THE NUTRITIVE VALUE OF FABA BEANS FOR YOUNG GROWING PIGS

by

Johnstone MacDonald Maltman

A thesis submitted to the
Faculty of Graduate Studies and Research in
partial fulfilment of the requirements for the degree of
Master of Science

Department of Animal Science
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ABSTRACT

Performance data, amino acid availabilites, nitrogen retention and digestible energy values were studied with all or some of, faba beans, autoclaved faba beans, dehulled faba beans and faba bean protein concentrate (F.P.C.). Soybean meal served as the control source of supplemental protein.

Performance data were collected from pigs initially weighing approximately 16.5 kg. consuming diets containing as much as 49.4% faba beans or its by-products over 21 and 22 day trials. The F.P.C. was included at a 7% level in diets for pigs initially weighing 7.5 kg..

It was found that pigs (20 kg.) fed pelleted diets containing faba beans or its by-products produced rates of gain which were not significantly different from those values recorded for pigs consuming the soybean meal diet, provided the methionine/cystine levels of the diet were adjusted by addition of DL - methionine to meet the pigs' requirements.

Feed efficiencies for pigs fed the faba bean, autoclaved faba bean and dehulled faba bean diets supplemented with DL - methionine were 6.3, 1.8, and 13.4% better respectively than for pigs fed the soybean meal diet. There was no significant difference in the rate of gain between pigs fed diets containing F.P.C. or soybean meal but the pigs consuming the F.P.C. diet were more efficient by approximately 10%.

Almost all apparent amino acid availabilities for F.P.C. were significantly higher than those for soybean meal, ranging between 88.8% to 96.8% for F.P.C., and between 83.6% to 94.9% for soybean meal. There were no significant differences between treatments for methionine and proline availabilities, but cystine in F.P.C. was

significantly less available.

In a separate test, apparent amino acid availabilities for dehulled faba beans were significantly greater than for soybean meal, except for methionine, cystine and proline where there were no significant differences among treatments. Individual availabilities ranged between 83.3% to 98.0% for dehulled faba beans, and between 86.0% to 96.5% for soybean meal. Compared to soybean meal, autoclaved faba beans and faba beans had significantly lower amino acid availabilities. In the case of the latter two ingredients, for essential amino acids, isoleucine, leucine and phenylalanine availabilities were significantly higher in autoclaved faba beans compared to faba beans. However cystine availability was significantly greater in faba beans.

Nitrogen retention as a percent of intake was not significantly different between the F.P.C. and soybean meal diets with values of 64.0% and 67.1% respectively. Tested separately, nitrogen retention as a percent of intake was greater ($P < .05$) for soybean meal (67.1%), followed by similar values for autoclaved and dehulled faba beans (58.2% and 58.5% respectively). The lowest value ($P < .05$) for all treatments was recorded by faba beans (54.5%).

Digestible energy values for faba beans and dehulled faba beans were 3802 and 4162 Kcal/kg. dry matter respectively using pigs with initial average test weights of 23.5 kg..

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INTRODUCTION

In the last few years large price fluctuations in the traditional protein feed supplements, soybean oil meal and fish meal, prompted producers and researchers to look at alternate protein supplements as replacements in diets for livestock.

One crop that has shown particular promise, with a long history of cultivation in Europe, is faba beans (Vicia faba L.). Seed was imported to Canada and research scientists began to investigate the value of faba beans for livestock production and crop purposes under Canadian conditions.

In 1972 experiments at the University of Manitoba were initiated with growing-finishing pigs as a follow-up to two years of crop testing. Pigs from 35 kg to market weight were the primary test animal since it is at this stage of development that the majority of feed is consumed. Therefore, the greater part of the feed cost is attached to this phase of swine production.

By replacing the soybean meal portion of the diet with faba beans, an alternative is presented which should reduce the cost of swine production. Faba beans can be grown under the climatic conditions of western Canada, whereas soybeans are restricted to small areas of eastern Canada, and for the most are imported for processing from the United States. When satisfactory, faba beans may be used without any further processing other than grinding. This could be accomplished on most farms, meaning that faba beans could be grown, processed, and fed on the farm producing them.

In the time period previous to 1970, little work was carried out in North America on faba beans. Most experimental testing was done in European centres and Great Britain. The literature generally concurred, that levels between 20% and 30% faba beans could be included in diets for finishing swine without adversly affecting performance. Data were limited and controversial as to why the faba beans should depress performance when 30% in the diet was exceeded with younger growing pigs.

It was the aim of this study to further our knowledge of faba beans, with specific reference to young growing pigs (7.5-27.0 kg.) Testing included diets where faba beans or some of its byproducts replaced soybean meal as the supplemental protein. These ingredients were, faba beans, dehulled faba beans, autoclaved faba beans and a new product, faba bean protein concentrate (F.P.C.). The pigs under test ranged from the prestarter/starter stage (7.5 kg.) to growing pigs (27.0 kg.).

Growth data were accumulated on the above faba bean products with and without methionine supplementation using feed consumption, rate of gain, and feed efficiency as parameters.

Amino acid availabilities were determined for young growing pigs, of faba beans, autoclaved faba beans, and dehulled faba beans as well as F.P.C.

A final experiment was designed to study the digestible energy content of faba beans and dehulled faba beans.

REVIEW OF LITERATURE

Up to the present time, faba beans have not been used extensively as a swine feed. It has been cultivated in Europe for many centuries and, until the recent use of the various oilseed crops, it represented the most important source of vegetable protein for human food as well as a minor animal feed (Eden 1968). Today more emphasis is being placed on its potential as feed for livestock.

It is possible to grow faba beans where barley or rapeseed has been grown successfully. Fertilization of faba beans with a small amount, 10-30 kg.N./ha. (9-26 lb.N./acre), is advised as a primer for the nitrogen fixing bacteria in the root nodules of the plant (Canada Grains Council Publication 1972). Since faba beans are a relatively new crop to North America, testing and breeding of varieties for disease resistance and early maturity is still proceeding. However, it appears that maturation occurs between 101 - 113 days on stubble fields, and is delayed to as many as 120 days on fallowed fields (Proc. First National Faba Bean Conference 1974). Being a legume, this plant has the ability to return to the soil from 100 - 170 lb. nitrogen per acre. It could become a valuable addition to a crop rotation cycle. Yields vary greatly in response to weather conditions and fertilization, and can reach in excess of 1350 kg./acre.

The main interest in faba beans is generated by its high level of lysine, approximately 1.35%, in association with its crude protein level of 25-30%, which makes it a valuable protein source for livestock production.

The proximate analyses and amino acid profiles of European and North American grown faba bean crops are reported in tables 1A, 1B and 1C. The two sulphur amino acids generally occur at levels of 0.19% methionine and 0.28% cystine for a total of 0.47% (1.93 gm / 16 gm N.) sulphur amino acids in the whole bean as compared to soybean meal (44%) containing approximately 0.65% methionine, and 0.60% cystine for a total of 1.25% (2.68 gm /16 gm N.) sulphur amino acids (Canada Grains Council Publication 1973). Variations in methionine and cystine do occur between varieties in response to environmental conditions, examples of which are cited by Hansen and Clausen (1969). These authors averaged six varieties grown in different locations finding 0.21% methionine and 0.33% cystine. Pastuszewska et al (1974) formulated diets with the "Pavane" variety of faba beans which contained 0.39% cystine and 0.23% methionine.

Eggum (1969) reported low levels of calcium and pantothenic acid in relation to soybean meal. Calcium was analyzed at a level of 1 gm/kg and pantothenic acid at 4.7 gm/kg. To put these values into perspective, tables 1D and II report analyses of faba beans in comparison to soybeans. The vitamin and mineral deficiencies are of a relatively minor nature and can easily be remedied by addition of a suitable vitamin/mineral premix.

Early studies with faba beans (Vicia faba L.) for pigs gave varied results, recommending levels between 10% and 25% of the diet be composed of faba beans (Sheehy 1955, Halnan and Garner 1953, Tinley 1950). Following this preliminary work it was reported that methionine was low in faba beans (Morrison 1957). Subsequently investigations began to determine the value of supplementation with methionine of faba bean diets.

Pioneering these studies were Aherne and McAleese (1964). They fed pigs over the weight range of 20 - 60 kg, with rate of gain and feed conversion as parameters of performance. Test rations were formulated to meet the methionine requirements of the pigs, with no regard for the cystine content of the feed ingredients. It is likely that an imbalance of sulphur amino acids was created because of this oversight and may explain why the pigs consuming methionine supplemented diets had poorer performance data than the control animals. Consequently, a recommendation was made that methionine was not a necessary supplement for pigs over the range of 20 - 60 kg , consuming diets with levels of faba beans not exceeding 30%. They also reported that an optimum response was found when faba beans did not exceed 20% of the diet.

Contrary to the results by Aherne and McAleese (1964), Balboa et al (1966) noted that addition of methionine to diets containing 30% faba beans improved growth of pigs, compared to animals receiving similar diets without supplemental methionine, over the weight range of 25 - 60 kg. Three diets were fed which provided energy and protein in a more suitable ratio than the diets formulated by Aherne and McAleese (1964), allowing a more valid comparison of the test diets to a control diet. These workers concluded that for growing pigs, supplementation of diets containing 30% faba beans with methionine improved the rate of gain to where it was equal to that for pigs consuming diets based on soybean meal.

Additional work recommending inclusion of synthetic methionine in diets containing faba beans, can be found in work by Henry and Rérat (1969) and Henry (1970).

The first study done by Henry and Rérat (1969) was conducted on pigs between 20 and 60 kg and compared three varieties of faba beans against a control soybean meal diet. Faba beans replaced

Table 1A Proximate Analysis of Faba Beans[1] and its by-products in comparison with Soybean Meal (44%)

	Faba Beans	Dehulled Faba Beans	F.P.C.	Soybean Meal[2]
Protein (N x 6.25)	23.9	28.8	65.0	44.0
Dry Matter (%)	88.6	90.2	96.7	89.6
Fat (%)	1.2	1.0	2.4	0.9
Fibre (%)	7.4	1.7	2.0	6.0
Energy (Kcal./kg.)	3988	4016	-	4120

1. Dept. of Animal Science, University of Manitoba 1975, Diana variety.

2. Canadian Grains for Pigs 1973 Canada Grains Council Publication.

Table 1B Proximate Analysis of North America and European Varieties of Faba Beans.

Reference	Huber 1972[1]	M.D.A. 1973[2]	Pastuszewska et al 1974[3]
Protein (%)	27.0	26.5	30.1
Dry Matter (%)	86.0	85.4	87.0
Fat (%)	1.3	0.9	0.6
Fibre (%)	7.0	9.2	7.5

1. European analysis of German faba beans.

2. Average nutrient content of Manitoba grown faba beans 1973.

3. Pavane variety of faba beans from France.

Table 1C Amino acid composition of Faba Beans compared to Soybean Meal (44%)

Amino Acid Source	Faba beans			S.B.M.
Reference	Clarke 1970	Pastuszewska et al 1974	This Study	This Study
Essential[1]				
ARG	10.30	9.75	7.96	6.81
HIS	2.55	2.60	2.36	2.48
ILE	4.35	4.20	4.44	4.52
LEU	7.87	7.45	7.40	7.62
LYS	6.59	6.05	5.75	5.86
MET	0.73	1.70	0.82	1.38
PHE	4.63	41.0	4.40	4.95
THR	4.02	3.55	3.30	3.67
VAL	4.92	4.65	4.46	4.86
Non-Essential				
ALA	4.20	4.10	4.07	4.24
ASP	11.88	11.20	10.46	11.24
CYS	0.84	1.30	1.11	1.30
GLU	19.68	16.55	16.74	17.14
GLY	5.57	4.35	4.61	4.10
PRO	-	4.55	4.10	5.00
SER	5.48	4.90	4.63	4.71
TYR	3.86	3.25	2.85	2.67

1. Values are reported in gm /16 gm N.

Table 1D Vitamin content of Faba Beans and Soybean Meal (mg /kg D.M.)

