Evaluation of faba beans (*Vicia faba* cv. Fiord) and sweet lupins (*Lupinus albus* cv. Kiev) as protein sources for growing pigs

T.S. Brand, R.C. Olckers and J.P. van der Merwe
Elsenburg Agricultural Development Institute, Private Bag XI, Elsenburg, 7607 Republic of South Africa

Recieved 10 March 1994; revised 14 November 1994; accepted 22 February 1995

Three diets were formulated to contain 16% crude protein (CP), 12.8 MJ/kg digestible energy (DE) and 0.9% lysine on an air-dry basis. The diets either contained 8.3% fishmeal, 20% faba beans plus 7.9% soybean oilcake meal (SBOK) or 20% low alkaloid lupins plus 8.8% SBOK as protein sources. The latter two diets were compared in a metabolism and nitrogen (N) balance trial using a completely randomized design and six pigs/treatment. All three diets were evaluated in a growth trial using 10 pigs (five boars and five gilts) over the growth interval 30–90 kg. The experimental design was a 3 (diets) × 2 (sex) factorial. Carcass characteristics were determined at the end of the growth trial. Pigs in the metabolism and N balance trial consumed 5% less ($P \leq 0.01$) of the lupin diet compared to the faba bean diet (1 370 vs. 1 440 g/d). No significant differences in the digestible energy (DE) content and in apparent N retention between the two diets occurred. In the growth trial lower intake levels ($P \leq 0.01$) were once again observed in pigs on the lupin diet (2 489 g/d) compared to the faba bean (2 637 g/d) and fishmeal diets (2 668 g/d). Pigs on the lupin diet grew ($P \leq 0.01$) slower than pigs on the other two diets (768 g/d vs. 857 g/d and 869 g/d for the faba bean and fishmeal diets respectively). The feed conversion ratio of pigs on the lupin diet (3.27 kg/kg gain) tended to be poorer than for those on the faba bean (3.03 kg/kg gain) and fishmeal diets (3.12 kg/kg gain). No significant differences were observed in dressing percentage (mean value of 78%), eye muscle area (mean value of 41.3 cm^2) or P_2-back-fat thickness (mean value of 16 mm) of pigs on the different diets. Both faba bean and low alkaloid lupins can be used at levels of up to 20% in diets of growing pigs, although lower production figures may be expected on lupin diets.

Drie garsgebaseerde diëte met 8.3% vismeel, 20% fababone plus 7.9% sojaboon-oliekoekmeel (SBOK) en 20% lae-alkaloïed-lupiene plus 8.8% SBOK as proteïenbronne is saamgestel om ongeveer 16% ruproteïene, 12.8 MJ-verteerbare energie en 0.9% lisien op 'n lugdroë basis te bevat. Die fababoon- en lupiendiëte is met mekaar vergelyk in 'n metabolisme en stikstof (N)-balansstudie met ses varke/dieet. Al die diëte (n = 10/dieet) is in 'n groeistudie met 10 varke (30–90 kg) vergelyk. Karkaseienskappe is aan die einde van die periode bepaal. Met die metabolismestudie het varke op die lupiendieet (1 370 g/d) laer ($P \leq 0.01$) innames gehad as varke op die fababoon dieet (1 440 g/d). In die groeistudie het varke op die lupiendieet (2 489 g/d) eweneens laer ($P \leq 0.01$) innames as op die fababoon (2 637 g/d) of vismeeldieet (2 668 g/d) gehad. Varke op die lupiendieet (768 g/d) het 11% ($P \leq 0.01$) stadiger gegroei as varke op die fababoon- en vismeeldiëte (857 g/d en 869 g/d respektiewelik). Die voeromsettingsdoeltreffendheid (nie betekenisvol) was onderskeidelik 3.27 kg/kg toename (lupiene), 3.03 kg/kg toename (fababone) en 3.12 kg/kg toename (vismeel). Geen betekenisvolle verskille in uitslagpersentasie (gemiddeld 78%), oogspieroppervlakte (gemiddeld 41.3 cm^2) of P_2-rugvetdikte (gemiddeld 16 mm) tussen diëte is waargeneem nie. Dit blyk dat sowel fababone as lae-alkaloïed-lupiene teen vlakke van tot 20% in diëte vir groeiende varke gebruik kan word, alhoewel 'n laer produksiepersentasie by varke op lupiengevoerde diëte verwag kan word.

