Agri-Food and Biosciences Institute

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The use of non-conventional diet formulations for finishing pigs

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1. EXECUTIVE SUMMARY

The potential for eliminating maize and fish meal, and reducing the levels of cereals in diets for finishing pigs was examined. Non-conventional feedstuffs are now being included in formulations to an increasing extent. However, the relationships between their chemical composition and book values and the nutrients which are actually available to the animal are much less predictable. In addition, the fatty acid profile of some by-products may have an adverse effect on carcase fat quality.

Four diets, ranging from one containing a proportion of maize and fish meal through to cereal contents from 70% to 20% were formulated and fed to 320 finishing pigs from 40 kg to slaughter. Growth performance and feeding behaviour were monitored over the finishing period and skatole (boar taint) and economic analyses were carried out.

Finishing pigs can perform equally well whether maize and fish meal are included in the diet or not. No significant diet effects on palatability or feeding behaviour were found. However, a non-significant trend towards reduced performance was observed when the cereal content of the diet was reduced to 30% even though a similar content of DE was maintained in the ration.

Killing out percentage and fat depths at the P_2 position tend to be reduced when by-product diets are fed.

Pig fat tends to follow the fatty acid profile of the diet and this resulted in the pig fat having a higher proportion of unsaturated fat when the by-product diets were fed. This is beneficial in terms of human health but negative in terms of feed processing, presentation and storage.

The incidence of skatole was not affected by the range of diets used in this study.

At today's prices (1997), cereal/soya diets, without maize or fish offer best opportunities. By-product diets must be bought competitively to be cost effective.

2. INTRODUCTION

One of the most fundamental questions to be answered when formulating diets for finishing pigs is which raw materials should be included in the formulation. A specialised computer programme designed for ration formulation is then used to calculate how much of each ingredient should be included to meet a particular specification. The basic assumption necessary for these packages to operate successfully is that the inclusion of each unit of nutrient gives an additive linear increase to the total in the diet. Traditionally, feedstuffs have been assessed on the basis of digestibility. This has advantages in that digestibility can be measured easily and at relatively low cost and results are both additives and independent of pig type. There are, however, limitations to the digestibility system since the energy contribution from protein and fibre is overestimated while that for oil is underestimated. This is partly because no account is made of how efficiently nutrients are metabolised to yield energy, and partly because no account is made of the site of feed digestion within the gut.

Non-conventional feedstuffs are now being included in formulations to an increasing extent. However, the relationships between their chemical composition and the nutrients which are actually available to the animal are much less predictable.

Another problem associated with the use of by-products is that of carcase fat quality. There is some evidence to suggest that carcase fat composition is affected by the composition of dietary fat. However, the relationship between fatty acid composition and fat quality is not clear.

One of the side effects of genetic selection over recent years is reduced voluntary feed intake of pigs. Finishing pigs on commercial units are considered as having good appetites when intakes are at approximately 2.2 kg/day. Many factors can influence feed intake including group size, water availability, feeding space both at the feeder and in the immediate area surrounding the feeder, pen shape, type of diet and diet change (Collier *et al,* 1972; Collier 1980).

In this study, all pigs were offered a 30% cereal diet for two weeks at the beginning of the finishing period when the pigs were approximately 40 kg live weight. At this point, pigs in three of the four treatments experienced an abrupt change of diet (Table 1). Their feeding behaviour was observed to identify the effect of change of diet.

The objective was to compare the performance from a high quality diet (including maize and fish meal) with that from a range of diets in which maize and fish meal and an increasing proportion of cereals were eliminated.

3. MATERIALS AND METHODS

3.1 Animals

Four hundred 10-week old animals (crossbreds from Landrace and Large White parentage by performance tested boars using semen from a local AI stud) in groups of 10 (5 boars, 5 gilts) were offered a diet with 30% cereals (Diet 3) for 2 weeks to allow the pigs to adjust to a diet with a low cereal content. This was the pre-experimental period. At 12 weeks of age, 8 pigs (4 boars, 4 gilts) balanced for gender and weight, were selected from each group of 10 and allocated in their groups of 8 to the four treatments.

3.2 Feeders and feeding regime

Pigs were offered the experimental diets *ad libitum* in single space wet and dry feeders (Verba) with water supplied by a nipple drinker in the feeder.

3.3 Housing

Pigs were finished from 12 weeks of age weighing approximately 40 kg to slaughter at 95 kg in fully slatted floor pens (0.4 m^2 per pig). The pigs were kept in mixed sex groups (boars and gilts) in houses with ACNV (Automatically Controlled Natural Ventilation).

3.4 Diets

Three diets were formulated to contain CP 21%, lysine 1.1% and DE 13.7 MJ/kg. Diets 1 and 2 both contained 70% cereals but maize and fish meal was removed from the formulation in Diet 2. Diet 3 contained 30% cereals. A fourth diet, Diet 4, was formulated to contain a low level of cereals but without the CP, lysine and DE constraints of Diets 1-3. Diet 4 contained 20% cereals, 22% CP, 1.1% lysine and a reduced DE of 13.4 MJ/kg. Composition and analyses of diets are shown in Tables 1, 2 and 3.