Vitamin[1]	Faba Beans	Soybean Meal
Thiamine	7.2	0.5 - 7.3
Riboflavin	4.5	4.2
Niacin	28.6	23.5
Pantothenic Acid	4.7	15.3
Pyridoxine	6.2	7.6
Biotin	0.24	-
Vitamin E (α tocopherols)	16.5	3.5
Other tocopherols (acetates)	(71)	-

1.Cited by Hansen and Clausen 1969.

Table II Mineral Composition of Faba Beans

Reference	Eden 1968[1]	Becker-Nehring[1]	Manitoba Crop 1973[2]	
Mineral			Whole	Dehulled
Calcium gm /kg D.M.	1.9	1.6	0.83	0.35
Phosphorus gm /kg D.M.	6.8	6.6	5.7	6.5
Sodium gm /kg D.M.	0.2	0.1	trace	trace
Chloride gm /kg D.M.	traces	traces	-	-
Potassium gm /kg D.M.	12.2	11.7	11.3	11.8
Magnesium gm /kg D.M.	1.3	1.3	1.3	1.1
Selenium gm /kg D.M.	1.0	0.1	-	-
Manganese mg /kg D.M.	14	9.4	13.0	12.0
Iron mg /kg D.M.	64	21 - 140	58.7	63.3
Copper mg /kg D.M.	-	4.6	12.0	12.2
Zinc mg /kg D.M.	54	47	46	49
Cobalt mg /kg D.M.	0.01	0.03	-	-
Molybdenum mg /kg D.M.	-	-	7.2	8.0

1. Cited by Henry 1970.

2. Dept. of Animal Science, University of Manitoba 1976.

soybean meal as the supplemental protein source in barley based diets. These diets were accepted by the pigs and there was no difference in feed consumption between the control and faba bean diets. Rate of gain was less for the pigs consuming the faba bean diets as compared to the soybean meal control diet, 439 gm./day and 477 gm./day respectively, and feed efficiency was also poorer, 3.55 against 3.29 respectively. The faba bean diets were supplemented with 0.2% DL - methionine though no mention is made of the final sulphur amino acid levels. No significant difference could be found in carcass evaluation between the two groups of pigs.

A second experiment by Henry et al (1970) was designed to determine whether supplementation of the sulphur amino acids to a level of 0.55% with synthetic DL - methionine gave a significant response in growth. They reported that, on barley based diets, methionine should be added to give optimum response with pigs between 27 and 60 kg.

The University of Manitoba (1974) also experimented with pigs between the weights of 22 and 90 kg. Diets were fed, in most cases, in a mash form and were unsupplemented with methionine. Some results showed that pigs which ingested diets containing the total supplemental protein as faba beans, consumed 20% less feed and had 20% lower gains. Pelleting the diets overcame the feed intake problem, with rates of gain and feed efficiencies improved, although not to the level of the soybean meal control diet. These results compare with Henry and Rérat (1969) showing faba beans depress performance when added in place of soybean meal. The University of Manitoba diets using faba beans, were unsupplemented and produced a 20% lower gain, while Henry and Rérat (1969) supplied 0.2% methionine to the faba bean diets and had only 8.7% depression in daily gains, compared to the control diet.

In working with methionine supplementation and heat treatment, the University of Manitoba (1974) was able to show some positive response with pigs 13.5 kg. to 27 kg., although the data were limited. The trend to improved performance concurs with work by Balboa et al (1966), Henry and Rérat (1969), and Bello et al (1972). Trials utilizing pigs from 35 kg. to 90 kg., where faba beans totally replaced soybean meal, gave rates of gain and feed efficiencies similar but slightly lower than the soybean meal control diet. With this weight category no difficulties in feed consumption or acceptance of the feed by the pigs, were encountered

When weanling rats were fed semi-purified diets containing faba beans as compared to casein, the fecal nitrogen values were significantly higher for faba beans. This was reported by Bello et al (1972). The diets containing faba beans were then supplemented with a mixture of essential amino acids to match those found in casein. An increase in the nutritive value of the faba beans was recorded, however it still remained below the value of casein. Heat treatment for five minutes at 120°C. improved nitrogen retention and growth by about 20%. Longer heating did not give comparable results, causing the value of faba beans to remain below that of casein.

LeDividiche (1973) working with growing rats, reached similar conclusions as the previous studies, with respect to methionine supplementation and heat treatment. Semi-purified diets with the test material as the only source of protein, were fed utilizing growth rate, protein efficiency ratio, nitrogen digestibility and nitrogen retention as criteria for estimating the value of the protein source. In the case of diets containing 49.5% faba beans, only methionine supplementation significantly improved the performance of the rats.

Heating for 15 minutes at 120°C. improved the parameters but not significantly over the uncooked faba bean diet or to the level of the soybean meal diet. If faba beans increase above 49.5% of the diet, this conclusion may not hold. Recently extensive data with poultry, primarily using broiler chicks, have been published by Marquardt et al (1973, 1974, 1976), with emphasis on the methionine requirement of birds consuming diets containing faba beans. They established that heat treatment of faba beans in diets containing less than 57% faba bean gave no significant growth response. But when levels of 85% and greater were included in poultry diets, then autoclaving gave a reduction in pancreas size of 25%, improved feed to gain ratio by 12%, and growth response by 7.3%. Wilson and McNab (1972) showed that a beneficial effect was gained by autoclaving faba beans when diets fed to broiler chicks contained more than 75% faba beans.

The nutritional value of many legume seeds is improved by heat treatment (Liener 1962) due to the destruction of toxic, heat labile factors, and this is most pronounced with beans. The level of toxic compounds present in the bean can vary widely between cultivars (DeMuelenaere 1964). Wilson and McNab (1972) and, Marquardt et al (1975) compared the levels of trypsin and chymotrypsin inhibitors of faba beans and soybeans to find the former protein source had 12 to 20% the level of both inhibitors found in the latter source.

In an attempt to examine the distribution of the inhibitory factors of faba beans, the hulls were separated from the testa. It was demonstrated that autoclaving dehulled beans, when composing 90% of the diet, resulted in significant improvement in feed to gain ratios and reduced pancreas size, whereas no response was observed with diets containing either raw, or autoclaved hulls (Marquardt and Campbell 1973). It was suggested, from this work that these anti-nutritive or inhibitory substances were largely located in the dehulled portion of the bean.

Replacement of whole beans by dehulled beans in diets for pigs, leads to improved digestibility of the nutrients (Henry and Bourdon 1973, Pastuszewska et al 1974). The increase in energy and nitrogen digestion coefficients can be attributed to a reduction in the fibre level of the diet as the hulls represent 13% of the whole seed by weight, yet contain 45% of the total fibre (Henry and Bourdon 1973). Although energy and protein digestibility are improved with dehulling, nitrogen retention was decreased when pigs were fed semi-purified diets (Pastuszewska et al 1974). Where dehulled beans made up 25% of the diet, there were no significant differences in performance of 34.9 kg pigs consuming a barley/soybean meal diet or a barley/soybean meal/dehulled faba bean diet (Henry and Bourdon 1973). A trend was evident for a slight drop in feed intake with the inclusion of dehulled faba beans in diets for poultry and swine (Marquardt and Campbell 1973, Pastuszewska et al 1974).

So far as it is known the faba bean protein concentrate (F.P.C.) tested in this study has not previously been examined as a possible protein supplement for pigs. Marquardt et al (1976) completed a study with the starch and protein fractions of faba beans by having various combinations of raw and autoclaved, starch and protein feed. Although not conclusive they suggested that the inhibitory substances probably followed the protein fraction. Before this, F.P.C. was used in bread studies, (McConnell et al 1974) and as an extender in beef

Table III Comparison of Energy and Nitrogen Digestibility of Faba Beans and Soybean Meal (44%) by Various Authors

	A	B			C		
Feedstuff	Faba Beans	Faba Beans	Dehulled Faba Beans	S.B.M.	Faba Beans	Dehulled Faba Beans	S.B.M.
% Digestible Energy	85.7	87	94	91	86.8	92.8	90.4
Kcal/kg D.M.	3845	3900	4100	4200	3700	4040	4000
% Digestible Nitrogen	-	80-85	89	89	83.2	90.5	88.6

A Nehring and Werner 1957

B Henry and Bourdon 1973

C Pastuszewska et al 1974

patties. These products did not achieve a large public acceptance.

Nehring and Werner (1957) estimated that faba beans in the whole form had 3,845 Kcal./kg. D.M. of digestible energy for the pig, and a digestibility coefficient for energy of 85.7%. Other authors added additional information as to the energy utilization of faba beans. These data are presented in Table III. Removing the hull from the bean improves energy digestibility by about 7%. Nitrogen digestibility increases 4 to 9% which makes it approximately equal to values obtained for soybean meal (44%) (Henry and Bourdon 1973).

MATERIALS AND METHODS

Growth trials were carried out to determine the value of feeding faba beans of the Diana variety and some of its by-products, with or without methionine supplementation for young growing pigs. Subsequent to this, amino acid availability and digestible energy studies were conducted with growing pigs. The pigs used were Managra, or, Managra crossbred with Lacombe and/or Yorkshire. Feed and water were provided ad libitum. Feed pelleted in a commercial California pellet mill (0.5 cm), was used in the growth trials, and feed pelleted in a portable Superior - Templewood pellet machine (0.25 cm) was used in the availability trials. A mash feed was used in the digestible energy trial. In both the availability and digestibility trials, the pigs were hand fed with some restriction of feed intake.

Further details of the individual studies are provided as follows:

Study A: Three diets were fed: Diet A represented a standard barley/ soybean meal diet, Diet B was composed of barley and faba beans and Diet C was made up of barley and dehulled faba beans. Table IV shows the composition and analysis of the diets. Initially the pigs weighed 15.6 kg for Treatment A, 15.8 kg for Treatment B, and 15.9 kg for Treatment C. Each of three pens held nine pigs and represented one treatment. Of the nine pigs there were six barrows and three gilts, and were on test for 21 days. The pigs were weighed individually and feed consumption recorded weekly.

Study B: This experiment was divided into two parts. Part I closely paralleled Study A, with the only change being the addition of another diet containing autoclaved faba beans. This addition was made to evaluate pig performance on faba beans with inactivation of the heat labile

Table IV Composition and Analysis of Diets for Study A

Diet	A	B	C
Ingredients	Control	Faba Beans	Dehulled Faba Beans
Faba Beans	-	48.35	43.35
Soybean Meal (44%)	25.25	-	-
Barley	72.75	49.40	54.40
Dicalcium Phosphate	0.50	0.75	0.75
Limestone	1.25	1.25	1.25
Salt/T.M.[1]	0.25	0.25	0.25
Vitamins[2]	+	+	+
Total	100.00	100.00	100.00
Chemical Analysis:			
Crude Protein (%)	19.80	18.00	18.50
Nitrogen (%)	3.17	2.88	2.97
Lysine (%)	0.85	0.83	0.89
Methionine (%)	0.29	0.19	0.19
Cystine (%)	0.32	0.23	0.24

[1] Supplied (per kg diet): sodium chloride 2.42 gm.; zinc 10 mg.; iron 15 mg.; manganese 3 mg.; copper 0.83 mg.; iodine 0.17 mg.; cobalt 0.10 mg.

[2] Supplied (per kg diet): vit. A 2200 iu; vit. D 330 iu; vit. B_{12} 11.0 ug; DL -tocopherol acetate 11 mg.; thiamine HCL 11 mg.; riboflavin 2.2 mg.; calcium - D - pantothenate 100 mg.; pyridoxine HCL 11.0 mg.; nicotinic acid 10.0 mg.; zinc 120 mg.; Mecadox 1.0 gm.

inhibitors. Part II saw the addition of methionine to the faba bean diets in order to evaluate the response of the pigs to methionine supplementation. For the autoclaving process, faba beans were subjected to a temperature of 121° C for 30 minutes. Composition and analysis of the diets are shown in Table V. Methionine was added in Part II, (DL - methionine hydroxy analogue) to meet the N.R.C. (1973) recommended total sulphur amino acid requirement. Diet A was a standard barley/soybean meal diet, Diet B contained faba beans, Diet C contained dehulled faba beans, and Diet D contained autoclaved faba beans. Initially the pigs weighed 16.7 kg for Treatment A. 16.5 kg for Treatment B, 16.7 kg for Treatment C and 16.8 kg for Treatment D. Each of four pens contained seven pigs consisting of four barrows and three gilts. Feed consumption and weight gain were recorded after 7 and 11 days in each part of the trial. The trial was of 22 days duration, each part 11 days.