Keywords: Faba bean, lupin, pigs, protein source.

Introduction

The demand for protein for human and animal nutrition is increasing and is likely to continue to do so. Protein is likely to become increasingly scarce and costly, particularly for animal nutrition (Protein Advisory Committee, 1990). It is desirable, therefore, that the nutritional potential of all protein feeds that can be grown in South Africa is fully exploited.

Sweet lupins (*Lupinus albus*) have been introduced as a legume ley crop in the Winter Rainfall Region of South Africa over the last few years, especially where cereal monoculture was practised. Faba beans (*Vicia faba*) have recently attracted attention as a promising grain legume suitable for cultivation in the region.

Although lupins and faba beans are relatively high in crude protein, 35.5% and 22.2% respectively (Brand *et al.*, 1992), problems could arise with the use of both sources in the diets of pigs as a consequence of the presence of antinutritional factors. Faba beans contain undesirable factors such as trypsin inhibitors (Marquart *et al.*, 1976), tannins (Jansman *et al.*, 1993b) and haemagglutonin (Marquart *et al.*, 1974). Lupins, on the other hand, may have undesirable levels of alkaloids (Erikson, 1988) and α-galactosides (Bourdon *et al.*, 1987a) or manganese (Batterham, 1979). Faba beans are low in sulphur amino acid methionine (Ortiz *et al.*, 1993), while lupins are deficient in lysine, sulphur amino acids and tryptophan (Bourdon *et al.*, 1987a). Another factor that may affect the utilization of the two protein sources is high levels of non-starch polysaccharides (Jansman *et al.*, 1993a).

Published results also differ on the utilization of lupins and faba beans by pigs. Kemm *et al.* (1987) found a decrease in the performance of early weaned piglets with an increase in the inclusion of commercially produced lupins (cv. Buttercup) in their diets (0%, 4%, 8% and 12%). In a second experiment they used certified alkaloid-free seed and found no differences between diets containing 0% or 8% lupin seed. There have also been reports of reduced growth rates of pigs given only 5% lupin seed (Hill, 1986), while Donovan *et al.* (1993) found a reduction in feed intake and performance at levels of 20% and 32% lupins in diets of starter pigs. According to Todorov (1988), lupins can be included at a level of 10% in the diet of growing-finishing pigs. Concerning the utilization of faba beans, Castell (1976) recommended that a level of 15% faba beans should not be

exceeded in diets of growing-finishing pigs. Aherne *et al.* (1977) found a gradual reduction in the growth rate of growing-finishing pigs as the level of faba beans in diets increased from 0% to 30%. The decrease in performance was particularly evident at levels of inclusion higher than 20% of the diet.

This experiment was therefore conducted to evaluate the effect of the replacement of fishmeal in diets of growing pigs by the locally available broad-leaf lupin cv. Kiev and the faba bean cv. Fiord.

Experimental procedures

Three experimental diets containing either 8.25% fishmeal, 20% faba beans plus 7.90% soybean oilcake or 20% sweet lupins plus 8.80% soybean oilcake as protein sources were formulated to be equal in crude protein (CP), digestible energy (DE) and the essential amino acids. The diets and their nutrient composition are presented in Table 1.