Table 1 Treatments and associated diets and diet changes

	Diet	
Treatment	10 - 12 weeks of age	12 weeks to slaughter
1	30% cereal	70% cereal (maize and fish)
2	30% cereal	70% cereal
3	30% cereal	30% cereal
4	30% cereal	20% cereal

Table 2 Composition (kg/t) of experimental diets

	1	**2**	**3**	**4**
Barley	261	403	183	100
Wheat	252	295	125	103
Maize	200	-	-	165
Soya 50	240	268	230	-
Herring	25	-	-	-
Limestone	3.5	4	5	8
Broiler fat	-	10	40	40
Sunflower	-	-	-	25
Molaferm	-	-	40	30
Copra	-	-	75	75
Rapeseed Ext.	-	-	65	100
Pollard meal	-	-	50	150
Maize by-product	-	-	125	150
Maize gluten feed	-	-	50	55
Methionine	-	0.25	0.1	-
Lysine	-	-	0.04	0.10
Dicalcium phosphate	10	11.5	5	-
Salt	3	3.5	2	2.5
Pig supplement	5	5	5	5
Avotan	0.4	0.4	0.4	0.4

Table 3 Composition (kg/t or MJ/kg) of experimental diets

	Diet			
	1	**2**	**3**	**4**
Cereals	700	700	300	200
DE	13.7	13.7	13.7	13.4
CP	205	205	205	217
Lysine	11	11	11	11

3.5 Measurements

Growth rate and feed conversion ratio from 40 kg to slaughter were recorded. In addition, daily feed intakes were recorded for the final week of the pre-experimental period and for the first week when the experimental diets were introduced. Carcase weight and carcase fatness were also measured for each pig.

Sample joints were taken at slaughter for dissection into skin, subcutaneous fat and lean. Fat samples from the neck region were also obtained and fatty acid profiles were determined using Gas Chromatography.

3.6 Behaviour

The behaviour at the feeder of the pigs on all four diets was recorded for the first two days after the diet was changed (Table 1). The number of visits to the feeder and the time spent at the feeder by all the pigs in the pen were recorded. These data were analysed to determine if pigs were spending longer at the feeder for any particular diet.

4. RESULTS

Results are shown in Table 4 and Figures 1-5. The mean daily feed intake was 2.1 kg across all four treatments and did not differ significantly between treatments. There were no significant differences between pigs on Diets 1, 2 and 3 for daily liveweight gain (dlwg) however pigs offered Diet 4 had a lower dlwg than pigs on the other 3 diets ($P<0.05$).

Feed conversion ration (FCR) was not affected by diet and the mean of the four treatments was 2.41. Pigs fed Diet 1 had a higher killing out percentage (kill out %) than pigs fed Diet 4 ($P<0.05$) with Diets 2 and 3 being intermediate. Feed:carcase gain ratios for the by-product diets (Diets 3 and 4) were 7% higher ($P<0.05$) than for the cereal-based diets (Diets 1 and 2). P_2 values for Diets 1 and 2 were higher than for Diet 4 ($P<0.05$) with the value for Diet 3 being intermediate. The lower P_2 value for Diet 4 meant that lean content of the carcase as estimated by the Ulster Probe Formula was higher for Diet 4 ($P<0.05$) than for Diets 1, 2 and 3.

Table 4 Performance of finishing pigs fed cereal and by-product based diets

	Diet					
	1	**2**	**3**	**4**	**s.e.m.**	**P**
Start wt (kg)	41	41	42	41	1.0	NS
Final wt (kg)	99	99	99	99	0.75	NS
DLWG (g/day)	910[a]	910[a]	880[a]	860[b]	14.1	<0.05
Feed intake (kg/day)	2.1	2.1	2.1	2.1	0.04	NS
FCR	2.38	2.37	2.44	2.45	0.039	NS
KO (%)	77.7[b]	77.3[ab]	76.3[ab]	75.8[a]	0.32	<0.001
Feed:carcase	2.98[a]	2.99[a]	3.17[b]	3.19[b]	0.053	<0.05
P_2 (mm)	9.7[b]	9.4[b]	9.2[ab]	8.3[a]	0.34	<0.05
Ulster Probe (%)	59.6[a]	59.8[a]	59.9[a]	60.9[b]	0.33	<0.05

Daily feed intakes for the final week of the pre-experimental period and the first week of the experimental period are shown in Figure 1. Mean individual feed intakes at the beginning of the last week of the pre-experimental period were approximately 1 kg when all pigs were fed Diet 3 and stabilised at approximately 1.5 kg per day after the experimental diets were introduced.

