin types. Faba beans, field peas and narbon beans did not differ in CP level, but values were lower ($P \leq 0.05$) than those of the lupin samples. The EE level of *L. albus* was 74% higher ($P \leq 0.05$) than that of *L. luteus* and 106% higher ($P \leq 0.05$) than *L. angustifolius*. Faba beans, narbon beans and field peas did not differ in EE content, but observed values were lower ($P \leq 0.05$) than those of lupins. Field peas had the lowest ADF concentration followed by faba beans with a 60% higher ($P \leq 0.05$) value. No significant differences were observed between narbon beans and faba beans and narbon beans and *L. albus*, while *L. albus* had a higher ($P \leq 0.05$) ADF content than faba beans. *Lupinus luteus* had a 17% higher ($P \leq 0.05$) ADF concentration than *L. albus*, while *L. angustifolius* had a 20% ($P \leq 0.05$) higher ADF content than *L. luteus*. Peas had a lower ($P \leq 0.05$) NDF value than the rest of the grain legumes. No significant differences in NDF were observed between faba beans, *L. albus* and narbon beans. *Lupinus luteus* and *L. angustifolius* did not differ significantly from each other, but had higher ($P \leq 0.05$) NDF values than the other legume grains. The NSC content was the highest in narbon beans, with the lowest value for faba beans.

The calcium concentration of the samples varied between 1.0 g/kg (faba beans) and 1.9 g/kg (*L. angustifolius*). Phosphorus concentration varied between 4.2 g/kg (*L. angustifolius*) and 7.6 g/kg (*L. luteus*). No extreme differences in trace mineral concentrations occurred except for the manganese concentration of *L. albus*, which contained approximately 10 times more manganese than the other legume grains.

Peas, faba beans and narbon beans had the highest HLM and did not differ from each other. *Lupinus luteus* had a lower ($P \leq 0.05$) HLM than faba beans and *L. angustifolius* than narbon beans, while no differences were found between *L. luteus* and *L angustifolius***.** *Lupinus albus* had a lower ($P \leq 0.05$) HLM than the rest of the grain legume species. Faba beans, *L. albus* and peas had the highest TSM and differed significantly ($P \leq 0.05$) from each other, while no difference occurred between field peas and narbon beans. *Lupinus angustifolius* and *L. luteus* did not differ from each other but had a lower ($P \leq 0.05$) TSM than narbon beans.

The dry matter digestibility, energy content as well as the lysine and methionine availability of the grain legumes are presented in Table 2. Peas had the highest dry matter digestibility (corrected for endogenous losses) (DMD), but did not differ from values obtained for narbon beans and faba beans. *Lupinus albus* had a lower ($P \leq 0.05$) DMD than narbon beans while no differences were observed between *L. albus* and faba beans. *Lupinus angustifolius* and *L. luteus* did not differ from each other but had a lower ($P \leq 0.05$) DMD than *L. albus*. *Lupinus albus* had the highest TMEn value, although not significantly higher than that of peas and narbon beans. No significant differences in TMEn were observed between peas, narbon beans, faba beans, *L. angustifolius* and *L. luteus*. However, Faba beans, *L. angustifolius* and *L. luteus* had a lower ($P \leq 0.05$) TMEn than *L. albus*.

Table 1 The physical characteristics, chemical composition and mineral concentration of the most important grain legumes cultivated in the Mediterranean rainfall area of South Africa

		Chemical composition*							Physical** characteristics		Mineral composition[1]						
Legume	n	DM (g/kg)	Ash (g/kg)	CP (g/kg)	EE (g/kg)	ADF (g/kg)	NDF (g/kg)	NSC (g/kg)	HLM (kg/hl)	TSM (g/1000 seeds)	Ca (g/kg)	P (g/kg)	Mg (g/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)
L. albus	12	943	35.9	381	93.2	170	1.73	316	73.5	341.7	1.6	4.5	1.6	5.00	33.9	405.0	33.7
L. angustifolius	8	942	33.0	338	45.2	241	2.37	346	77.5	127.6	1.9	4.2	1.8	3.41	34.6	26.9	50.0
L. luteus	4	930	45.2	393	53.5	200	2.28	280	78.2	115.9	1.7	7.6	2.6	5.01	55.3	59.1	53.7
Faba beans	2	922	27.9	260	13.8	132	1.61	542	81.3	442.2	1.0	4.6	1.1	4.26	20.2	15.3	90.3
Narbon beans	2	930	30.4	237	11.4	160	1.78	538	80.3	169.9	0.9	5.9	1.1	4.82	41.9	20.4	79.5
Field peas	4	913	30.1	247	12.3	829	1.08	45.4	81.8	207.2	0.7	5.1	1.3	4.80	39.0	26.3	67.2
LSD ($P \leq 0.05$)		1.33	0.28	4.29	3.14	3.04	4.92	1.01	2.88	42.3	0.02	0.08	0.03	3.54	13.34	345.8	33.5
s.e. (pooled)		0.64	0.14	2.08	1.52	1.48	2.38	0.49	1.40	20.0	0.01	0.04	0.01	1.18	6.48	167.9	16.3