In a digestion trial the two diets with either 20% faba beans or 20% lupins were compared to each other in a metabolism trial. Twelve Large White X SA Landrace boars with a mean live mass of 40 kg were used as experimental animals. Pigs were subjected to a 10-day adaption period followed by a seven-day collection period, during which time faeces and urine were collected, while pigs were housed in metabolism crates. Pigs had free access to water at all times. A daily amount of 1 500 g air-dry meal was fed to each pig in two equal portions at 08:00 and 13:00. Procedures followed in the collection and analysis of faeces samples are described in detail by Kemm & Ras (1971).

Table 1 Composition of the experimental diets (as-fed basis)

Composition	Experimental diets		
	Diet 1 Faba bean	Diet 2 Lupins	Diet 3 Fishmeal
Ingredient (% as-fed basis)			
Barley	55.0	55.0	56.0
Faba bean	20.0	–	–
Sweet lupins	–	20.0	–
Fishmeal	–	–	8.25
Soyabean oilcake	7.9	8.8	–
Maizemeal	13.31	10.0	13.9
Wheaten bran	–	1.15	18.1
Synthetic lysine	0.14	0.12	0.18
Feed lime	0.50	1.35	1.19
Monocalcium phosphate	–	2.38	1.13
Dicalcium phosphate	1.95	–	–
Fine salt	1.00	1.00	1.00
Minerals & vitamins	0.20	0.20	0.20
Determined analysis (DM basis)			
Dry matter, %	88.5	89.4	89.2
Ash, %	5.8	7.1	6.6
Crude protein, %	18.0	19.5	17.1
Fat, %	3.3	4.9	4.3
Crude fibre, %	6.0	7.4	5.5
Calcium, %	0.8	0.9	0.8
Phosphorus, %	0.6	0.8	0.7

Representative samples from the respective diets were chemically analysed for dry matter (DM), nitrogen (N), ether extract (EE), crude fibre (CF), calcium (Ca) and phosphorus (P) by standard AOAC methods (AOAC, 1984). Gross energy determinations of the diets and faeces were carried out on a CP 400 adiabatic bomb calorimeter. The alkaloid content of faba bean and lupin seed was determined by the method described by Ruiz (1977). Tannin concentration in the seed was determined by the modified Jerumanis procedure (Daiber, 1975). The amino acid composition of the seed, after acid hydrolysis in a sealed tube, was analysed using a Beckmann Model 6300 amino acid analyser.

A growth trial was carried out with 30 Large White X Landrace pigs (15 gilts and 15 boars), approximately 80 days of age, with a mean (± S.e) live mass of 26.7 ± 0.4 kg. They were individually housed in flat-deck type cages (1.6 m × 1 m), fitted with a self-feeder and equipped with an automatic water nipple. The room temperature was not controlled and fluctuated between 20 °C and 30 °C. The pigs were randomly allocated to the three experimental treatments. The experimental diets, containing either faba beans, sweet lupins or fishmeal (Table 1) were fed *ad libitum* to 10 pigs per diet (five of each sex). The trial ended when the pigs were slaughtered at a mean live mass of 86.7 ± 0.3 kg. Feed intake and live mass were measured every four days. The allometric autoregressive model for the description of growth as proposed by Roux (1976), and described by Siebrits (1986), was used to calculate mean live mass gains for the growth interval 30–90 kg live mass.

After the pigs were slaughtered, carcasses were stored in a refrigerator for 24 h at 4 °C. Dressing percentages, eye muscle area and P_2-fat measurements were subsequently determined as described by Olckers (1991).

Differences between treatment means during the metabolism trial were analysed by one-way analysis of variance procedures. Growth trial data were analysed according to a 2 (sex) × 3 (diets) factorial design. Carcass data were analysed with end mass as covariant. All statistical procedures used are described by Snedecor & Cochran, 1980.

Results and discussion

The chemical composition of the experimental diets is summarized in Table 1. The diet containing lupin seed as protein source had a slightly higher CP and CF content than the other two diets, while the diet with faba beans had a slightly lower EE content than the other two diets.