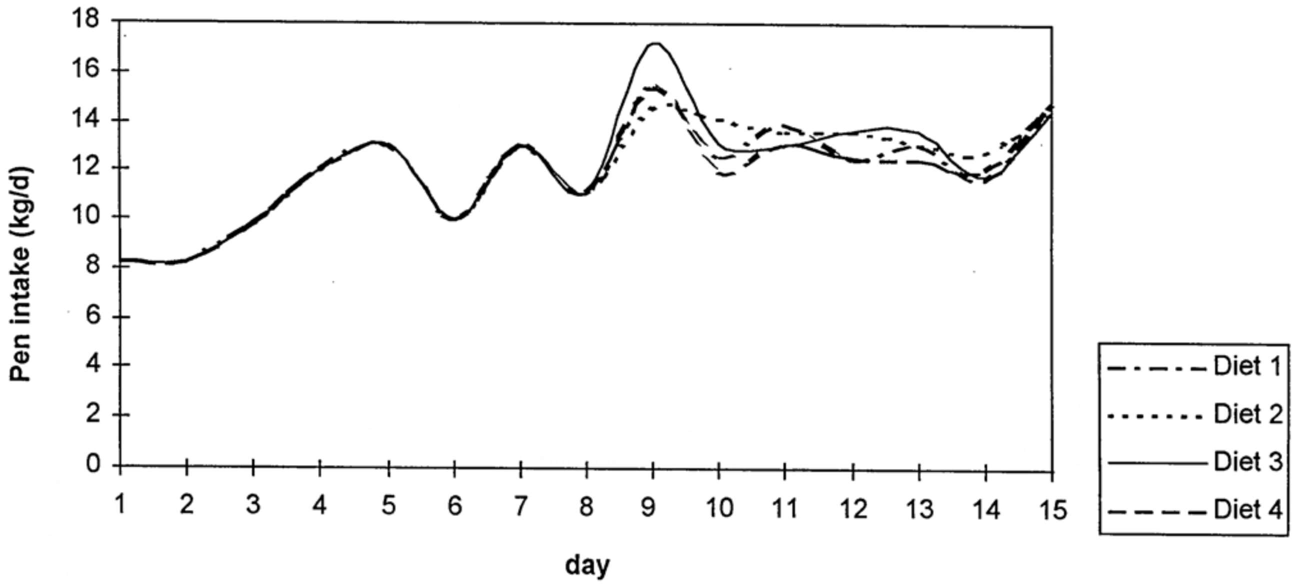

Figure 1 Feed intake per pen (kg/day)

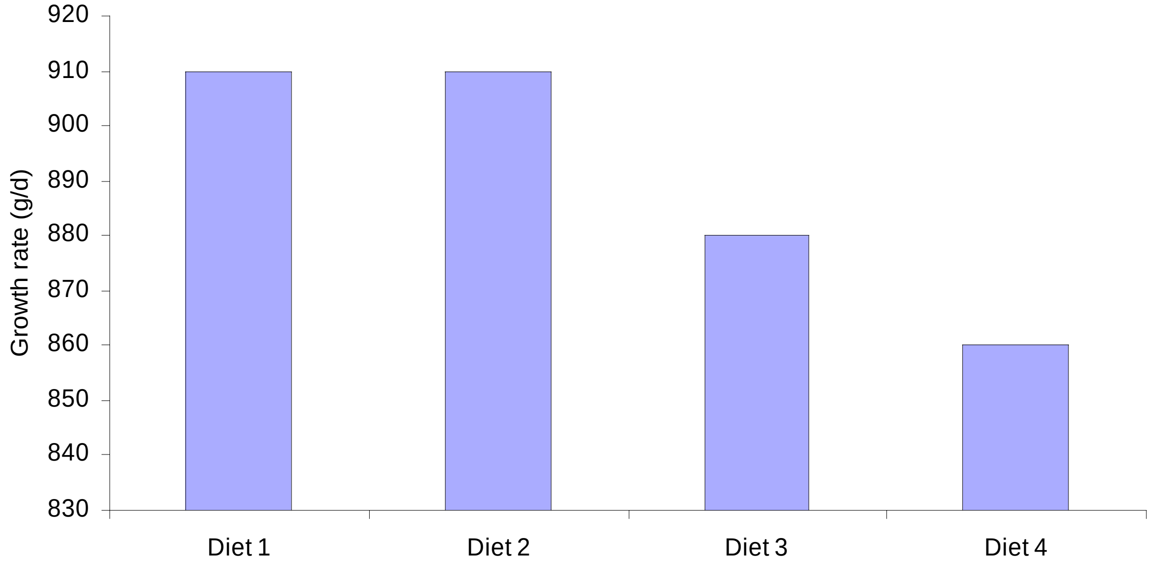

Figure 2 Growth rate of pigs (g/day)

