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
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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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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
[1]				
Essential				
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).