The chemical and amino acid compositions of the faba bean and lupin seed used in the study are presented in Table 2. The CP content of sweet lupin seed was 60% higher than faba bean seed, with corresponding higher amino acid concentrations. The CF content of sweet lupin seed was slightly higher that the CF content of faba bean seed. Lupins also had a higher ether extract value than faba beans. Faba beans did not contain any alkaloids, while the lupin seed used in this study (cv. Kiev) had an alkaloid content of 0.01%. Faba beans (cv. Fiord) on the other hand had a tannin content of 0.48%, while the sweet lupin seed had a tannin content of 0.09%. The CP content of faba beans and sweet lupins

Table 2 Chemical composition of the protein sources tested (DM basis)

Composition	Protein source	
	Faba beans cv. Fiord	Sweet lupins cv. Kiev
Dry matter	90.4	92.7
Ash	2.7	3.1
Crude protein	23.3	37.5
Ether extract	2.3	9.8
Crude fibre	13.9	15.3
Tannins	0.48	0.09
Alkaloids	0	0.01
Essential amino acids plus cystine:		
Arginine	2.09	4.35
Cystine	0.41	0.86
Histidine	0.58	0.83
Isoleucine	0.80	1.24
Leucine	1.66	2.50
Lysine	0.98	1.40
Methionine	0.19	0.28
Phenylalanine	0.94	1.33
Threonine	0.83	1.31
Valine	0.85	1.15
Calcium	0.20	0.50
Phosphorus	0.23	0.36

used in this study was a bit lower than values reported in the literature (30.3% and 41.0% on a DM basis; Bourdon *et al.*, 1987b).

The metabolism data for the two diets with either faba beans or lupins as protein source are presented in Table 3. Pigs on the faba bean diet ingested 5.2% more ($P \leq 0.01$) DM than pigs on the lupin diet, while no differences in DM digestibility were found between the two diets. The digestible energy (DE) content of the diet containing lupins was 3.2% (not significant, NS) higher than the diet with faba beans, despite its containing 23% more CF (Table 1). The high digestibility of the lupin diet was in accordance with results reported by Taverner (1975), who also found lupins to be highly digestible. He ascribed the high digestibility to the very low amounts of lignin in the fibre fractions of lupin seed.

The faba bean diet had a 6.6% ($P \leq 0.05$) lower apparent N digestibility than the lupin diet, which was also explained by the 24% higher N excretion in the faeces as found in the N retention study. No significant differences in apparent N retention between the two diets occurred, although the N retention, as percentage of N intake, was 12.6% (NS) lower than the faba bean diet compared to the lupin diet. The lower protein digestibility and apparent N retention found with the faba bean diet may probably be related to the tannin content of faba beans as illustrated in Table

Table 3 Energy and nitrogen metabolism data of pigs (n = 6) fed either diets with faba beans and soybean oilcake or sweet lupins and soybean oilcake as protein sources

Measurement	Experimental diets	
	Diet 1 Faba beans	Diet 2 Sweet lupins
Energy metabolism data:		
DM intake, g/day	1 441 ± 9	1 370 ± 18*
DM digestibility, %	74.5 ± 2.1	74.3 ± 1.2
DE, MJ/kg DM	12.4 ± 0.4	12.8 ± 0.2
ME, MJ/kg DM$^+$	12.1 ± 0.4	12.4 ± 0.2
Nitrogen metabolism data:		
Nitrogen content, g/kg DM	18.0	19.5
Apparent N digestibility, %	72.3 ± 2.3	78.4 ± 1.5*
Nitrogen intake, g/d	41.5 ± 0.2	42.8 ± 0.6
Nitrogen excretion		
1. Faeces, g/d	11.5 ± 1.0	9.3 ± 0.7
2. Urine, g/d	13.5 ± 0.8	14.1 ± 0.6
3. Total, g/d	25.0 ± 1.3	23.4 ± 1.2
Apparent N retention, g/d	16.4 ± 1.1	19.4 ± 0.9
N retention as percentage of N intake, %	39.7 ± 2.9	45.3 ± 2.4

* Values differ significantly ($P \leq 0.05$)
$^+$ Gaseous loss not taken into account

2. Tannin-protein complexes are believed to be responsible for low protein digestibility and the inhibition of important digestive enzymes (Deshpande *et al.*, 1986).