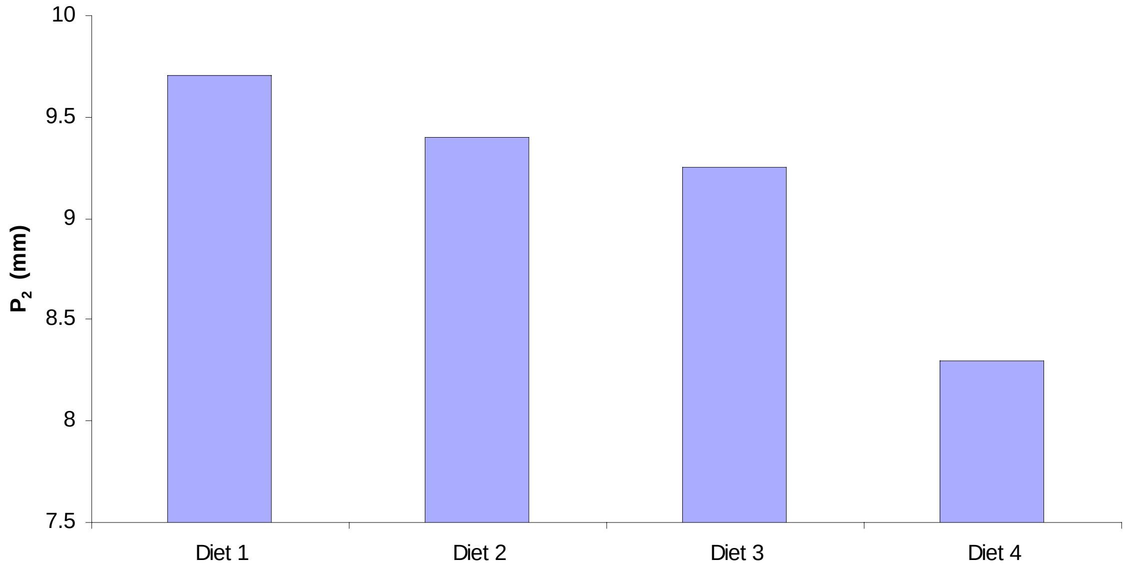

Figure 3 P_2 (mm) fat depths

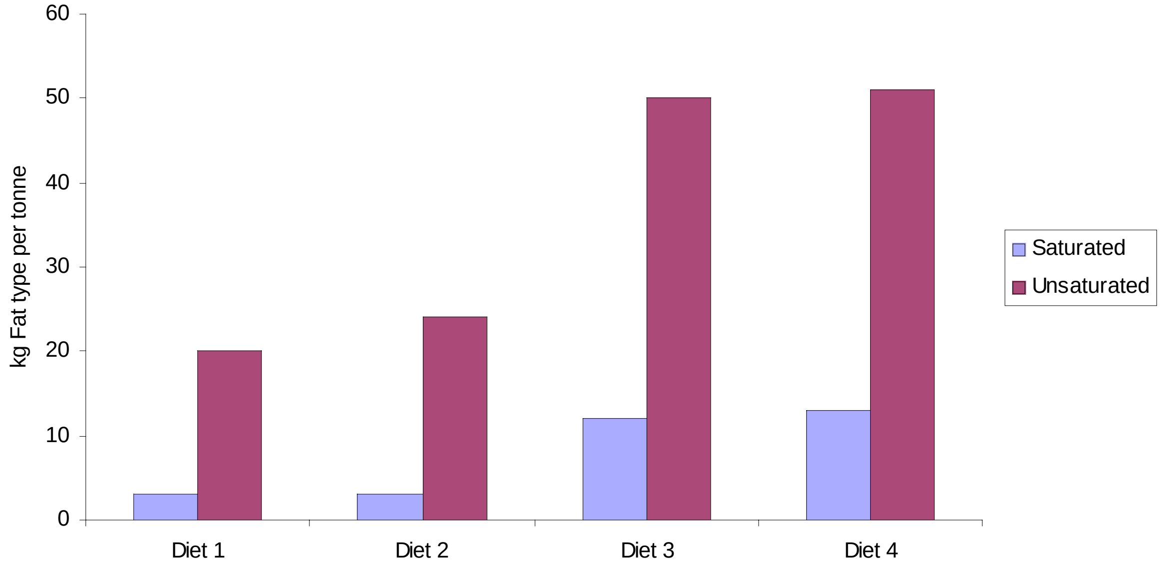

Figure 4 Kilogrammes of each fat type per tonne (as fed basis)

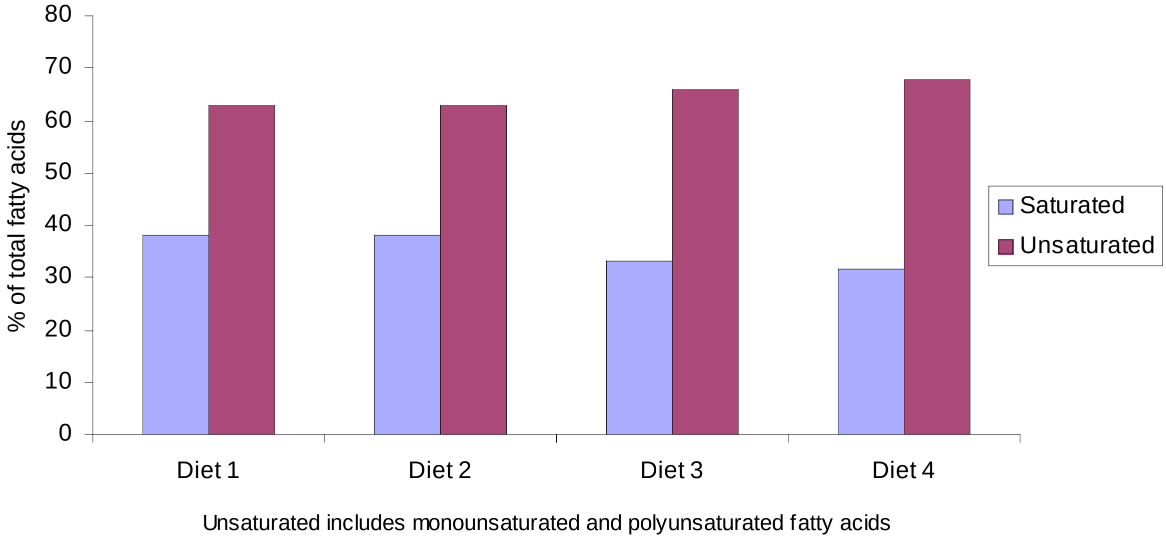

Figure 5 Fatty acid profile of pig fat samples

Sample joints taken from pigs fed Diet 4 (Table 5) had a higher lean content (P<0.01) and a lower subcutaneous fat content (P<0.001) than the cereal treatments, with the values for Diet 3 being intermediate. There were no significant treatment effects on skin content of joints.

Table 5 Composition (g/kg) of sample joints

	Diet				s.e.m.	P
	1	2	3	4		
Lean	820[a]	826[a]	836[ab]	852[b]	5.5	<0.01
Subcutaneous fat	127[b]	121[b]	111[ab]	95[a]	5.4	<0.001
Skin	67	52	53	65	9.5	NS

For explanation of statistical terms – see Appendix 3

The composition of fat and lean samples are shown in Tables 6-8. There was a significant (P<0.05) interaction between gender and diet on DM content of lean samples in that gilts had a higher DM content than boars for the cereal diets but not for the by-product diets. Treatment effects on total nitrogen, ash and total lipid contents of the lean samples were not significant, mean values being 36.83, 11.3 and 17.3 respectively. The mean total nitrogen and lipid contents of the fat samples were 9.95 and 742 respectively. The DM content of fat samples from treatment 1 was higher than those from treatments 2 and 4 (P<0.01) with the value for treatment 3 being intermediate. Only trace levels of ash were present in the fat samples.