* Dry matter basis,
** As received
CP – crude protein; EE – ether extract; ADF – acid detergent fibre; NDF – neutral detergent fibre; NSC – non-structural carbohydrates
HLM – hectolitre mass
TSM – thousand seed mass

Table 2 The amino acid concentration, amino acid availability and true metabolisable energy content of grain legumes cultivated in the Mediterranean rainfall area of South Africa (DM-basis)

Legume type	n	Amino acid concentration (/ kg DM)		Amino acid concentration (/ kg protein)		Amino acid availability		Energy metabolism data	
		Lysine (g/kg)	Methionine (g/kg)	Lysine (g/kg)	Methionine (g/kg)	Lysine (%)	Methionine (%)	DM digestibility (%)	TMEn (MJ/kg)
L. albus	12	19.6	1.7[b]	51.5[a]	4.5[ab]	83.3	76.2	57.9[b]	12.49[bd]
L. angustifolius	8	18.6	1.4[a]	54.7[ab]	4.1[a]	84.3	78.1	53.1[a]	10.46[a]
L. luteus	4	22.2	2.0[c]	56.0[ab]	5.1[bc]	83.4	80.1	50.6[a]	10.20[a]
Faba beans	2	17.0	1.4[a]	65.5[bc]	5.2[bc]	82.3	75.5	62.7[bc]	10.90[a]
Narbon beans	2	17.5	1.3[a]	73.9[c]	5.4[c]	89.8	84.5	65.0[c]	11.25[ab]
Field peas	4	19.3	1.8[bc]	78.5[c]	7.4[d]	86.0	76.5	66.6[c]	11.35[abc]
LSD ($P \leq 0.05$)		0.64	0.03	1.36	0.07	9.82	23.10	0.68	0.68
s.e. (pooled)		0.31	0.01	0.15	0.01	4.76	11.21	6.3	6.3

[a.b.c.d] Means with common superscripts within columns did not differ ($P > 0.05$)

TMEn – nitrogen corrected true metabolisable energy

No significant differences were observed in the lysine content of the different grain legumes. The lysine concentration of the different types of legumes varied between 22.2 g/kg for *L. luteus* to 17.0 g/kg for faba beans. However, lysine content of the sources, expressed as a percentage of protein, differed significantly ($P \leq 0.05$). Peas, for example, had a 52% higher value than *L. albus*. *Lupinus luteus* and peas were superior in methionine content and did not differ from each other. *Lupinus albus* had a lower ($P \leq 0.05$) methionine content than *L. luteus*. *Lupinus angustifolius*, faba beans and narbon beans did not differ from each other but had a lower ($P \leq 0.05$) methionine content than *L. albus*. Methionine content, expressed as percentage of protein was, for example, 80% higher in field peas than in *L. angustifolius*. No significant differences were observed in lysine or methionine availability coefficients of different grain legumes. The lysine availability coefficients varied from 82.3% for faba beans to 89.8% for narbon beans. Methionine availability coefficients varied from 75.4% for faba beans to 84.5% for narbon beans.

Discussion

King (1990) found CP levels for *L. albus* and *L. angustifolius* of respectively 387 g/kg DM and 322.5 g/kg DM. These values correspond well to values found in the present study. According to Gous (1998) the lysine availability of *L. albus* varied between 80.0 - 89.0%, while the methionine availability varied between 81.1 - 90.7%. The lysine availability values were similar to values found in the present study, while Gous (1998) reported higher methionine availabilities. The lysine and methionine availability for *L. angustifolius* (84.1 and 83.6%) cv Merrit and (82.8 and 77.3%) (Gous 1998) were in the same range as the present values. The TMEn values for *L. albus* cultivars, Esta, Kiev and Astra (15.18 MJ/kg, 14.82 MJ/kg and 12.82 MJ/kg, respectively) recorded by Gous (1998) were higher than the values obtained in the present study. Similarly, the TMEn values for *L. angustifolius* obtained in the present study were lower than literature values (Helderberg, 11.41 MJ/kg; Eureka, 10.66 MJ/kg; Merit, 11.31 MJ/kg) (Gous 1998). Bourdon *et al.* (1987) reported that the EE level in *L. albus* is 110.3 g/kg, which is higher than the values found in the present study. According to Brand (1996) the ADF and NDF values of South African lupins were 166 g/kg and 198 g/kg (*L. albus* cv Hamburg), and 234 g/kg and 268 g/kg (*L. luteus* cv Eureka), respectively. The ADF values obtained in the present study were similar to those values, but the NDF values were lower.