The statistical parameters calculated from the growth data by the autoregression model are presented in Table 4. The growth, feed utilization and DM intake data calculated from this model are summarized in Table 5. Pigs on the lupin diet consumed approximately 6% ($P \leq 0.05$) less food than pigs on both the faba bean and fishmeal diets, while the average daily gain (ADG) of pigs on this diet was also about 11% ($P \leq 0.05$) lower than on the other two diets. The feed conversion ratio (FCR) of pigs on the lupin diet tended to be 5% lower than on the other two diets, although differences were not significant (NS). Practically no differences were observed between the diets containing faba beans or fishmeal as protein sources.

The poorer performance of pigs on the lupin diet could not be ascribed to alkaloids, since the cultivar Kiev contained only 0.01% alkaloids, which was lower than 0.03%, the point at which feed rejection was found to occur (Pearson & Carr, 1977). The possible detrimental effect of α-galactoside sugars in lupin seeds, which are not affected by digestive enzymes but are believed to cause increased flatulence and a decreased feed transit time (Costaing *et al.*, 1982), is unknown. The effect of high levels of manganese, which is believed to depress growth rate and haemoglobin synthesis (Batterhom 1979), is also unknown. Detrimental effects due to unbalanced amino acids seem to be unlikely, since the diets were formulated to contain adequate concentrations of the essential amino acids. The most probable explanation for the

Table 4 Statistical parameters used in calculating the data presented in Table 5

	Statistical parameters				
Treatment	$\bar{\rho}$ In/4 days	$\bar{a}$ In (MJ)	$\bar{\mu}$ In (MJ)	$\bar{a}$ DE* × mass	$\bar{b}$ DE × mass
Diets					
Faba beans	0.944	8.761	6.521[a]	−0.891	0.675
Lupins	0.946	8.730	6.341[b]	−0.991	0.682
Fishmeal	0.946	8.808	6.561[a]	−1.055	0.694
Sex					
Boars	0.945	8.778	6.489	−1.077[a]	0.699
Gilts	0.946	8.754	6.458	−0.880[b]	0.668

$\bar{\rho}$ Slope of autoregression
$\bar{a}$ Asymptote of cumulative DE intake
$\bar{\mu}$ Mean initial ln (cumulative DE intake) value
$\bar{a}$ Mean intercept of ln (live mass) – ln (cumulative DE) regressions
$\bar{b}$ Mean slope of ln (live mass) – ln (cumulative DE) regressions
* Digestible energy (MJ/kg DM)
[a, b] Denote significant ($P \leq 0.01$) differences in columns

lower utilization may be the higher fibre content of the lupin diet (Kemm *et al.*, 1987) and the resultant lower utilization of energy owing to the higher proportion of energy digested in the hind gut (Just, 1981). Lupins were found to have a much lower starch content (0.3–0.5%) compared to faba beans (30–40%) (Cerning-Beroad & Fillatre, 1976) which will affect the amount of energy digested in the hind gut. The production data on the diet containing lupins in our study were lower than results obtained by Kemm (E.H. Kemm & M.N. Ras, 1988, unpublished data) with pigs on diets containing 10% lupins (cv. Buttercup; alkaloid free) in their diets over the same growth interval.

There was no detrimental effect on production for pigs on the diet containing faba beans compared to those on the fishmeal diet. The higher tannin content of faba beans seemed to have no detrimental effect on production at this inclusion level. Wiseman (1987) recommended limited amounts of inclusion of grain sorghum in diets of poultry only when tannin concentrations exceeded 0.3%. These results were similar to those reported by Mateos & Puchal (1981) and Ahern *et al.* (1977) who also found no or little reduction in the performance of pigs on diets with up to 20% faba beans as protein source. The positive results in our study may be ascribed to the fact that faba beans did not supply all the supplementary protein in the diets. Several authors, as quoted by Thacker & Bowland (1985), found a reduction in pig performance with faba beans as sole source of supplementary protein.