Table 6 The effect of diet on DM content of samples of lean from boars and gilts

Diet	Boars	Gilts	s.e.m.	P
1	252[a]	264[d]	1.8	<0.05
2	258[bc]	264[d]		
3	259[bcd]	262[cd]		
4	256[ab]	258[bc]		

Table 7 The effect of diet on composition of samples of lean meat and fat

	Diet				**s.e.m.**	**P**
	1	**2**	**3**	**4**		
Lean						
Total N	36.75	36.96	36.98	36.64	0.165	NS
Ash (fresh)	11.3	11.4	11.2	11.2	0.13	NS
Total lipid	18.3	18.0	16.3	16.6	1.08	NS
Fat						
Total N	9.94	9.18	9.78	10.91	0.493	NS
DM	813[b]	815[a]	805[ab]	781[a]	7.6	<0.01
Ash (fresh)	0	0	0	0	0	-
Total lipid	750	756	745	717	10.9	NS

Samples of lean from gilts had a lower nitrogen content (P<0.001) than boars but ash and lipid contents were not significantly different, the mean values for the latter two being 11.3 and 17.4% respectively. Samples of fat from gilts had significantly lower nitrogen contents (P<0.01), higher DM contents (P<0.001) and higher total lipid contents (P<0.001) than samples taken from boars.

Table 8 The effect of gender on composition of samples of lean meat and fat

	Gender			
	Boars	**Gilts**	**s.e.m.**	**P**
Lean				
Total N	36.44	37.23	0.116	<0.001
Ash (fresh)	11.2	11.3	0.09	NS
Total lipid	17.2	17.5	0.76	NS
Fat				
Total N	10.68	9.22	0.349	<0.01
DM	781	826	5.4	<0.001
Ash (fresh)	0	0	-	-
Total lipid	714	770	7.7	<0.001

A summary of the results of fatty acid analysis is shown in Tables 9-13 and the values for the individual fatty acids are shown in Appendix 1. The individual fatty acids are expressed as a percentage of total fatty acids. The cereal-based diets (Diets 1 and 2) had lower contents of saturated and monounsaturated fatty acids than the by-product diets. Diet 1 had the highest content of polyunsaturated fatty acids while Diet 2 had the highest monounsaturated/saturated (M/S) ratio. Since the by-product diets had higher total fat contents, the intakes of all types of fatty acids, but polyunsaturated fatty acids in particular, were higher than for the cereal diets.

Table 9 Fatty acid profile of diets (% of total fats)

	Diet analysis			
	1	**2**	**3**	**4**
Total saturated	15.72	13.02	19.08	19.75
Total monounsaturated	26.98	39.50	33.17	34.84
Total polyunsaturated	56.26	47.03	47.91	45.06
M/S	1.72	3.03	1.74	1.76
As fed (g/kg feed intake)				
Total saturated	3.70	3.5	11.6	12.4
Total monounsaturated	6.4	10.6	20.2	21.8
Total polyunsaturated	13.4	12.7	29.2	28.3
Total fat	23.5	26.8	61.0	62.5

Table 10 The effect of diet on fatty acid profile of fat

	Diet					
% of total fatty acids	**1**	**2**	**3**	**4**	**s.e.m.**	**P**
Total saturated	37.5^c	37.8^c	34.0^b	32.3^a	0.30	<0.001
Total monounsaturated	39.9^b	38.8^b	36.6^a	35.4^a	0.32	<0.001
Total polyunsaturated	22.6^a	23.4^a	29.4^b	32.2^c	0.40	<0.001
Monounsaturated/saturated	1.07^{ab}	1.03^a	1.08^{ab}	1.10^b	0.014	<0.01

Table 11 The effect of gender on fatty acid profile of fat

	Gender			
% of total fatty acids	**Boar**	**Gilt**	**s.e.m.**	**P**
Total saturated	35.5	35.2	0.21	NS
Total monounsaturated	36.5	38.8	0.23	<0.001
Total polyunsaturated	27.9	25.9	0.29	<0.001
Monounsaturated/saturated	1.03	1.11	0.010	<0.001

Table 12 The effect of diet on fatty acid profile of lean

	Diet					
% of total fatty acids	**1**	**2**	**3**	**4**	**s.e.m.**	**P**
Total saturated	36.6[b]	36.3[b]	34.0[a]	32.8[a]	0.28	<0.001
Total monounsaturated	38.4[b]	37.6[b]	32.6[a]	30.9[a]	0.51	<0.001
Total polyunsaturated	25.0[a]	26.1[a]	33.5[b]	36.2[b]	0.68	<0.001
Monounsaturated/saturated	1.05[b]	1.04[b]	0.96[a]	0.94[a]	0.014	<0.001

Table 13 The effect of gender on fatty acid profile of lean

	Gender			
% of total fatty acids	**Boar**	**Gilt**	**s.e.m.**	**P**
Total saturated	34.9	35.0	0.20	NS
Total monounsaturated	34.1	35.7	0.36	<0.01
Total polyunsaturated	31.0	29.4	0.48	<0.05
Monounsaturated/saturated	0.98	1.02	0.010	<0.01

Samples of fat from pigs fed cereal-based diets had higher levels of saturated and monounsaturated fatty acids (P<0.001) than fat from pigs fed by-produced diets. The cereal-based diets produced fat with lower levels of polyunsaturated fatty acids (P<0.001). Samples of fat from pigs fed Diet 2 had the lowest M/S ratio (P<0.01) while the values for Diets 1, 3 and 4 were not significantly different.