Study C: This experiment tested a new product, faba bean protein concentrate (F.P.C.) as a complete replacement for soybean meal in diets for young weanling pigs. Two diets were tested, one representing a normal prestarter/starter ration consisting of wheat and soybean meal (Diet A), and the second diet had F. P. C. replacing the soybean meal, (Diet B). The composition and analysis of the rations are given in Table VI. Pigs were arranged in two pens of 12 pigs each with seven barrows and five gilts per group. Initial weight of pigs for Treatment A was 7.8 kg , and for Treatment B, 7.8 kg. The treatment period covered 21 days.

Study D: This study was a repeat of Study C. Diets were as described in Study C. with composition and analysis displayed in Table VII. This study used 16 pigs, eight barrows and eight gilts, per treatment for a 21 day test. Initially pigs weighed 7.5 kg for both treatments.

Study E: Following the growth trials a test was done to determine

Table V Composition and Analysis of Diets for Study B

Diet	A	B	C	D
Ingredients	Control	Faba Beans	Dehulled Faba Beans	Autoclaved Faba Beans
Faba Beans	-	49.40	43.35	49.40
Soybean Meal (44%)	25.25	-	-	-
Barley	72.75	48.35	54.40	48.35
Dicalcium Phosphate	0.50	0.75	0.75	0.75
Limestone	1.25	1.25	1.25	1.25
Salt/T.M.[1]	0.25	0.25	0.25	0.25
Vitamins[2]	+	+	+	+
Total	100.00	100.00	100.00	100.00
Chemical Analysis:				
Crude Protein (%)	18.90	17.30	18.26	17.52
Nitrogen (%)	3.02	2.77	2.92	2.80
Lysine (%)	0.88	0.84	0.89	0.80
Methionine (%)	0.27(0.28)[3]	0.19(0.40)	0.19(0.39)	0.18(0.32)
Cystine (%)	0.28(0.29)	0.22(0.23)	0.23(0.26)	0.22(0.23)

[1] Supplied (per kg diet): sodium chloride 2.42 gm.; zinc 10 mg.; iron 15 mg.; manganese 3 mg.; copper 0.83 mg.; iodine 0.17 mg.; cobalt 0.10 mg.

[2] Supplied (per kg diet): vit. A 2200 iu; vit. D 330 iu; vit. B12 11.0 ug; DL-tocopherol acetate 11 mg.; thiamine HCL 11 mg.; riboflavin 2.2 mg.; calcium - D - pantothenate 100 mg.; pyridoxine HCL 11.0 mg.; nicotinic acid 10.0 mg.; zinc 120 mg.; Mecadox 1.0 gm.

[3] Values in parentheses indicate amino acid levels in Part II of the test.

Table VI Study C Faba Bean Protein Concentrate compared to Soybean Meal in diets for Young Pigs.

Diet Ingredients	A Control	B F.P.C.
Wheat	75.23	80.10
Sugar	5.00	5.00
Soybean Meal (44%)	14.00	-
F.P.C.	-	9.00
Fishmeal	4.00	4.00
Dicalcium Phosphate	0.62	0.55
Limestone	0.90	1.03
Salt/T.M.[1]	0.25	0.25
Vitamins[2]	+	+
Methionine	-	0.07
Total	100.00	100.00
Chemical Analysis:		
Crude Protein (%)	21.27	19.71
Nitrogen (%)	3.40	3.15
Lysine (%)	0.91	0.77
Methionine (%)	0.30	0.26
Cystine (%)	0.30	0.30

1 Supplied (per kg diet): sodium chloride 2.42 gm.; zinc 10 mg.; iron 15 mg.; manganese 3 mg.; copper 0.83 mg.; iodine 0.17 mg.; cobalt 0.10 mg.

2 Supplied (per kg diet): vit. A 2200 iu; vit. D 330 iu; vit. B_{12} 11.0 ug; DL-tocopherol acetate 11 mg.; thiamine HCL 11 mg.; riboflavin 2.2 mg.; calcium - D - pantothenate 100 mg.; pyridoxine HCL 11.0 mg.; nicotinic acid 10.0 mg.; zinc 120 mg.; Mecadox 1.0 gm.

Table VII Study D Faba Bean Protein Concentrate compared to Soybean Meal in diets for Young Pigs.

Diet Ingredients	A Control	B F.P.C.
Wheat	74.64	80.49
Sugar	5.00	5.00
Soybean Meal (44%)	13.00	-
F.P.C.	-	7.00
Fishmeal	5.00	5.00
Dicalcium Phosphate	0.70	0.70
Limestone	1.37	1.46
Salt/T.M.[1]	0.25	0.25
Methionine	0.04	0.10
Vitamins[2]	+	+
Total	100.00	100.00

Chemical Analysis:

Crude Protein (%)	20.23	19.91
Nitrogen (%)	3.24	3.19
Lysine (%)	0.83	0.76
Methionine (%)	0.32	0.29
Cystine (%)	0.32	0.29

1 Supplied (per kg diet): sodium chloride 2.42 gm.; zinc 10 mg.; iron 15 mg.; manganese 3 mg.; copper 0.83 mg.; iodine 0.17 mg.; cobalt 0.10 mg.

2 Supplied (per kg diet): vit. A 2200 iu; vit. D 330 iu; vit. B_{12} 11.0 ug; Dl-tocopherol acetate 11 mg.; thiamine HCL 11 mg.; riboflavin 2.2 mg.; calcium - D - pantothenate 100 mg.; pyridoxine HCL 11.0 mg.; nicotinic acid 10.0 mg.; zinc 120 mg.; Mecadox 1.0 gm.

the amino acid availabilities from faba bean protein concentrate. This test utilized round metabolism cages described by Bell (1948). A modification was necessary for cages which held female pigs used in this experiment. Cages containing gilts were wrapped with a transparent plastic film to prevent loss of urine over the sides of the collection platform. The diets were composed largely of cornstarch with the test material the sole source of protein. Vitamins and minerals were balanced as to the specifications of the 1973 N.R.C. requirements for swine. Composition and analysis of the diets are given in Table VIII. Two groups of eight pigs composed the 16 test animals. Within each group of eight pigs there were four gilts and four barrows. Under test conditions, two barrows and two gilts were fed each diet, while the second group of eight pigs were fed standard grower diet. When the first collection period was completed, the second group of pigs were placed on test and the first group was given the grower diet. Each group was on test twice, giving 16 values for each diet gathered from four collection periods. Initial average weight of the test animals was 15.3 kg.

The animals were allowed an adaptation period of five days, feed and water provided ad libitum. After this, feces and urine were collected for three days. During the collection period feed and water were given three times daily at eight hour intervals. Urine was collected in a plastic collection vessel containing 25 ml of 6N HCl. Daily volumes were recorded, a sample taken and frozen immediately at -20 C for future analysis. Fecal material was collected daily and dried in a forced air dryer at 60 C. The total fecal collection for the three days was ground and a sub-sample of this was used for analysis purposes.

Study F: In this experiment faba beans, dehulled faba beans, and

Table VIII Study E Amino Acid Availability from Faba Bean Protein Concentrate as compared to Soybean Meal (44%)

Diet Ingredients	A Control	B F.P.C.
Soybean meal (44%)	43.00	-
FPC	-	29.00
Cornstarch	50.85	64.59
Soybean Oil	3.00	3.00
Dicalcium Phosphate	1.75	1.75
Limestone	0.40	0.66
Salt/T.M.[1]	0.50	0.50
Chromic Oxide	0.50	0.50
Vitamins[2]	+	+
Total	100.00	100.00

Chemical Analysis:

Crude Protein (%)	20.96	19.01
Nitrogen (%)	3.35	3.04
Lysine (%)	1.26	1.13
Methionine (%)	0.30	0.17
Cystine (%)	0.28	0.21

[1] Supplied (per kg diet): sodium chloride 2.42 gm.; zinc 10 mg.; iron 15 mg.; manganese 3 mg.; copper 0.83 mg.; iodine 0.17 mg.; cobalt 0.10 mg.

[2] Supplied (per kg diet): vit. A 2200 iu; vit. D 330 iu; vit. B_{12} 11.0 ug; DL-tocopherol acetate 11 mg.; thiamine HCL 11 mg.; riboflavin 2.2 mg.; calcium - D pantothenate 100 mg.; pyridoxine HCL 11.0 mg.; nicotinic acid 10.0 mg.; zinc 120 mg.; Mecadox 1.0 gm.

autoclaved faba beans, were tested for amino acid availabilities in comparison to soybean meal. The composition of each diet is reported in Table IX. Initial average weight of the pigs was 16.1 kg.. There were two pigs on each of the four treatments and between each test period the animals were allowed a recuperation of four days on a grower ration to minimize any carry-over effect from the previous test diet. For the collection of feces and urine, the procedure was exactly the same as that followed in Study E. However, in this study eight barrows were used in a 4 x 4 latin square design.

Study G: The object of this experiment was to determine digestible energy values of faba beans and dehulled faba beans. Daily, all pigs were self-fed the basal diet, an amount equal to 3% of their body weight. Four of six pigs were fed in addition to this, an extra 25% of the daily weight of the basal diet, as either whole or dehulled faba beans. Composition of the basal diet is shown in Table X. In each treatment there were two pigs, and they were housed in round metabolism cages previously described in Studies E and F. The six barrows had an average initial weight of 23.5 kg. and were tested in a 3 x 3 simple crossover design. An adaptation period of five days was followed by a three day collection period of fecal material. No recovery period between five day adaptation periods was allowed since the feed consumed was sufficient to supply all the animals' requirements.

Amino acid levels were determined on a Model 116 Beckman Amino Acid Analyser, according to the method of Bragg et al (1966). Modifications include hydrolysis for a period of 15 hours and reconstitution of the sample to a volume of 100 ml. with a sodium citrate buffer at pH 2.2. One half ml. of each sample was analyzed. To analyze for methionine and cystine, the samples were first oxidized with performic acid as described by Hirs (1967), then treated as a normal hydrolysate.

Table IX Study F Amino Acid Availability from Faba Beans, Dehulled Faba Beans and Autoclaved Faba Beans as compared to Soybean Meal (44%)

Diet	A	B	C	D
Ingredients	Control	Faba Beans	Autoclaved Faba Beans	Dehulled Faba Beans
Faba Beans	-	77.50	77.50	64.25
Soybean Meal (44%)	42.00	-	-	-
Cornstarch	51.85	15.42	15.42	28.67
Soybean Oil	3.00	3.00	3.00	3.00
Dicalcium Phosphate	1.75	3.08	3.08	3.08
Limestone	0.40	-	-	-
Salt/T.M.[1]	0.50	0.50	0.50	0.50
Chromic Oxide	0.50	0.50	0.50	0.50
Vitamins[2]	+	+	+	+
Total	100.00	100.00	100.00	100.00
Chemical Analysis:				
Crude Protein (%)	18.19	19.92	19.53	19.40
Nitrogen (%)	2.91	3.19	3.13	3.10
Lysine (%)	1.30	1.20	1.24	1.23
Methionine (%)	0.29	0.17	0.17	0.15
Cystine (%)	0.29	0.25	0.22	0.23

[1] Supplied (per kg diet): sodium chloride 2.42 gm ; zinc 10 mg ; iron 15 mg ; manganese 3 mg ; copper 0.83 mg ; iodine 0.17 mg ; cobalt 0.10 mg

[2] Supplied (per kg diet): vit. A 2200 iu; vit. D 330 iu; vit. B_{12} 11.0 ug; DL-tocopherol acetate 11 mg ; thiamine HCL 11 mg ; riboflavin 2.2 mg ; calcium - D - pantothenate 100 mg ; pyridoxine HCL 11.0 mg ; nicotinic acid 10.0 mg ; zinc 120 mg ; Mecadox 1.0 gm

Table X Study G Digestibility of the Energy in Faba Beans and Dehulled Faba Beans as Compared to Soybean Meal (48%)

Composition of the Basal Diet

Ingredients	
Soybean Meal (48%)	70.16
Wheat	20.44
Soybean Oil	3.50
Methionine	0.50
Dicalcium Phosphate	3.50
Limestone	1.00
Salt/T.M.[1]	0.40
Chromic Oxide	0.50
Vitamins[2]	+
Total	100.00
Chemical Analysis:	
Crude Protein (%)	36.02
Nitrogen (%)	5.76
Lysine (%)	2.14
Methionine (%)	0.81
Cystine (%)	0.46

1 Supplied (per kg diet): sodium chloride 2.42 gm ; zinc 10 mg ; iron 15 mg ; manganese 3 mg ; copper 0.83 mg ; iodine 0.17 mg ; cobalt 0.10 mg

2 Supplied (per kg diet): vit. A 2200 iu; vit. D 330 iu; vit. B_{12} 11.0 ug; DL-tocopherol acetate 11 mg ; thiamine HCL 11 mg ; riboflavin 2.2 mg ; calcium - D - pantothenate 100 mg ; pyridoxine HCL 11.0 mg ; nicotinic acid 10.0 mg ; zinc 120 mg ; Mecadox 1.0 gm

Tryptophan was not determined.