Table 5 Means (± SE) for performance data of pigs calculated for the growth interval 30–90 kg live mass on the experimental diets

	Measurement		
Treatment	DM intake (g DM/day)	Live mass gain (g/day)	Feed utilization* (kg/kg gain)
Diets			
Faba beans	2 637[a] ± 46 (99)	857[a] ± 26 (99)	3.08 ± 0.07 (99)
Sweet lupins	2 489[b] ± 46 (93)	768[b] ± 26 (88)	3.27 ± 0.07 (105)
Fishmeal	2 668[a] ± 46 (100)	869[a] ± 26 (100)	3.12 ± 0.07 (100)
Sex			
Boars	2 622 ± 38	881[1] ± 21	2.99[1] ± 0.006
Gilts	2 574 ± 38	781[2] ± 21	3.32[2] ± 0.06

[a, b] Values with different subscripts differ significantly ($P \leq 0.05$)
[1, 2] Values with different subscripts differ significantly ($P \leq 0.01$)
* On an as-fed basis

The carcass characteristics of the pigs for the different treatments are presented in Table 6. No significant differences in either dressing percentage, eye muscle area or P_2-back-fat thickness occurred between pigs on the different diets. Back-fat thickness varied between 14.5 mm and 17.1 mm, eye muscle area varied between 39.9 cm^2 and 43.3 cm^2 while the mean dressing percentage was 78.1%. Kemm (E.H. Kemm & M.N. Ras, 1988, unpublished data) similarly found that the inclusion of lupins of up to 10% did not affect back-fat thickness of pigs. Pearson & Carr (1976) found lower dressing percentages with pigs on lupin diets compared to diets containing either fishmeal or meat bonemeal. They attributed this difference to the higher fibre content of the lupin diet. Other researchers like Barnett & Batterham (1981) and Donovan *et al.* (1993), however, found no effect of lupin inclusion on dressing percentage. Mateos & Puchal (1981) similarly also found no effect of faba bean inclusion of up to 20% on the carcass yield of pigs.

No significant differences occurred in DM intake between sexes (Table 5) while boars grew 13% faster ($P \leq 0.01$) and had a 11% ($P \leq 0.01$) better FCR than gilts. Gilts, on the other hand, had a 2% ($P \leq 0.01$) higher dressing percentage, while back-fat thickness was increased by 20% ($P \leq 0.01$). Eye muscle area was independent of sex.

Conclusions

This study indicated that both the faba bean cultivar Fiord and the low alkaoid lupin cultivar Kiev can be used at levels of up to 20% in the diets of growing-finishing pigs, although a lower intake, slower growth rate and poorer FCR may be expected on lupin diets. This lower performance is possibly related to the higher fibre content of lupins. The use of both protein sources

Table 6 Mean (± SE) for carcass characteristics of pigs fed diets with different protein sources

	Measurement		
Treatment	Dressing = percentage (%)	Eye muscle area (cm^2)	P_2 = fat measurement (mm)
Diet			
Faba beans	78.1 ± 0.4	39.9 ± 1.4	16.5 ± 1.1
Sweet lupin	78.3 ± 0.5	40.6 ± 1.6	14.5 ± 1.3
Fishmeal	77.8 ± 0.4	43.3 ± 1.4	17.1 ± 1.1
Sex			
Boars	77.3[1] ± 0.3	42.1 ± 1.1	14.6[a] ± 0.8
Gilts	78.8[2] ± 0.3	40.4 ± 1.1	17.5[b] ± 0.8

[a, b] Values with different superscripts differ significantly ($P \leq 0.05$)
[1, 2] Values with different superscripts differ significantly ($P \leq 0.01$)

will be dependent on their availability and price. An advantage of both protein sources is that they can be used directly on the farm after they have been ground, without further processing. It may be good practice not to supply all supplementary protein in a balanced diet from these sources (Thacker & Bowland, 1985), but to combine it with other protein sources.