The saturated fatty acid content was similar for boars and gilts while boars had lower monounsaturated fatty acid contents (P<0.001), higher polyunsaturated fatty acid contents (P<0.001) and a lower M/S ratio (P<0.001).

Samples of lean taken from pigs fed the by-product diets had lower contents of saturated and monounsaturated fatty acids (P<0.001) but higher contents of polyunsaturated fatty acids (P<0.001). The M/S ratio was also lower for the by-product diets.

Samples of lean taken from boars and gilts were not significantly different in terms of saturated fatty acid content. Samples of lean from boars had lower levels of monounsaturated fatty acids (P<0.01) and higher levels of polyunsaturated fatty acids (P<0.05) than samples taken from gilts. The M/S ratio was also lower for boars than gilts (P<0.01).

There were no differences in the time spent feeding by pigs in any one of the four treatment diets (Tables 14 and 15).

Table 14 Time spent at the feeder by pigs offered Diets 1 to 4

Total time at feeder (hr)	70% cereal (m & fl)	70% cereal	30% cereal	20% cereal	s.e.m.	P
per pen (8 pigs)	4.46	4.28	4.77	3.98	0.573	NS
per pen	0.56	0.54	0.59	0.50	0.07	NS

Table 15 Number of visits to feeder by pigs offered Diets 1 to 4

Visits per day	70% cereal (m & fl)	70% cereal	30% cereal	20% cereal	s.e.m.	P
per pen (8 pigs)	355	383	330	360	38.9	NS
per pen	44.4	47.8	41.2	45.0	4.86	NS

5. DISCUSSION

Diet 1 was formulated to a "typical" Northern Ireland specification for finishing pigs, containing maize, fish meal and a high level of cereals. The fact that in performance terms, Diets 1 and 2 were the same indicates that maize and fish meal can be eliminated from formulations for finishing pigs, with considerable cost savings. This is a very important result given the socio-economic and political factors in force at the present.

Many factors impinge on the balance of trade between Northern Ireland, other European countries and the US. These factors will determine whether the cost of fish meal will become prohibitively expensive or even available for use in feed formulations. While maize has many attractive characteristics for ration formulation including high palatability, this study demonstrates that it is not necessary for finishing pig diets.

Comparing Diet 3 (30% cereals) with Diets 1 and 2, all performance parameters, with the exception of feed:carcase gain ratio, were not significantly different. However, there was a trend towards reduced performance with the 30% cereal diet. These diets were formulated to contain equivalent levels of digestible energy (DE). The observed trend may be due to a fundamental problem in that the DE system may not be adequate for predicting animal performance when comparisons are made between different diet types. The relationship between chemical composition and the nutrients which are actually available to the animal are much less predictable for by-products and therefore another system may be required if diets are to be formulated more closely to their "true" energy value. One alternative system is that of "Net energy" (NE). This is much more costly and difficult to determine than DE and is also not without limitations. However, NE does provide a closer estimate of the true energy available for maintenance and production purposes by excluding all the losses incurred in the utilisation of the energy source.

Daily feed intake patterns when the experimental diets were first introduced were similar indicating that there were no palatability problems for pigs of approximately 40 kg live weight. The fact that feed intakes were similar for all four diets during the total experimental period suggests that by-product diets and cereal diets are equally palatable to finishing pigs.

This is in line with the feed intake results which were 2.1 kg/day/pig on all four treatment diets. The purpose of examining the behaviour was to investigate how the pigs reacted to the new diet. It is obvious from the comparison of feeding behaviour for pigs on Diets 1, 2 and 4 (new diets) with the feeding behaviour of pigs on Diet 3 that changing the diet did not reduce the frequency of visits to the feeder or time spent feeding (Tables 14 and 15).
The lack of difference in time spent at the feeder combined with similar intakes for all diets give some indication on the palatability of the diet. If pigs had found one diet to be particularly unpalatable then intakes would have been expected to be lower, or time spent at the feeder increased. Increased time at the feeder has implications for both welfare and productivity of pigs. Morrow and Walker (1994) found that aggression at the feeder and incidence of queuing increased when duration of feeder visits increased. This led to poorer food conversion and reduced welfare.

The fact that kill out % tended to decrease as the level of by-products in the diet increased is in keeping with the findings of Batterham (1989). This effect appears to be due to a shift in the site of digestion and absorption towards the hindgut. This causes a reduction in kill out % because of the increase in size of the hindgut and also a concomitant increase in gut fill.

Most significant effects are associated with the performance of pigs fed Diet 4 (20% cereals). It was not possible with the range of ingredients available at the time of experimentation to formulate Diet 4 to have equivalent DE levels to the other three diets. Therefore, it must be stressed that the significant reduction in growth performance of pigs fed Diet 4 must not be attributed solely to the presence of by-products, but also, in part, to the lower DE content. Furthermore, while there was a statistically significant reduction in daily liveweight gain with Diet 4, this would only add a total of 3 days to the finishing period from 40 kg to 100 kg. Thus in terms of days to slaughter, the effect is small.

The effect of diet on feed to carcase gain has major implications for the industry. Feed represents the largest variable cost in a finishing enterprise and therefore feed cost and feed conversion ratio are critical determinants of profit. While feed conversion ratios were not significantly different between treatments, the combined effect of kill out % and feed conversion ratio meant that more of the by-product diets were required per kg carcase gain. Since producers are paid on a carcase basis, this value is very important. Clearly the relative values of feed and carcase will determine whether any reduction in the price of feed which may arise from the use of lower quality diets such as Diet 4 compensates for the extra amount required to finish the animal.

These are product value advantages associated with the use of by-products. The tendency for P_2 to be reduced when by-products are fed means that more animals will attain higher grades with consequent bonuses.