Dietary and fecal nitrogen content were determined by the macro-kjeldhal method (Horowitz 1965). Feces from each experiment were collected, dried in a forced air dryer at 60° C., and ground through a 1 millimeter mesh screen in a Wiley mill. Dry matter and fibre were determined as outlined in the Official Methods of Analysis of the A.O.A.C. (1970). Energy values were determined with a Parr bomb calorimeter. Analysis of variance of the experiments was performed according to procedures outlined in Snedecor and Cochrane (1967). Differences among treatments were assessed by using the Student - Newman - Keul multiple range test.

Chromic oxide content of feed and feces was obtained according to the atomic absorption spectrophotometry method of Williams et al (1962).

Chromic oxide was utilized in the fecal determinations of digestibilities, rather than total collections. Literature has satisfactorily demonstrated the reliability of this compound as a nutritional tool (Schürch et al, 1969). Care must be taken to ensure that the animals being used for the experiments have consumed the diet long enough to reach equilibrium in the gut. On a normal consumption plane this would be four days. However, if consumption drops, five or six days should be allowed. In particular, this might be a problem with diets high in cornstarch or fibre. As well, the sample taken for analysis must be representative of at least one day's fecal output. After grinding the dried sample, and before a quantity is taken for analysis, the sample should be stirred to achieve homogeneity of the fecal material and chromic oxide. The chromic oxide has a tendency to adhere to the sides of the plastic collection storage bags, and also it may settle to the bottom of the sample on storage due to the fine particle size. If these precautions are observed, no problems with accuracy will be encountered in analysis.

Results of Study A are reported in Table X1. Overall feed intake on the faba bean diet was about 9% lower than the control diet while intake for the dehulled faba bean diet was about 20% lower than the control feed intake. It was found over the 3 week test period that faba beans and dehulled faba beans gave similar rates of gain which were significantly less ($P < .05$) than the control diet. Feed efficiency was best for the soybean diet with the dehulled faba bean and faba bean diets poorer by 14% and 18% respectively.

The outcome of Study B is shown in Table X11. Part A involved feeding the test protein sources without methionine supplementation, in comparison to soybean meal.

For the 11 day test period, feed intake was greatest for the pigs fed the autoclaved faba bean diet. Pigs fed the soybean meal or dehulled faba bean diet had identical levels of feed intake while pigs fed the faba bean diet ate 13% less than the level recorded for the soybean meal diet. These large differences in feed intake were not reflected in rates of gain for, as noted, the diets containing the various types of faba beans gave similar rates of gain but significantly ($P < .05$) lower than the soybean meal diet. Feed efficiency was much better for the soybean meal diet than the faba bean diet, the autoclaved faba bean diet, or the dehulled faba bean diet which were 36%, 48%, and 65% poorer respectively than the soybean meal diet.

Supplementation with DL-methionine gave an immediate response (Table X11 - Part B). Average feed consumption on the faba bean and autoclaved faba bean diets was the same as the control, while pigs fed the dehulled faba bean diets ate 19% less than pigs on the soybean meal

Table X1 Study A Performance of pigs fed Faba Beans or Dehulled Faba Beans as the only source of supplementary protein in diets based on Barley, in comparison with Soybean Meal (44%)

		Response Criteria		
	Experimental Diet	Feed Consumption (Kg./day)	Rate of Gain (Kg./day)	Feed Efficiency
Period I (7 days)	Soybean Meal	1.16	0.47	2.48
	Faba Bean	1.20	0.33	3.69
	Dehulled Faba Bean	1.16	0.32	3.68
Period II (7 days)	Soybean Meal	1.43(1.30)[1]	0.59(0.53)	2.43(2.44)
	Faba Bean	1.09(1.15)	0.41(0.37)	2.63(3.10)
	Dehulled Faba Bean	1.03(1.10)	0.42(0.36)	2.46(2.97)
Period III (7 days)	Soybean Meal	1.61(1.40)	0.69(0.58)a[2]	2.33(2.41)
	Faba Bean	1.57(1.29)	0.62(0.45)b	2.52(2.84)
	Dehulled Faba Bean	1.34(1.17)	0.55(0.43)b	2.44(2.75)

1 Figures in parentheses represent pig performance over total time of trial. The figures preceding parentheses are for that period only.

2 Values with the same subscript are statistically similar; a > b.

- 9 pigs per treatment, average initial weights of 15.57 kg , 15.66 kg , and 15.84 kg for control, faba bean and dehulled faba bean diets respectively.

Table X11 <u>Study B</u> Performance of pigs fed Faba Beans, Autoclaved Faba Beans, and Dehulled Faba Beans as the only source of supplementary protein in Barley based diets, in comparison with Soybean Meal (44%), with and without addition of methionine.

	Experimental Diet	Response Criteria: Feed Consumption (Kg./day)	Rate of Gain (Kg./day)	Feed Efficiency
Part A[2]				
	Soybean Meal	1.23	0.58	2.12
	Faba Bean	1.14	0.37	3.08
Period I	Autoclaved Faba Bean	1.26	0.39	3.27
(7 days)	Dehulled Faba Bean	1.22	0.37	3.30
	Soybean Meal	0.86(1.13)	0.32(0.51)a	2.66(2.21)
	Faba Bean	0.71(1.02)	0.26(0.34)b	2.75(3.01)
Period II	Autoclaved Faba Bean	1.33(1.28)	0.41(0.39)b	3.26(3.26)
(4 days)	Dehulled Faba Bean	0.88(1.13)	0.15(0.31)b	5.85(3.64)
Part B				
	Soybean Meal	1.56	0.56	2.78
	Faba Bean	1.48	0.63	2.33
Period I	Autoclaved Faba Bean	1.58	0.62	2.52
(7 days)	Dehulled Faba Bean	1.34	0.54	2.47
	Soybean Meal	1.67(1.60)	0.64(0.59)a[1]	2.60(2.71)
	Faba Bean	1.72(1.57)	0.58(0.61)a	2.97(2.55)
Period II	Autoclaved Faba Bean	1.61(1.58)	0.54(0.59)a	2.94(2.66)
(4 days)	Dehulled Faba Bean	1.35(1.34)	0.59(0.56)a	2.27(2.39)

[1] Figures in parentheses represent pig performance over total time of trial. The figures preceding parentheses are for that period only. Values with the same subscript are statistically similar; a > b.

[2] Part A - sulphur amino acids supplied by natural ingredients only; Part B - synthetic DL-methionine added to 1973 N.R.C. recommendations.
- 7 pigs per treatment, average initial weights of 16.65 kg , 16.52 kg , 16.70 kg , and 16.83 kg for control, faba bean, autoclaved and dehulled faba bean diets respectively.

diet. There were no significant differences between diets in average daily gain. Comparison of the final feed efficiency values for Part B showed the dehulled bean diet the best followed by the faba bean, autoclaved faba bean and soybean meal diets which were poorer by 7%, 11%, and 13%, respectively. Feed efficiency improved markedly from Part A to Part B in diets containing the different faba bean by-products. With supplementation in Part B, feed efficiency values of the faba bean, autoclaved faba bean and dehulled faba bean diets improved 18%, 23% and 52% respectively.

In Study C, the value for the amino acid content of F.P.C. was based on earlier analysis. This data proved to be incorrect, resulting in markedly lower lysine content than calculated. In addition, during the course of the experiment an outbreak of scours occurred, in particular affecting feed consumption and rates of gain in Period II, Table XIII. Feed consumption and rate of gain were inferior due to these factors which added to the inaccuracy in assessing the value of F.P.C.. A repeat experiment, Study D, was conducted.

The results of Study D are report in Table XlV. It was found that at the end of the 21 day test period, no significant differences in rates of gain could be noted between the control and F.P.C. diets. Feed consumption and rate of gain were similar for both groups of pigs throughout periods II and III.

In period I the F.P.C. diet had a feed efficiency value 33% better than the soybean meal diet. In period II the margin narrowed to 5% in favour of the F.P.C. diet and, finally in period III there was no difference between the two treatments. The overall feed efficiency values showed the F.P.C. diet 11% better than the soybean meal diet.

Table XIII Study C Performance of pigs fed Faba Bean Protein Concentrate (F.P.C.) as the only source of supplementary protein in wheat based diets, compared to Soybean Meal (44%)

	Experimental Diet	Feed Consumption (Kg./day)	Rate of Gain (Kg./day)	Feed Efficiency
Period I (7 days)	Soybean Meal	0.46	0.31	1.51
	F.P.C.	0.37	0.25	1.52
Period II (7 days)	Soybean Meal	0.31(0.39)[1]	0.20(0.25)	1.57(1.53)
	F.P.C.	0.28(0.33)	0.15(0.20)	1.85(1.65)
Period III (7 days)	Soybean Meal	0.91(0.56)	0.66(0.39)a[2]	1.37(1.44)
	F.P.C.	0.74(0.47)	0.53(0.31)b	1.40(1.50)

[1] Figures in parentheses represent pig performance over total time of trial. The figures preceding parentheses are for that period only.
- 12 pigs per treatment, average initial weights of 7.81 kg for F.P.C., 7.76 kg for control.

[2] Values with the same subscript are statistically similar; a > b.

Table XIV Study D Performance of pigs fed Faba Bean Protein Concentrate (F.P.C.) as the only source of supplementary protein in Wheat based diets, compared with Soybean Meal (44%)

	Experimental Diet[1]	Feed Consumption (Kg./day)	Rate of Gain (Kg/day)	Feed Efficiency
Period I (7 days)	Soybean Meal	0.49	0.17	3.00
	F.P.C.	0.46	0.21	2.24
Period II (7 days)	Soybean Meal	0.57(0.53)[2]	0.23(0.20)	2.45(2.68)
	F.P.C.	0.53(0.49)	0.24(0.22)	2.20(2.22)
Period III (7 days)	Soybean Meal	0.58(0.54)	0.30(0.23)a[3]	1.92(2.34)
	F.P.C.	0.54(0.51)	0.28(0.24)a	1.94(2.11)

[1] 16 pigs per treatment, average initial weights of 7.54 kg for both treatments.

[2] Figures in parentheses represent pig performance over total time of trial. The figures preceding parentheses are for that period only.

[3] Values with the same subscript are statistically similar.

Study E utilized semi-purified diets with the test material as the only source of protein and cornstarch making up the remaining portion of the diet. Table XV records individual amino acid availabilities for F.P.C. and soybean meal (44%), as well as digestibility of dry matter and nitrogen and nitrogen retention as a percent of nitrogen intake.

For eight of the essential amino acids, F.P.C. has significantly greater availability ($P < .05$). In the case of methionine, the two protein sources show no significant difference, although the soybean meal is slightly higher. Nitrogen and dry matter digestibility are significantly higher ($P < .05$) for F.P.C. than for soybean meal. Nitrogen retention as a percent of intake, shows no statistical difference between treatments.

Examination of the essential amino acids shows the F.P.C. has its most available amino acids represented by arginine, histidine, leucine, and lysine, then isoleucine, phenylalanine, threonine and valine, with methionine the least available. The soybean meal control has arginine and histidine as its most available amino acids, followed by leucine lysine, methionine and phenylalanine, with isoleucine, threonine and valine as its least available essential amino acids.