References

AOAC, 1984. Official methods of analysis (13th ed.). Association of Official Analytical Chemists, Washington DC.

AHERNE, F.X., LEWIS, A.J. & HARDING, R.T., 1977. An evaluation of faba beans (*Vicia faba*) as a protein supplement for swine. *Can. J. Anim. Sci.* 57, 321.

BARNETT, C.W. & BATTERHAM, E.S., 1981. *Lupinus angustifolius* cultivar Unicrop as a protein and energy source for weaner pigs. *Anim. Feed. Sci. Technol.* 6, 27.

BATTERHAM, E.S., 1979. *Lupinus albus* cv. Ultra and *Lupinus angustifolius* cv. Unicrop as protein concentrates for growing pigs. *Aust. J. Agric. Res.* 30, 639.

BOURDON, D., FEVRIER, C., LECLERCQ, B., LESSIRE, M. & PEREZ, J.M., 1987a. Comments on raw materials. In: Feeding of non-ruminant livestock. Ed. Wiseman, J. Butterworths, London. p. 123.

BOURDON, D., FEVRIER, C., PEREZ, J.M., LEBAS, F., LECLERCQ, B., LESSIRE, M. & SAUVEUR, B., 1987b. Comments on raw materials. In: Feeding of non-ruminant livestock. Ed. Wiseman, J. Butterworths, London. p. 123.

BRAND, T.S., FRANCK, F., BRAND, A.A., DURAND, A. & COETZEE, J., 1992. An evaluation of faba bean (*Vicia faba*) and Lupin (*Lupinus albus*) stubble and seed for sheep. *S. Afr. J. Anim. Sci.* 22, 170.

CASTAING, J., CONDURE, R., FEKETE, J., GROSJEAN, F. & LENILLET, M., 1982. Utilization de la Graine de Lupin Daux Klaina Chex le Porcelet Sevre le Porc en croissanceffinition. *J. Rec. Procine en France* 14, 307.

CASTELL, A.G., 1976. Comparison of faba beans (*Vicia faba*) with soybean meal or field peas (*Pisum sativum*) as protein supplements in barley diets for growing-finishing pigs. *Can. J. Anim. Sci.* 56, 425.

CERNING-BEROAD, J. & FILIATRE, A., 1976. A comparison of the carbohydrate composition of legume seed: horse-beans, peas and lupins. *Cereal Chemistry* 53, 968.

DAIBER, K.H., 1975. Enzyme inhibition by polyphenols of sorghum grain and malt. *J. Sci. Food Agric.* 26, 1399.

DESHPANDE, S.S., CHERYAN, M. & SALUNKHE, D.K., 1986. Tannin analysis of food products. *CRC Critical Reviews Food Sci. Nutr.* 24(4), 401.

DONOVAN, B.C., McNIVEN, M.A., VAN LUBEN, T.A., ANDERSON, D.M. & MacLEOD, J.A., 1993. Replacement of soyabean meal with dehydrated lupin seeds in pig diets. *Anim. Feed Sci. Technol.* 43, 77.

ERICKSON, J.P., 1985. Lupins show potential as protein source for livestock. *Feedstuffs* 57, 22.

HILL, G.D., 1986. Recent developments in the use of lupins in animal and human nutrition. Proc. 4th Int. Lupin Conf., 15–22 August 1986. Geraldon, W. Austr. Dept. Agric., Perth. W.A., p. 40.