Carcase lean content was estimated using the Ulster Probe formula and by dissection. The higher lean content by dissection of samples taken from pigs fed Diet 4 was due to the lower content of fat. The lean content of pigs fed Diet 4 was significantly higher using the Ulster Probe formula – mainly due to the P_2 factor in the calculation. Thus by-product diets tend to improve grading and carcase value irrespective whether producers are paid by P_2 or lean meat content.

It was not possible with the range of by-products available at time of experimentation to formulate a diet with a cereal content of 20% or less to the same specification as Diets 1, 2 and 3 in this experiment. Therefore, in the future it may have to be accepted that a more flexible approach be taken to diet formulation and a wider range of materials be considered.

All feedstuffs, but by-products in particular, should be thought of as a variable package of nutrients. For home mixers to compete with the compounder in reaching target dietary specification, regular ingredient analysis must be performed. This is obviously much easier and more cost effective for the compounder who is likely to have the necessary equipment and facilities at the mill, especially with the advent of Near Infra-red Reflectance Spectroscopy (NIRS) analysis which is much more rapid than traditional wet chemistry procedures. Raw materials should always be evaluated for their true cost per nutrient relative to the other ingredients used in the ration.

Extra care may also have to be taken with feed storage as levels of by-products are included, particularly those with higher levels of oil. Higher levels of Vitamin E may also have to be included at the formulation stage to prevent the occurrence of oxidative rancidity.

Several of the by-products used in this study contained considerable levels of oils. Indeed, one obvious way to increase the DE content of the diet is to increase the oil level. However, it is well known that Northern Ireland has one of the highest morbidity and mortality rates from coronary heart disease in the world. The consuming public has become much more health conscious in the recent past. It is not surprising, therefore, that awareness of fat intake and its implications for human health have received much attention. Not all dietary fats are harmful to human health. Unsaturated fatty acids, and polyunsaturated fatty acids (PUFAs) in particular are beneficial to human health, largely through their effect on blood cholesterol levels.

Samples of fat and lean from pigs fed by-product diets had significantly lower contents of both saturated and monounsaturated fatty acids but had more polyunsaturated fatty acids than those from pigs fed cereal diets. St. John *et al.* (1987) and Miller *et al*. (1990) reported that increasing the monounsaturated fatty acid component of fat resulted in a product that was perceived to be more healthy while cooking and sensory properties were not affected. However, Rhee *et al.* (1990) found that increasing the monounsaturated fatty acid component of fat resulted in a decrease in keeping quality.

Since the type of fat deposited correlates highly with dietary fat in pigs, one advantage of by-product diets is that they can be formulated to include beneficial dietary fats and so provide a healthy pork product for human consumption. A complicating factor, however, is the effect that various types of fat have on carcase fat quality. Most are agreed that saturated fats in animal diets have a positive effect on carcase fat quality in that it tends to produce fat that is firm and white. On the other hand, monounsaturated and especially the polyunsaturated fatty acids have a negative influence on carcase fat quality in that it tends to produce fat that is soft, grey and “oily” (Madsen *et al*., 1992).

Boars in our study were not significantly different from gilts in terms of saturated fatty acid content of fat or lean. Boars tended to have less monounsaturated but more polyunsaturated fatty acids than gilts. Some of the differences in the present study from the observation of Malmfors, Lundström and Hansson (1978) could be due to differences in genetic quality of pigs used in the studies. For example, the outer layer of fat is more saturated than the inner one, which is laid down first. Therefore, the effect of genetic selection for lean deposition may have limited to some extent the expression of gender differences observed by Malmfors *et al*. (1978).

Consumer pressure demands more healthy products in terms of polyunsaturated fatty acid content, however, in the case of pork, the consumer may require education to accept the slightly different appearance in fat. In addition, processors and retailers will have to reconsider traditional methods of storage and presentation.

6. REFERENCES

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APPENDIX 1 FATTY ACID PROFILES

Table 1 The effect of diet on C18:4ω3 content of samples of fat from boars and gilts

Diet	Boars	Gilts	s.e.m.	P
1	0.68[a]	0.97[c]	0.058	<0.05
2	0.90[bc]	0.95[c]		
3	0.83[abc]	0.81[abc]		
4	0.78[ab]	0.70[a]		

Table 2 Fatty acid profiles of the experimental diets

	Diet					
	1	2	3	4	s.e.m.	P
C14:0	0.89[b]	0.30[a]	0.70[b]	0.70[b]	0.044	<0.001
C14:1	0.05[ab]	0.01[a]	0.16[b]	0.13[ab]	0.028	<0.01
C16:0	12.39[b]	9.26[a]	11.87[ab]	13.08[b]	0.692	<0.01
C16:1ω7	0.50[b]	0.31[a]	0.55[b]	0.52[b]	0.022	<0.001
C17:0	0.00	0.16	0.20	0.30	0.094	NS
C18:0	2.03[a]	2.70[a]	5.47[b]	4.93[b]	0.251	<0.001
C18:1ω9	25.31	38.04[b]	30.78[ab]	31.94[ab]	1.909	<0.01
C18:1ω7	1.12	1.14	1.68	2.25	0.336	NS
C18:2tt	0.00[a]	0.00[a]	0.07[b]	0.08[b]	0.010	<0.001
C18:2ct	0.00[a]	0.00[a]	0.08[b]	0.10[b]	0.011	<0.001
C18:2tc	0.00	0.00	0.00	0.00	0.000	NS
C18:2ccω6	47.22[b]	36.95[a]	41.14[ab]	38.25[a]	1.574	<0.01
C18:3γω6	0.00[a]	0.02[a]	0.32[b]	0.11[ab]	0.160	<0.05
C18:3αω3	6.09[a]	8.37[b]	4.64[a]	5.10[a]	0.332	<0.001
C20:0	0.28[a]	0.39[a]	0.46[b]	0.42[ab]	0.025	<0.001
C18:4ω3	1.38[b]	1.08[a]	1.12[ab]	0.95[a]	0.072	<0.01
C20:4ω6	0.00	0.03	0.00	0.00	0.014	NS
C22:0	0.13[a]	0.21[a]	0.38[b]	0.32[b]	0.055	<0.05
C20:5ω3	0.90	0.36[a]	0.32[a]	0.27[a]	0.079	<0.05
C22:4ω6	0.00[a]	0.11[ab]	0.21[b]	0.17[b]	0.039	<0.01
C22:6ω4	0.67[b]	0.13[a]	0.00[a]	0.02[a]	0.029	<0.001