The non-essential amino acids for F.P.C. have greater than 90% availability with the exception of alanine which is slightly below 90%. Soybean meal has aspartic acid, cystine, glutamic acid, proline and serine with greater than 90% availability, while alanine, glycine, and tyrosine are less than 90% available. The availability of cystine from soybean meal is statistically greater than cystine from F.P.C..

Study F (Table XVI) shows arginine and histidine the most available essential amino acids for all treatments. The trend is for isoleucine, leucine, lysine and phenylalanine to be the next most available group within

Table XV Study E Apparent Availability of Amino Acids (%) for Growing Pigs

Amino Acids	Soybean Meal	Faba Bean Protein Concentrate	$S\bar{x}$
	Source of Protein[1]		
Essential			
ARG	94.9 b[2]	96.8 a	0.7
HIS	92.5 b	94.5 a	0.9
ILE	87.7 b	91.9 a	1.5
LEU	89.2 b	93.4 a	1.2
LYS	88.7 b	93.5 a	1.2
MET	90.0 a	88.8 a	1.4
PHE	90.1 b	92.7 a	1.2
THR	88.0 b	91.6 a	1.4
VAL	87.0 b	91.4 a	1.8
Non-Essential			
ALA	83.5 b	89.2 a	2.1
ASP	91.6 b	93.4 a	1.2
CYS	93.9 a	92.3 b	1.6
GLU	93.5 b	95.8 a	0.9
GLY	86.6 b	91.5 a	1.8
PRO	93.3 a	93.9 a	1.1
SER	92.6 b	94.6 a	0.9
TYR	88.1 b	91.4 a	1.6
Nitrogen digestibility	88.6 b	91.6 a	1.9
Dry Matter digestibility	91.9 b	93.4 a	0.9
Nitrogen Retention (as a % of intake)	67.1 a	63.9 a	3.4

[1] Each treatment consisted of 16 pigs.

[2] Values with the same subscript are statistically similar. a > b.

Table XV1 Study F Apparent Availability of Amino Acids for Growing Pigs

Amino Acids %	Soybean Meal	Faba Beans	Autoclaved Faba Beans	Dehulled Faba Beans	$S\bar{x}$
	Source of Protein[1]				
Essential					
ARG	96.5 a[2]	93.1 b	93.7 b	98.0 a	0.7
HIS	95.0 a	88.4 b	89.0 b	96.9 a	1.5
ILE	90.1 b	82.3 c	84.1 c	94.1 a	1.1
LEU	90.9 b	84.0 c	88.6 b	94.6 a	0.9
LYS	91.7 a	87.0 b	87.6 b	94.7 a	1.4
MET	87.5 a	63.5 b	65.0 b	88.3 a	1.9
PHE	91.8 b	83.7 c	85.5 c	94.4 a	0.8
THR	89.5 a	80.7 b	81.5 b	93.0 a	1.5
VAL	89.3 b	81.5 c	82.9 c	93.9 a	1.1
Non-Essential					
ALA	86.0 c	76.8 c	77.6 b	91.3 a	1.1
ASP	92.4 a	85.3 b	85.3 b	95.2 a	1.1
CYS	91.9 a	80.8 b	78.6 b	92.7 a	1.3
GLU	94.5 a	88.1 b	89.7 b	96.5 a	0.9
GLY	87.7 b	77.1 c	78.5 c	93.1 a	1.7
PRO	94.0 a	77.0 b	79.6 b	94.9 a	2.5
SER	93.0 a	85.0 b	85.7 b	95.3 a	1.1
TYR	88.1 a	77.0 b	80.0 b	91.3 a	1.4
Nitrogen dig.	90.3 b	82.3 c	82.6 c	93.7 a	1.1
Dry Matter dig.	93.2 a	82.5 b	82.7 b	94.2 a	0.7
Nitrogen Retention (as a % of intake)	67.1 a	54.5 b	58.2 b	58.5 b	2.6

[1] Each treatment consisted of 8 pigs.

[2] Values with the same subscript are statistically similar. a > b > c.

treatments. In general, threonine and valine are next in availability while methionine is the least available for all treatments. Generally speaking, the essential amino acids from dehulled beans are significantly more available than for the other treatments, followed by the soybean meal, autoclaved faba beans, and finally faba beans.

Differences in availability of amino acids between faba beans and autoclaved faba beans are small with values significantly greater for autoclaved faba beans in three instances (leucine, isoleucine, and phenylalanine). Both lysine and methionine are significantly more available in soybean meal and dehulled faba beans, in comparison to faba beans and autoclaved faba beans.

There is no pattern which is consistent, as far as grouping the non-essential amino acids for availability within treatments. As a whole the dehulled faba bean diet had more available non-essential amino acids, followed by the soybean meal diet, and finally the autoclaved faba bean and faba bean diets with few significant differences. Cystine was equally available in dehulled faba beans or soybean meal, and was significantly more available than in faba beans. Cystine in faba beans was more available ($P < .05$) than in autoclaved faba beans.

Nitrogen digestibility was significantly greater for the dehulled faba beans, followed by soybean meal, while autoclaved faba beans and faba beans were similar in nitrogen digestibility.

Dry matter digestibilities were similar to the nitrogen digestibilities, for their respective treatments, in percentage values and levels of significance.

Soybean meal gave the best value for nitrogen retention as a percent of intake and was significantly higher ($P < .05$) than all other treatments. The autoclaved faba bean and dehulled faba bean diets were similar and were significantly greater than the faba bean diet.

Study G had as its objective, the determination of digestible energy values for faba beans and dehulled faba beans. The digestible energy coefficients were derived by extrapolation from a graph. Digestible energy decreased from dehulled beans to whole beans with values of 4162 cal/gm. D.M. and 3802 cal/gm. D.M. respectively. The basal diet gave a value of 3824 cal/gm. D.M.. Results are reported in Table XV11.

Table XV11 Study G Digestible Energy Values[1] of Faba Bean and Dehulled Faba Beans for Growing Pigs

Feedstuff	Digestible Energy[2] Kcal./kg. D.M.	Digestible Energy Coefficient
Basal Diet	3824	85.4
Whole Beans	3802	84.5
Dehulled Beans	4162	93.5

[1] Expressed on a 100% dry matter basis.

[2] Each value derived from 6 pigs.

In Study A for the first and second weeks, rate of gain was about 30% less for the pigs fed the faba bean diet, when compared to pigs fed the soybean meal diet. However, in the last week of test, feed consumption and rate of gain for pigs fed the faba bean diet approached the values for pigs fed the soybean meal diet. The corresponding feed efficiency values for pigs fed the faba bean diet were poor in the first week of test but were much improved in weeks two and three. Pigs fed the diets containing dehulled faba beans showed the lowest feed consumption of the three experimental diets throughout the test. This resulted in pigs fed the dehulled faba bean diet consistently showing the poorest cumulative weekly rate of gain. The overall feed efficiency value for these pigs was slightly better than for pigs consuming the faba bean diet, but still inferior to the value produced by the pigs consuming the soybean meal diet.

Study B, Part A produced similar results to those of Study A with the faba bean diet again out-performing the dehulled faba bean diet. Pigs fed autoclaved faba beans showed a slight improvement over the faba bean and dehulled faba bean treatments.

In Study B, Part B,all faba bean treatments responded dramatically to DL-methionine, so that the overall outcome was no significant difference in average daily gain among treatments. In general, feed efficiency favoured the faba bean treatments, with the greatest response shown by pigs consuming the dehulled faba bean diet. Part of the improvement in feed efficiency would be due to the difference in pig size when the DL-methionine treatment was begun. Similar responses to methionine supplementation of faba bean diets have been reported by other authors working with pigs, weanling rats, and chicks (Balboa et al 1966; Bello et al 1972; Wilson and McNab 1972;

LeDividiche 1973).

Where faba beans were fed in mash diets for young growing pigs, pigs fed the soybean meal control diet gave significantly greater weight gains (Stothers 1974). Although direct comparison of these studies with that test are not possible, it can be noted that unheated faba beans in a mash diet resulted in a depressed feed consumption and average daily gain to a greater extent than for pigs fed similar diets in these studies where the diets were pelleted.

It appears that from the results of Study B,Part B, faba beans, dehulled faba beans or autoclaved faba beans can replace soybean meal totally as the supplementary protein source for pigs initially weighing about 20 kg., provided DL-methionine is included in the pelleted diet to meet the animals' requirements.

It is known that heat treatment plays a role in improving utilization of faba beans (Bello et al 1972; Marquardt and Campbell 1973). In these studies the response of pigs consuming heated faba beans as compared to faba beans may be reduced, as a result of the heating of the faba beans in all diets during the pelleting process. More comparative data on the effects of different heat treatments on faba beans for pigs would be valuable.

In these studies a longer test period may have given clearer trends on which to base conclusions, as there seems to be some compensatory feed consumption and rates of gain in Study B, Part B.

Study C and D gave contradictory results, but as has been explained, the diets in Study C were not formulated correctly so this discussion will be concerned primarily with Study D. The results of Study D suggest that F.P.C. can successfully replace the soybean meal portion in a prestarter/starter diet for pigs weighing initially 7.5 kg. and fed up to 12.6 kg..

In the first two periods (Table XlV) it appeared that F.P.C. in the diets would out-perform the soybean meal diets. However, the final result was no significant difference in average daily gain between treatments, although feed efficiency favoured the F.P.C. diet.

To be sure of the results presented in Table XlV it might have been better to extend the test period for longer than 21 days, and also replace part of the fish meal with more F.P.C.. The performance of the pigs fed the F.P.C. diet was relatively consistent from period to period suggesting that perhaps this protein source is more acceptable to weanling pigs than that of soybean meal. As far as the author is aware, there have not been any other published studies testing F.P.C. in diets for young pigs.

It is of interest to note that in Study C the lysine level was about 20% below the required level while feed consumption and average daily gain were about 20% less, suggesting a linear relationship between lysine level and growth rate.

Study E showed that the amino acids of F.P.C. are more highly available than soybean meal for all essential amino acids except methionine where they are equally available. Considering the outcome of the growth trials of Study D, it would be expected that the two test proteins would at least be equally available to the animals, so the growth data and amino acid availability data can be seen as supporting each other. The metabolic utilization of nitrogen, expressed by showing nitrogen retained as a percent of intake, was equal for the two treatments suggesting that any substances which might be present in faba beans, that would retard growth or nutrient retention, are not present in appreciable amounts in the F.P.C. product. However, work done using broiler chicks fed raw or autoclaved F.P.C. gave some indication that at the higher level of F.P.C. (34.9%) used in chick diets, autoclaving might produce an improved utilization of the protein

(Marquardt et al 1976). As with Study D, there is no other published pig data available to compare with this study.

Experiments by Pastuszewska et al (1974) and Sauer (1972) with data showing amino acid availabilities of faba beans and dehulled faba beans are given in Table XVIII as well as the data from these studies. All three experiments utilized diets which had the test protein as the only source of nitrogen with cornstarch making up the rest of the diet. Sauer (1972) had 4 animals per treatment and his reported standard errors are equal to or lower than those obtained in this study. Pastuszewska et al (1974) had 4 animals per treatment but did not report any standard errors. This study had eight pigs per treatment and standard errors are reported for the individual amino acids as well as nitrogen digestibility. The availabilities of the amino acids of soybean meal compare well for all 3 studies, varying only 1 or 2% from each other. No cystine values were reported by Sauer (1972).

For the faba bean diets the results of Sauer (1972) and this study compare very favorably, while the values obtained by Pastuszewska et al (1974) were much lower. Since Pastuszewska et al (1974) did not report standard errors it is not possible to determine the variation between pigs. In general, the dehulled faba bean diet in the work of Pastuszewska et al (1974) also showed availabilities much lower than those of this study.

Faba beans had nitrogen digestibilities in this study and that of Sauer (1972), differing by less than 1%, but the value of Pastuszewska et al (1974) was 3.5% less, which is still reasonably comparable. The separation between the nitrogen digestibility coefficients increases with dehulled faba beans to 7.5% lower for Pastuszewska et al (1974), from this study. Sauer (1972) did not test dehulled faba beans. The reason for the differences between this study and that of Pastuszewska et al (1974) could not be determined.