JANSMAN, A.J.M., VERSTEGEN, M.W.A. & HUISMAN, J., 1993a. Effects of dietary inclusion of hulls of faba beans (*Vicia faba* L) with low and high content of tannins on digestion and some physiological parameters in piglets. *Anim. Feed. Sci. Technol.* 43, 239.

JANSMAN, A.J.M., HUISMAN, J. & VAN DER POEL, A.F.B., 1993b. Ileal and faecal digestibility in piglets of faba beans (*Vicia faba* L) varying in tannin content. *Anim. Feed Sci. Tecnol.* 42, 83.

JUST, A., 1981. Energy evaluation of feedstuffs and diets for growing pigs. *Pig News and Information* 2, 401.

KEMM, E.H. & RAS, M.N., 1971. The use of dried molasses in porker rations. *S. Afr. J. Anim. Sci.* 1, 9.

KEMM, E.J., MINAAR, J.P., RAS, M.N. & DAVIE, S.J., 1987. Lupin seed meal (*Lupinus albus* cv Buttercup) as a source of protein for early weaned piglets. *S. Afr. J. Anim. Sci.* 17, 37.

MARQUART, R.R., CAMPBELL, L.D., STOTHERS, S.C. & McKIRDY, J.A., 1974. Growth responses of chicks and rats fed diets containing four cultivars of raw or autoclaved faba beans. *Can. J. Anim. Sci.* 54, 117.

MARQUART, R.R, CAMPBELL, L.D. & WARD, T., 1976. Studies with chicks on the growth depressing factor(s) in faba beans (*Vica faba* L. var. minor). *J. Nutr.* 106, 275.

MATEOS, G.G. & PUCHAL, F., 1981. Nutritional value of broad beans (*Vicia faba* L. major) for swine. *Nutr. Rep. Int.* 23, 347.

OLCKERS, R.C., 1991. Evaluering van gars as voedingsbron in varkdiëte in die Winterreenstreek. M.Sc.(Agric)-tesis. Universiteit van Stellenbosch, Stellenbosch 7600, Suid-Afrika.

ORTIZ, L.T., CENTENO, C. & TREVINO, J., 1993. Tannins in faba bean seeds: effects on the digestion of protein and amino acids in growing chicks. *Anim. Feed Sci. Technol.* 41, 271.

PEARSON, G. & CARR, J.P. 1976. Lupin-seedmeal (*Lupinus angustifolius* cv. Uniwhite) as a protein supplement to barley-based diets for growing pigs. *Anim. Feed Sci. Technol.* 1, 631.

PEARSON, G. & CARR, J.R., 1977. A comparison between meals prepared from the seeds of different varieties of lupin as protein supplements to barley-based diets for growing pigs. *Anim. Feed Sci. Technol.* 2, 49.

PROTEIN ADVISORY COMMITTEE, 1990. Memorandum on protein supply and demand for animal production. Compiled by J.G. Cloete, Animal and Dairy Science Research Institute, Private Bag X2, Irene 1675, South Africa.

ROUX, C.Z., 1976. A model for the description and regulation of growth and production. *Agroanimalia* 8, 83.

RUIZ, L.P., 1977. A rapid screening test for lupin alkaloids. *N.Z. J. Agric. Res.* 20, 51.

SIEBRITS, F.K., 1986. Application of the allometric autoregressive growth description in studies of growth and body composition. *Pig News Inf.* 7, 413.

SNEDECOR, G.W. & COCHRAN, W.G., 1980. Statistical methods (7th ed.). The Iowa State University Press. Ames, Iowa, USA.

TAVERNER, M.R., 1975. Sweet lupin seed meal as a protein source for growing pigs. *Anim. Prod.* 20, 413.

THACKER, P.A. & BOWLAND, J.P., 1985. Faba beans: an alternative protein supplement for use in pig diets. *Pig News Inf.* 6, 25.

TODOROV, M.A., 1988. Feeds and feedstuffs in Europe. 2.3 Cereals, pulses and oilseeds. *Livest. Prod Sci.* 19, 47.