Reichert & MacKenzie (1982) found the CP level of field peas to vary between 145 g/kg and 289 g/kg. Gatel (1984) found the average CP and lysine concentrations of field peas to be 255 g/kg and 18.6 g/kg, respectively. These values were slightly lower than the values found in the present study. The methionine concentration of peas was 2.1 g/kg (Jacyno *et al*., 1992), which is slightly higher than the value found in this study. The average EE content of the pea cultivars studied was similar to the value (11 g EE/kg) presented by Gatel (1984). According to Bourdon *et al*. (1987) the ADF and NDF values of peas are 87.0 g/kg and 120.0 g/kg, respectively. The ADF value corresponds with the values in the present study, while their NDF value is higher. According to Savage & Deo (1989) the TMEn value of peas vary from 12.32 to 15.63 MJ/kg, which is higher than values obtained in the present study.

Faba beans normally contain between 280.0 g/kg (Jacyno *et al*., 1992) and 300.0 g/kg (Bourdon *et al*., 1987) protein, while the lysine and methionine concentrations are 19.0 g/kg and 2.4 g/kg (Bourdon *et al*., 1987). Bourdon *et al.* (1987) found the ME value for faba beans to be 12.75 MJ/kg. This value is considerably higher than the value found in the present study. The ADF and NDF values of faba beans collected in the present study were considerably higher than literature values (95.4 g/kg and 126.4 g/kg respectively; Bourdon *et al.,* 1987), which probably explains the lower observed TMEn value.

The CP content of narbon beans may vary between 260.0 g/kg and 320.0 g/kg (Abd El Moneim 1992). This value is higher than the value found in the present study. Eason *et al*. (1990) indicated that the methionine and lysine concentration of narbon beans were 2.1 g/kg and 15.6 g/kg, respectively. These values are higher for methionine and lower for lysine than values found in the present study. The apparent nitrogen corrected ME (AMEn) value for narbon beans was 11.93 MJ/kg, with ADF, NDF and EE values of respectively 129.0, 211.0 and 12.0 g/kg (Eason *et al*., 1990). Ether extract and ADF values are similar to values found in this study, while the NDF was found to be considerably lower in the present study.

The Ca, P and trace element concentrations for lupins, faba beans and peas recorded in the present study compared well with those reported by Thacker & Bowland (1985) and Wiseman (1987).

The superior TMEn value of *L. albus* is a result of the significantly higher EE content as well as the lower husk to kernel ratio. The husk of *L. albus* constitutes 180.0 g/kg of the seed, while the husk of *L. angustifolius* constitutes 260.0 g/kg of the seed. Most of the fibre is situated in the husk of the seed (Brand, 1996). The relatively high TMEn value found with field peas is probably a result of a low fibre content. The higher TMEn value found with narbon beans compared to faba beans may be related to the anti-nutritional factors present in faba beans (Jacyno *et al*., 1992). The low digestibility and TMEn of *L. albus* and *L. angustifolius* were partly a result of the high fraction of ADF, as well as the presence of the pentosans, arabinose and xylose in the fibre which is indigestible in poultry (Jacyno *et al*., 1992). According to Evans & Cheung (1993) the arabinose and xylose concentrations of *L. angustifolius* are 47.0 g/kg and 36.0 g/kg, respectively. The pentosan concentrations of soybean, peas and faba beans were 57.0, 48.0 and 32.0 g/kg, respectively. Regression analysis on the data gathered on the chemical composition of lupins revealed that the EE content accounted for 66% of the variation in TMEn, while ash and EE accounted for 74% of the variation in TMEn. Gross energy and CP accounted for 81% of the variation in TMEn.

Conclusion

It is evident from this study that large variations occurred in the composition and energy content of grain legumes. Values obtained in this study may be useful in future diet formulations. It is evident that most of the grain legumes contain high levels of fibre, which may limit high inclusion levels of these sources, especially in diets for broilers. Anti-nutritional factors may also be a detrimental factor in the utilization of legume grains (Van der Poel *et al*., 1993). These include alkaloids (Erikson, 1985), alpha-glycosides (Bourden *et al*., 1987) and high levels of manganese (Batterham, 1979) in lupins, trypsin inhibitors (Marquart *et al*., 1976), tannins (Jansman *et al*., 1993) and haemaglutonin (Marquart *et al*., 1976) in faba beans as well as high levels of non-starch polysaccharides (Jansman *et al*., 1993) in all grain legumes. Future studies may be necessary to collect more information on the presence of anti-nutrition factors in grain legumes as well as optimum inclusion levels in poultry diets.

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