Although the amino acid availabilities and nitrogen digestibility

Table XVIII Comparison of Apparent Availabilities for Pigs of Soybean Meal (44%), Faba Beans, and Dehulled Faba Beans

Feedstuff	Soybean Meal			Faba Beans			Dehulled Faba Beans	
Reference	A	B	C	A	B	C	A	B
Amino Acid (%)								
Essential								
ARG	94.4	96.5	95.3	89.6	93.1	91.1	94.6	98.0
HIS	93.0	95.0	94.3	82.0	88.4	88.5	91.2	96.9
ILE	88.7	90.1	89.8	74.3	82.3	81.5	84.0	94.1
LEU	89.5	90.9	90.9	78.5	84.0	85.1	86.7	94.6
LYS	89.2	91.7	90.5	77.9	87.0	84.4	86.3	94.7
MET	87.9	87.5	86.7	76.1	63.5	69.2	85.6	83.3
PHE	90.4	91.8	91.9	75.6	83.7	83.7	84.6	94.4
THR	88.0	89.5	88.9	73.1	80.7	80.2	82.4	93.0
VAL	88.1	89.3	88.9	74.9	81.5	80.7	84.3	93.9
Non-Essential								
ALA	86.0	86.0	85.9	69.9	76.8	75.8	81.1	91.3
ASP	92.0	92.4	90.8	81.7	85.3	85.5	88.4	95.2
CYS	89.5	91.9	-	72.4	80.8	-	84.0	92.7
GLU	94.0	94.5	94.5	85.2	88.1	89.2	91.2	96.5
GLY	88.0	87.7	89.3	74.8	77.0	74.5	85.0	93.1
PRO	91.9	94.0	93.6	77.8	77.9	62.3	88.9	94.9
SER	90.7	92.9	92.6	81.5	85.0	85.9	88.9	95.3
TYR	89.8	88.1	90.3	72.8	76.8	80.3	85.1	91.3
Nitrogen	89.5	90.3	90.5	78.8	82.3	81.9	86.2	93.7

A Pastuszewska et al 1974 - 4 pigs per treatment

B Results of this study - 8 pigs per treatment

C Sauer 1972 unpublished data - 4 pigs per treatment

Table XIX Digestibility and Metabolic Utilization of Nitrogen

Nitrogen Source	Soybean Meal		Faba Beans		Dehulled Faba Beans		Autoclaved Faba Beans	
Reference	A	B	A	B	A	B	A	B
Digestibility of Nitrogen								
N. ingested (gm./day)	33.5	52.0	32.9	35.0	30.9	27.0	-	40.6
N. excreted (gm./day) in feces	3.5	5.0	6.9	6.2	4.3	1.7	-	7.1
N. digestibility (%)	89.5	90.3	78.8	82.3	86.2	93.7	-	82.6
Metabolic utilization of Nitrogen								
N. excreted in urine (gm./day)	10.6	12.8	10.3	9.7	12.9	9.3	-	9.9
N. retained (gm./day)	18.1	34.1	15.7	19.1	13.7	15.8	-	23.7
N. retained as a % of intake	54.1	67.1	47.7	54.5	44.2	58.5	-	58.2

A Pastuszewska et al 1974, study done with pigs weighing initially 25.0 kg.

B This study, using pigs weighing initially 23.5 kg.

coefficients seem to suggest that dehulled beans are a better protein source than soybean meal, faba beans, or autoclaved faba beans, the metabolic utilization of nitrogen does not support this conclusion (Table XlX). For productive purposes, the nitrogen which is available to the animal is that amount not excreted in the urine or feces. When this amount of nitrogen is expressed as the percent retained of the nitrogen ingested, it allows a comparison of the relative efficiency of utilization of the protein by the animal. The results of this study show the soybean meal diet had a 9% higher retention value for nitrogen than either dehulled faba beans or autoclaved faba beans. The faba bean diet was lowest with a retention as a percent of intake about 4% lower than the autoclaved faba beans.

Pastuszewska et al (1974) also found the soybean meal diet gave the best nitrogen retention as a percent of intake, but the faba bean and dehulled faba bean diets were lower by 6.5% and 10% respectively, than the soybean meal diet.

From Table XlX by comparing the data of Pastuszewska et al (1974) with that of this study, it can be seen that the level of feed intake between pigs on the same treatments is comparable except for the soybean meal diet, where the pigs of this study consumed the most grams of nitrogen per day. This should have the effect of increasing rate of passage and possibly decreasing nitrogen digestibility and retention. However, the actual result is a higher retention of nitrogen as a percent of intake, by 13% for the soybean meal and dehulled faba bean diets, and 6.8% for the faba bean diet, of this study over the results of Pastuszewska et al (1974). In part, the lower nitrogen retention values by Pastuszewska et al (1974) can be related to lower digestibilities already noted.

It seems that within the range of feed consumption in this study, the values for nitrogen digestibility and retention as a percent of intake were not greatly affected since all treatments gave results consistently higher than those of Pastuszewska et al (1974).

The digestible energy values determined in Study G compare well with other research data. Studies similar in design have their results given in Table XX.

Henry and Bourdon (1973), determined the energy values of faba beans and soybean meal by substituting the test protein for variable portions of the basal diet, which was composed of corn and soybean meal (44%). Two of the diets contained faba beans at levels of 15 and 30% and two of the diets contained soybean meal at 10 and 20% levels, leaving the fifth group of pigs eating the basal diet. This gave three points by which the digestible energy coefficient could be calculated for each test protein. The second experiment carried out by these researchers was to determine the utilization of the energy for dehulled faba beans in comparison with faba beans and soybean meal. One level of test protein was fed and the energy digestibility calculated using the values derived in the first experiment.

Pastuszewska et al (1974) fed four diets, consisting of a protein-free diet and three diets containing soybean meal, or faba beans or dehulled faba beans in variable combinations with cornstarch, as previously discussed. To determine the energy digestibility of the test proteins, the value of the protein-free diet was used as the basal figure and the respective coefficient for the test protein was calculated based on the value obtained for the single substitution level.

Energy values obtained by Henry and Bourdon (1973) and Pastuszewska et al (1974) are 11.2% and 10.6% higher respectively than the N.R.C. (1973) value. The differences may be due to their source of soybean meal and method of extraction of oil from the meal.

In this study the procedure was to feed a basal diet then add the test

Table XX . Digestible Energy Values of Soybean Meal, Faba Beans and Dehulled Faba Beans for Young Pigs.

Energy Source	Soybean Meal			Faba Beans			Dehulled Faba Beans		
Reference	A	B	D	A	B	C	A	B	C
% Digestible Energy	91.0	89.8	-	87.0	84.5	84.5	94.0	89.8	93.5
D.E. Kcal./kg. D.M.	4200	4000	3750	3900	3700	3802	4100	4040	4162

A Henry and Bourdon 1973, 4 pigs per treatment initially weighing 34.9 kg. (expt. I) and 44.2 kg. (expt. II)

B Pastuszewska et al 1974, 4 pigs per treatment initially weighing 25.0 kg.

C This study, 6 pigs per treatment initially weighing 23.5 kg.

D National Research Council 1973.

protein to the basal diet. Once the digestibility coefficient was obtained from the graph then the Kcal./kg. D.M. can be calculated by simple multiplication.

The energy values obtained for the diets were plotted on a graph and extrapolated back to 100% of test material.

Comparing the three studies, all the values for faba beans expressed on a Kcal./kg. D.M. basis are within 5% of each other with this study intermediate to the other two.

Several compounds have been implicated in explaining the impaired performance of some animals fed faba beans and/or its by-products. These compounds include trypsin inhibitor(s), hemmagglutinin, tannins, as well as the structure of the protein molecule in some plant proteins. Trypsin inhibitor acts by causing hypertrophy of the pancreas and hypersecretion of enzymes (Haines and Lyman 1961; Leiner and Kakade 1969). Both trypsin inhibitor and pancreatic enzymes are rich in cystine, with the cystine contained in the trypsin inhibitor relatively unavailable (Neurath 1961; Kakade 1969, 1973).

Thus, where faba beans are fed there is potentially low availability of sulphur containing amino acids, and an increased metabolic need due to hypersecretion of enzymes.

Hemmagglutinins are present in faba beans but to date have been a bigger problem in human nutrition. Marquardt et al (1975) concluded that neither trypsin inhibitors or hemmagglutinins severely inhibited faba bean utilization by the chick.

Tannins are extremely reactive substances and have the ability to combine with and precipitate proteins (Bate-Smith 1962). The purified tannin isolated from the faba bean, when incorporated in chick diets at a level of 4% will cause severely inhibited nutrient retention and some mortality (Marquardt unpublished,1976). Assays of the level of tannins in the faba beans show levels of less than 0.5% of the faba bean (Marquardt unpublished,1976). Therefore, the level of tannins in the growth diets of this study would be less than 0.25%. The magnitude of inhibition of nutrient utilization for pigs at this concentration has yet to be established, but this may be a contributing factor to the depressed availability of the nutrients of faba beans.

Dehulling the faba bean removes virtually all of the tannin (Tanguy and Martin 1973), and fibre, which causes a dramatic increase in availability of amino acids. Study F shows availabilities for dehulled faba beans greater than those for soybean meal, although the metabolic utilization of nitrogen was 8.5% lower than for soybean meal. Since the effect of the trypsin inhibitor and hemmagglutinin can be considered small, and the tannins have been eliminated, there must be some alternate explanation for the lower nitrogen retention as a percent of intake.

In their natural state, plant proteins can be shown to be resistant to proteolytic enzymes (Grau and Carroll 1958; Leiner 1958), i.e. kidney bean globulins were shown resistant to proteolytic attack and acted as inhibitors to digestive enzymes (Seidle and Jaffé 1969). Nitsan and Leiner (1976) observed that amino acid absorption of raw soybean flour was delayed to a more distal portion of the small intestine. Absorption of the end-products of digestion for heated soybean flour began in the jejunum, and levels of amino acids from raw soybean flour digestion did not begin to decline until digesta reached the ileum. It is proposed that the ileum is less efficient in absorbing amino acids than the combined absorptive capacity of the jejunum and ileum (Abidi 1976), therefore the net result would be lower nitrogen retention. Heating the soy flour denatured the protein molecule enough to allow enzyme attack which improved utilization and retention of nitrogen.

The results of Study F, show lower nitrogen retention as a percent of intake for faba beans when compared with autoclaved faba beans. It has also been demonstrated that autoclaving dehulled faba beans gives an improved nitrogen retention, and, that autoclaving F.P.C. may improve nitrogen retention for broiler chicks (Marquardt and Campbell 1973; Marquardt et al 1976).

Another aspect which should be considered is the effect cecal micro-organisms play in alteration of dietary protein. Experiments measuring the difference between ileal and fecal amino acid levels of the digesta clearly show that the cecal micro-organisms can degrade certain amino acids and synthesize others, changing the fecal amino acid pattern compared to ileal amino acid patterns (Easter 1973; Zebrowska 1973; Holmes 1974; Sauer 1976). It is possible that the dehulled faba beans gave high apparent amino acid availabilities because of a large amount of degradation by the cecal micro-organisms. This degradation would be reflected in a lower nitrogen retention as a percent of intake, than would be indicated by the amino acid availabilities, as shown in Study F.

SUMMARY

1. Addition of DL-methionine to meet the young pigs' requirements allowed the total replacement of soybean meal by faba beans where as much as 49.4% faba beans were used in pelleted diets, for pigs initially weighing approximately 20 kg..

Pigs fed dehulled faba beans showed the greatest response to DL-methionine supplementation in comparison to the part of the study where no DL-methionine was supplied.

Autoclaving the faba beans was of some benefit when no DL-methionine was included in the diet, however some of the effect of autoclaving may have been reduced due to the heating associated with pelleting.

2. Faba bean protein concentrate successfully replaced the soybean meal portion of the diet for prestarter/starter pigs weighing initially 7.5 kg.. Feed consumption and rate of gain for pigs consuming diets containing F.P.C. instead of soybean meal, were consistent and essentially equal to the values recorded for the pigs consuming the soybean meal diet. However, feed efficiency was better by 10% for pigs fed the F.P.C. diet in comparison with pigs fed the soybean meal diet.

The essential amino acid availabilities for the F.P.C. were better than the corresponding values of soybean meal, except for methionine where they were equally available. More detailed studies conducted over a longer period are required to determine if F.P.C. can also replace part or all of the fish meal used in the diets for young growing pigs.

3. Overall amino acid availabilities for faba beans and other faba bean products are, from highest to lowest, dehulled faba beans followed by autoclaved faba beans, which have slightly higher availabilities than faba beans.

Dehulling the faba bean reduces the fibre component of the diet

considerably but also removes the tannins which may play a role in reducing nutrient availability.

Although the dehulled faba beans gave the highest amino acid availabilities, the nitrogen retention as a percent of intake was no greater than for the autoclaved faba beans. Additional heat treatment may be of value for dehulled faba beans, to render the protein more susceptible to digestive enzymes. The high amino acid availabilities of dehulled faba beans may be due in part to degradation of the undigested amino acids in the cecum.

Further studies on the effect of tannins on nutrient retention and nature of the faba bean protein as it is affected by heat, may provide ways in which the faba bean and its by-products can be used to greater advantage in swine diets.

4. Using the NRC (1973) value for soybean meal as a standard, the digestible energy content of faba beans is equal to, and the value for dehulled faba beans exceeds that set by the NRC (1973). Thus, on an energy basis, both faba beans and dehulled faba beans could be considered as suitable replacements for soybean meal.

In review, based on this study where faba beans are considered as the only supplemental protein source for feeding young growing pigs, it should be realized that the depression in pig performance is multi-factored, a lack of sulphur containing amino acids being the most serious problem. It would be expected that there are levels of faba beans, lower than those used in this study, which should give satisfactory results, i.e. partial replacement of supplementary protein sources.

Lewis and Aherne (1976) working with pigs between 10 and 90 kg., replaced variable amounts of soybean meal with faba beans without providing supplemental methionine. It was concluded that the optimal level of faba beans was between 10 to 25% of the diet with little or no effect on feed efficiency. However, average daily feed and rate of gain were decreased slightly in comparison to the control diet, using soybean meal as the supplemental protein source.

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Appendix Table 1 Analysis of Variance between treatments for Studies A,B,C, and D: Mean Squares for Rate of Gain

	Study A		Study B			Study C		Study D	
				Part A	Part B				
	d.f.		d.f.			d.f.		d.f.	
Treatment M.S.	2	.04000	3	.03740	.00317	1	.02269	1	.00100
Error M.S.	24	.00417	24	.00948	.00848	22	.00516	30	.00230

Appendix Table II Analysis of Variance between treatments for Study E: Mean Squares for amino acid availabilities, nitrogen as a percent of intake, and dry matter digestibility.

Source of Variation	Treatment	Period	Sex	TxP	TxS	SxP	Error
Degrees of Freedom	1	3	1	3	1	3	19
Amino Acids							
Essential							
ARG	28.86	6.74	4.02	1.73	0.01	0.46	1.07
HIS	32.20	4.10	4.01	1.12	0.00	1.65	1.73
ILE	136.73	48.21	21.40	4.38	0.00	8.18	4.53
LEU	136.25	34.64	13.04	3.29	0.02	5.39	3.00
LYS	177.66	55.83	34.07	10.08	5.38	6.38	2.93
MET	11.14	120.78	16.85	5.03	9.28	3.94	3.86
PHE	52.05	34.68	11.39	0.87	0.02	5.46	2.82
THR	103.32	38.95	12.73	4.24	0.04	4.61	3.65
VAL	156.07	57.25	17.50	11.80	0.04	8.38	6.46
Non-essential	1	3	1				26
ALA	252.68	118.96	43.75	-	-	-	8.90
ASP	48.22	23.38	8.10	-	-	-	2.64
CYS	21.06	56.61	4.11	-	-	-	4.96
GLU	39.54	18.29	16.35	-	-	-	1.49
GLY	146.12	64.26	16.50	-	-	-	6.13
PRO	2.24	13.67	0.00	-	-	-	2.54
SER	33.64	15.59	3.06	-	-	-	1.49
TYR	90.59	41.86	8.89	-	-	-	4.80
Nitrogen	77.16	2.75	5.93	235.60	16.63	12.70	23.52
Dry Matter	17.88	15.05	-	-	-	-	1.68

Appendix Table III Analysis of Variance among treatments for Study F: Mean Squares for amino acid availabilities, nitrogen retention as a percent of intake, and dry matter digestibility.

Source of Variation	Treatment	Period	Pigs	Error
Degrees of Freedom	3	3	7	18
Amino Acids %				
Essential				
ARG	43.57	1.22	2.50	0.87
HIS	146.87	0.39	5.50	4.67
ILE	235.85	13.90	15.57	2.61
LEU	192.83	4.25	9.69	1.50
LYS	106.00	4.79	14.70	3.71
MET	1160.48	23.68	50.98	6.84
PHE	206.17	5.71	8.49	1.31
THR	291.13	5.36	10.91	4.33
VAL	264.56	14.10	22.02	2.28
Non-essential				
ALA	390.62	12.44	21.57	2.55
ASP	202.65	0.84	6.49	2.24
CYS	428.50	4.13	11.22	3.51
GLU	125.19	1.99	4.74	1.54
GLY	465.59	6.08	3.25	5.48
PRO	705.52	26.96	19.63	12.07
SER	211.25	0.65	4.44	2.20
TYR	366.10	60.54	8.07	4.06
Nitrogen	289.98	9.44	26.65	13.40
Dry Matter	329.64	0.58	2.56	1.32

Appendix Table IV Individual amino acid availabilities for pigs fed the soybean meal diet from Study E.

	Period I				Period II				Period III				Period IV			
Pig	93	64	25	83	22	69	52	080	93	64	25	83	22	69	52	080
Sex	F	M	F	M	M	F	M	F	F	M	F	M	M	F	M	F
A.A.%																
LYS	89.0	83.0	82.7	78.6	88.8	90.5	91.6	88.5	93.9	89.1	92.4	86.4	90.4	92.7	90.5	91.8
HIS	93.3	92.2	90.6	90.5	91.5	93.2	93.8	90.9	94.9	92.9	92.4	90.0	94.0	94.5	92.6	93.1
ARG	94.7	93.1	92.9	91.7	94.9	95.2	96.3	94.5	97.0	95.4	95.4	93.4	96.3	96.7	95.5	95.8
ASP	92.2	88.0	88.1	86.1	91.5	90.7	94.0	91.1	94.6	92.2	92.9	89.6	93.8	93.9	93.1	93.7
THR	88.5	83.5	83.7	82.4	87.2	87.3	90.9	86.5	91.8	88.7	89.1	86.3	90.6	91.3	89.6	90.6
SER	92.7	89.9	89.9	89.2	92.5	92.2	94.7	91.5	95.0	93.0	93.4	91.3	94.1	94.4	93.6	94.1
GLU	93.8	90.2	90.3	88.7	93.1	92.8	95.1	93.2	96.4	94.3	95.0	91.8	95.7	95.8	95.0	95.7
PRO	93.3	92.0	91.2	89.7	92.5	92.8	95.1	92.6	95.6	95.9	94.5	91.2	94.8	95.3	91.4	95.5
GLY	87.1	81.4	80.9	77.5	85.6	85.8	91.0	86.0	91.5	87.8	89.9	84.0	89.4	89.4	88.7	90.0
ALA	83.8	75.9	75.8	72.2	82.3	82.6	89.2	83.2	89.7	84.8	86.9	79.7	87.8	88.3	86.8	87.8
CYS	95.4	95.0	96.2	93.9	96.0	96.0	96.9	95.6	93.8	91.4	91.7	89.5	92.3	93.1	92.3	94.0
VAL	87.3	81.7	81.5	78.8	86.3	85.9	91.4	86.1	91.8	90.4	89.4	83.8	89.5	90.0	88.6	89.8
MET	92.9	90.5	95.0	88.2	93.0	92.9	95.1	93.0	91.0	86.4	86.6	81.9	89.6	88.1	86.8	89.2
ISO	88.3	83.2	83.1	80.7	86.9	86.9	91.9	87.1	92.2	88.2	89.7	84.7	90.2	90.7	89.6	90.5
LEU	89.6	85.2	85.3	83.1	88.4	88.6	93.0	88.6	92.9	89.7	90.8	87.2	91.4	91.7	91.1	91.4
TYR	88.1	83.4	84.9	79.9	88.7	86.6	92.8	87.4	90.3	86.0	89.7	88.2	90.2	90.2	90.8	91.9
PHE	90.5	86.6	86.9	84.4	89.8	90.0	93.6	89.9	92.9	89.7	90.7	87.4	92.5	92.7	92.1	92.4

Appendix Table V Individual amino acid availabilities for pigs fed the F.P.C. diet from Study E.

	Period I				Period II				Period III				Period IV			
Pig	56	62	26	84	63	57	82	29	56	62	26	84	63	57	82	29
Sex	F	M	F	M	M	F	M	F	F	M	F	M	M	F	M	F
A.A. %																
LYS	91.4	89.4	93.2	90.6	94.7	94.8	93.8	94.8	94.2	93.8	93.2	90.9	94.5	94.8	95.0	96.2
HIS	94.6	93.3	95.1	94.8	94.1	94.3	95.1	94.8	94.9	95.0	93.6	90.6	95.2	95.1	95.2	96.9
ARG	96.4	95.9	96.7	96.3	94.4	97.0	97.5	97.4	97.3	97.5	96.6	94.9	97.5	97.4	97.8	98.7
ASP	92.8	90.4	93.0	93.8	94.6	94.9	94.9	95.4	94.7	94.7	93.4	89.6	95.1	95.1	95.6	96.8
THR	89.4	85.5	90.5	91.2	92.5	92.4	92.4	93.8	92.7	92.3	90.5	86.9	92.9	93.3	93.7	95.3
SER	93.2	90.9	93.5	94.5	95.2	94.7	95.4	95.7	95.4	95.3	94.1	91.7	95.6	95.7	96.0	97.3
GLU	95.0	92.8	95.3	95.0	96.4	96.5	96.3	96.9	96.3	96.1	95.2	92.5	96.6	96.7	97.0	97.8
PRO	92.8	90.5	92.8	92.9	94.0	92.6	94.9	94.1	95.0	95.3	93.1	90.3	95.7	95.1	95.9	96.8
GLY	89.5	85.4	87.6	89.5	91.8	90.7	92.4	92.5	92.3	92.2	90.3	84.8	93.3	93.1	94.1	95.1
ALA	86.4	81.3	87.7	84.9	91.4	91.6	90.9	92.4	90.6	90.0	88.3	81.8	91.3	91.7	92.6	93.8
CYS	94.3	93.3	94.3	94.1	95.0	93.9	96.9	94.2	90.0	91.1	88.4	80.0	93.4	89.8	93.1	95.3
VAL	89.4	85.6	89.9	89.3	92.6	93.0	92.7	93.8	92.8	92.6	90.6	85.6	93.1	93.0	93.9	95.3
MET	90.5	87.8	91.7	91.2	94.2	94.6	94.1	94.6	84.1	85.3	81.2	83.2	85.7	85.0	87.7	90.3
ISO	89.8	85.9	90.6	90.1	93.0	93.3	92.9	94.4	93.0	92.8	91.4	86.1	93.5	93.6	94.3	95.4
LEU	91.7	88.2	92.2	91.9	94.2	94.6	94.4	95.5	94.4	94.2	92.8	89.1	94.6	94.7	95.1	96.3
TYR	89.7	87.7	90.3	90.0	92.1	92.4	93.0	93.8	91.2	92.5	90.7	86.2	91.5	91.6	94.6	95.6
PHE	90.7	87.5	91.4	91.5	93.6	93.5	94.0	94.5	93.8	93.7	92.3	88.0	94.2	94.0	94.5	95.9

Appendix Table VI Individual amino acid availabilities for pigs from Study F.

	Period I								Period II							
Pig	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Diet[1]	C	C	W	W	A	A	D	D	W	W	A	A	D	D	C	C
A.A.%																
LYS	92.8	91.9	87.4	91.1	87.3	85.1	94.5	92.8	91.6	87.6	90.9	87.8	93.3	96.4	92.1	90.5
HIS	96.0	95.4	88.1	91.8	89.8	87.6	96.8	95.5	92.7	87.1	84.5	90.2	96.9	97.7	95.0	94.3
ARG	97.3	96.6	92.8	95.1	93.4	92.1	97.8	96.9	95.4	92.8	95.3	93.5	97.9	98.5	96.8	96.0
ASP	93.5	92.3	87.8	84.6	84.4	85.3	95.0	93.2	85.0	88.0	87.9	85.3	94.3	95.2	92.5	91.0
THR	90.8	88.9	84.7	79.1	79.8	79.6	93.0	90.4	80.6	84.9	84.1	80.5	92.0	93.2	89.0	87.6
SER	93.8	92.5	87.1	83.0	85.1	86.1	95.4	93.2	83.8	87.6	88.3	85.4	94.2	95.3	92.5	91.0
GLU	95.5	94.6	90.3	88.6	88.9	89.5	96.3	94.3	88.3	90.6	91.8	89.9	95.9	96.7	94.8	93.7
PRO	94.2	93.7	75.1	82.2	77.3	65.6	94.6	92.1	79.0	77.1	84.3	83.6	94.3	94.7	93.6	94.5
GLY	89.5	88.0	79.2	77.6	76.4	77.9	92.7	90.5	77.2	80.3	81.6	78.7	91.9	93.2	88.2	86.5
ALA	88.3	86.3	81.1	78.0	75.3	77.1	90.9	87.6	76.7	81.3	82.1	78.1	89.4	91.4	86.2	83.3
CYS	93.5	90.8	85.8	79.7	75.8	79.0	92.9	90.1	82.8	85.4	81.3	77.4	92.4	92.6	92.1	90.8
VAL	91.9	90.1	86.6	83.1	81.9	81.3	93.6	91.6	83.4	86.5	87.0	84.2	93.0	94.2	90.0	88.2
MET	89.1	89.0	71.8	65.5	59.0	67.2	82.9	77.7	65.3	69.5	71.0	68.0	81.3	84.1	86.8	85.1
ISO	92.4	90.9	87.3	84.3	82.9	81.6	94.0	92.1	83.8	87.3	87.1	84.4	93.2	94.3	91.0	89.5
LEU	92.6	91.1	87.5	83.8	84.5	84.9	94.4	92.7	84.3	87.6	88.2	85.7	93.7	94.8	91.1	89.6
TYR	89.1	86.8	75.9	71.0	75.6	81.6	89.8	87.8	70.8	77.4	81.7	77.3	88.8	90.4	86.9	85.0
PHE	93.6	92.0	86.9	83.7	85.4	84.1	94.1	92.1	84.2	87.4	88.0	86.5	93.4	94.4	92.0	90.7

[1] C - soybean meal; W - faba bean; A - autoclaved faba bean; D - dehulled faba bean.

Appendix Table VII Individual amino acid availabilities for pigs from Study F.

	Period III								Period IV							
Pig	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Diet	A	A	D	D	C	C	W	W	D	D	C	C	W	W	A	A
A.A. %																
LYS	90.5	90.9	96.3	92.6	89.1	88.4	83.0	85.5	95.9	96.0	93.4	95.0	83.7	85.8	85.3	83.1
HIS	92.4	93.3	97.8	96.2	93.6	93.9	84.4	87.3	97.2	97.4	96.5	95.6	87.4	88.5	86.9	87.2
ARG	95.4	95.8	98.6	97.7	96.1	96.3	91.1	92.5	98.3	98.5	96.7	96.1	91.7	93.0	92.6	91.8
ASP	86.2	85.8	96.2	94.8	90.3	91.2	80.5	88.1	96.4	96.6	94.4	94.0	84.4	84.1	82.6	85.1
THR	82.7	81.2	94.4	92.1	86.4	87.7	73.9	83.9	94.4	94.5	93.2	92.4	80.0	78.8	81.1	82.9
SER	85.6	86.3	96.0	95.0	91.7	92.5	81.3	87.6	96.6	96.6	94.9	94.2	85.4	84.5	83.3	85.4
GLU	89.9	89.8	97.2	96.1	92.3	93.8	83.5	89.7	97.4	98.4	96.0	95.5	87.5	86.5	88.0	90.0
PRO	82.8	78.8	95.7	95.7	91.5	93.1	77.0	67.9	96.2	96.0	95.6	95.6	82.0	75.5	81.7	82.9
GLY	79.0	78.5	94.4	92.4	82.6	85.6	71.4	79.1	94.6	95.0	90.6	90.3	76.3	75.5	76.7	78.9
ALA	78.5	77.1	93.2	91.0	80.3	83.8	70.3	74.7	93.3	93.9	89.9	89.6	75.6	76.3	74.7	77.9
CYS	76.8	80.5	92.8	91.9	90.1	90.3	77.4	81.0	94.2	94.6	95.4	92.1	77.3	77.1	77.6	80.6
VAL	84.4	84.1	95.5	92.7	83.6	86.8	74.8	80.2	94.8	95.4	91.8	91.7	77.9	79.3	79.1	81.3
MET	62.0	70.4	86.4	79.9	81.2	82.5	55.5	60.6	86.4	87.5	91.2	88.6	62.4	57.7	59.0	63.7
ISO	84.4	84.2	95.6	92.9	85.0	87.6	75.6	80.9	94.9	95.5	92.4	92.3	80.0	79.2	83.1	85.2
LEU	86.5	86.4	95.8	94.0	87.4	89.4	78.9	83.4	95.9	96.1	93.2	92.7	83.1	83.4	83.0	85.4
TYR	76.6	78.1	92.4	92.3	86.5	89.2	75.6	79.5	95.0	94.0	91.1	90.4	81.4	83.2	83.7	85.7
PHE	85.3	85.9	95.6	93.7	88.7	90.5	78.6	82.6	95.7	95.9	93.6	93.2	82.7	83.2	83.3	85.3

Appendix Table VIII Individual nitrogen digestibility values for pigs from Study E.

Percent nitrogen digestibility for pigs fed the soybean meal diet.

	Period I				Period II				Period III				Period IV			
Pig	93	64	25	83	22	69	52	080	93	64	25	83	22	69	52	080
Sex	F	M	F	M	M	F	M	F	F	M	F	M	M	F	M	F
Dig.	85.3	78.3	78.9	70.4	82.2	78.3	93.8	79.9	93.3	86.9	90.2	77.7	88.8	85.4	87.6	90.2

Percent nitrogen digestibibility for pigs fed the F.P.C. diet.

Pig	56	62	26	84	63	57	82	29	56	62	26	84	63	57	82	29
Sex	F	M	F	M	M	F	M	F	F	M	F	M	M	F	M	F
Dig.	98.8	94.8	95.5	97.5	94.3	93.3	93.9	96.8	94.1	94.1	91.6	88.1	96.1	93.3	94.0	94.7

Appendix Table IX Individual nitrogen digestibility values for pigs from Study F.

	Period I								Period II							
Pig	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Diet	C	C	W	W	A	A	D	D	W	W	A	A	D	D	C	C
Dig.%	92.1	90.1	84.7	82.5	80.4	83.5	93.8	89.5	82.8	85.4	84.9	83.2	93.1	94.1	92.5	88.5
	Period III								Period IV							
Pig	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Diet	A	A	D	D	C	C	W	W	D	D	C	C	W	W	A	A
Dig.%	81.8	83.7	95.1	92.8	86.3	88.9	77.3	81.8	95.3	95.6	92.4	91.8	81.7	81.8	80.1	83.0

Appendix Table X Amino acid composition of diets for Studies A and B.

	Study A			Study B							
				Part I				Part II			
A.A.%	Soybean Meal	Faba bean	Dehulled Faba bean	Soybean Meal	Faba bean	Dehulled Faba bean	Autoclaved Faba bean	Soybean Meal	Faba bean	Dehulled Faba bean	Autoclaved Faba bean
LYS	0.85	0.83	0.89	0.88	0.84	0.89	0.80	1.07	0.95	1.00	0.92
HIS	0.40	0.37	0.40	0.42	0.38	0.40	0.36	0.50	0.40	0.42	0.40
ARG	1.01	1.12	1.22	1.00	1.17	1.28	1.14	1.17	1.18	1.24	1.26
ASP	1.75	1.55	1.67	1.65	1.50	1.63	1.89	1.89	1.58	1.68	1.58
THR	0.67	0.56	0.60	0.65	0.50	0.58	0.57	0.70	0.57	0.60	0.60
SER	0.80	0.67	0.72	0.76	0.51	0.71	0.68	0.80	0.64	0.69	0.67
GLU	4.17	3.32	3.56	4.01	3.00	3.44	3.25	4.41	3.28	3.53	3.37
PRO	1.52	1.11	1.15	1.47	1.29	1.21	1.20	1.58	1.14	1.24	1.12
GLY	0.83	0.92	0.98	0.77	0.68	0.73	0.72	0.88	0.75	0.77	0.75
ALA	0.78	0.80	0.86	0.78	0.66	0.72	0.68	0.89	0.74	0.77	0.72
CYS	0.32	0.23	0.24	0.28	0.22	0.23	0.22	0.29	0.23	0.26	0.23
VAL	1.02	0.86	0.92	0.98	0.84	0.85	0.90	1.09	0.90	0.92	0.87
MET	0.29	0.19	0.19	0.27	0.19	0.18	0.19	0.28	0.40	0.39	0.32
ISO	0.83	0.70	0.73	0.80	0.68	0.73	0.70	0.87	0.70	0.74	0.71
LEU	1.43	1.23	1.30	1.21	1.29	1.57	1.26	1.34	1.27	1.34	1.27
TYR	0.52	0.42	0.44	0.49	0.46	0.50	0.47	0.50	0.39	0.39	0.50
PHE	1.05	0.84	0.90	1.01	0.82	0.84	0.79	1.09	0.81	0.85	0.82

Appendix Table X1 Amino acid composition of diets for Studies C, D, E and F.

	Study C		Study D		Study E		Study F			
A.A.%	Soybean Meal	F.P.C.	Soybean Meal	F.P.C.	Soybean Meal	F.P.C.	Soybean Meal	Faba bean	Dehulled Faba bean	Autoclaved Faba bean
LYS	0.91	0.77	1.24	1.12	1.26	1.13	1.29	1.20	1.23	1.25
HIS	0.45	0.44	0.51	0.48	0.51	0.47	0.55	0.50	0.50	0.52
ARG	1.05	1.01	1.39	1.61	1.42	1.70	1.44	1.72	1.82	1.76
ASP	1.46	1.24	2.19	1.82	2.32	2.03	2.32	2.16	2.31	2.15
THR	0.63	0.58	0.72	0.58	0.75	0.64	0.82	0.70	0.71	0.78
SER	0.85	0.80	0.92	0.77	0.98	0.86	0.99	0.92	0.95	0.90
GLU	4.79	4.86	3.61	2.84	3.69	3.15	3.68	3.49	3.61	3.61
PRO	1.34	1.37	0.95	0.67	1.06	0.83	1.01	0.91	0.85	0.95
GLY	0.84	0.80	0.82	0.69	0.88	0.75	0.86	0.85	0.86	0.90
ALA	0.77	0.72	0.84	0.69	0.89	0.75	0.89	0.84	0.87	0.86
CYS	0.27	0.32	0.30	0.30	0.28	0.21	0.29	0.25	0.23	0.23
VAL	0.91	0.82	0.98	0.82	1.00	0.90	1.03	0.96	1.02	1.00
MET	0.24	0.32	0.30	0.27	0.30	0.17	0.29	0.17	0.15	0.17
ISO	0.80	0.73	0.91	0.74	0.93	0.81	0.96	0.86	0.90	0.98
LEU	1.41	1.30	1.52	1.30	1.58	1.44	1.60	1.50	1.59	1.56
TYR	0.45	0.44	0.50	0.40	0.54	0.47	0.51	0.54	0.50	0.58
PHE	0.91	0.85	0.99	0.76	1.00	0.82	1.02	0.92	0.90	0.91