where t = trans, c = cis and Mono/sat = monounsaturated/saturated ratio

Table 3 Fatty acid content of the feed sample x fat content of the diet

	Analysis x content			
	1	2	3	4
C14:0	2.11	0.80	4.26	4.38
C14:1	0.13	0.03	0.95	0.80
C16:0	29.49	24.96	72.31	82.01
C16:1ω7	1.18	0.82	3.36	3.27
C17:0	0.00	0.44	1.24	1.86
C18:0	4.83	7.28	33.32	30.91
C18:1ω9	60.24	102.56	187.51	200.26
C18:1ω7	2.67	3.07	10.23	14.11
C18:2tt	0.00	0.00	0.40	0.49
C18:2ct	0.00	0.00	0.51	0.64
C18:2tc	0.00	0.00	0.00	0.00
C18:2ccω6	112.38	99.62	250.62	239.83
C18:3γω6	0.00	0.05	1.96	0.71
C18:3αω3	14.49	22.57	28.27	31.98
C20:0	0.67	1.05	2.80	2.63
C18:4ω3	3.29	2.90	6.84	5.96
C20:4ω6	0.00	0.08	0.00	0.00
C22:0	0.31	0.56	2.29	2.02
C20:5ω3	2.15	0.97	1.96	1.69
C22:4ω6	0.00	0.29	1.30	1.07
C22:6ω4	1.59	0.34	0.00	0.15

Table 4 The effect of diet on fatty acid profiles of samples of lean meat

	Diet					
	1	2	3	4	s.e.m.	P
C14:0	1.80^{a}	1.78^{a}	2.10^{b}	1.99^{ab}	0.063	<0.001
C14:1	1.02	1.08	0.94	1.04	0.117	NS
C16:0	23.75^{c}	23.37^{c}	22.03^{b}	20.81^{a}	0.192	<0.001
C16:1ω7	2.86^{b}	2.74^{b}	2.11^{a}	1.86^{a}	0.080	<0.001
C17:0	0.34	0.38	0.29	0.44	0.051	NS
C18:0	10.66^{b}	10.70^{b}	9.56^{a}	9.52^{a}	0.167	<0.001
C18:1ω9	31.77^{b}	31.00^{b}	27.33^{a}	25.82^{a}	0.522	<0.001
C18:1ω7	2.75^{b}	2.81^{b}	2.17^{a}	2.19^{a}	0.082	<0.001
C18:2tt	0.02	0.01	0.02	0.01	0.005	NS
C18:2ct	0.00	0.00	0.02	0.01	0.008	NS
C18:2tc	0.00	0.00	0.00	0.00	0.000	NS
C18:2ccω6	20.56^{a}	21.48^{a}	27.98^{b}	30.45^{b}	0.517	<0.001
C18:3γω6	0.02	0.03	0.03	0.04	0.010	NS
C18:3αω3	0.80^{a}	1.04^{ab}	1.24^{ab}	1.48^{b}	0.095	<0.001
C20:0	0.03	0.04	0.04	0.05	0.013	NS
C18:4ω3	0.33	0.34	0.22	0.26	0.048	NS
C20:4ω6	2.78^{a}	2.81^{a}	3.50^{ab}	3.59^{b}	0.260	<0.05
C22:0	0.00	0.00	0.00	0.00	0.000	NS
C20:5ω3	0.09	0.07	0.09	0.08	0.018	NS
C22:4ω6	0.10	0.09	0.11	0.10	0.025	NS
C22:6ω4	0.25	0.28	0.25	0.21	0.063	NS

Table 5 The effect of diet on fatty acid profiles of samples of fat

	Diet					
	1	2	3	4	s.e.m.	P
C14:0	1.45^{a}	1.42^{a}	1.94^{a}	2.16^{b}	0.059	<0.001
C14:1	0.03^{a}	0.06^{ab}	0.10^{b}	0.08^{b}	0.010	<0.001
C16:0	22.78^{c}	22.57^{c}	20.41^{b}	19.62^{a}	0.143	<0.001
C16:1ω7	2.12^{b}	1.96^{b}	1.62^{a}	1.55^{a}	0.045	<0.001
C17:0	0.35^{a}	0.49^{b}	0.42^{ab}	0.40^{a}	0.020	<0.001
C18:0	12.79^{c}	13.12^{c}	10.97^{b}	9.91^{a}	0.205	<0.001
C18:1ω9	35.75^{b}	34.83^{b}	33.32^{a}	32.32^{a}	0.301	<0.001
C18:1ω7	1.97^{b}	1.90^{b}	1.53^{a}	1.48^{a}	0.070	<0.001
C18:2tt	0.03	0.03	0.05	0.03	0.007	NS
C18:2ct	0.00^{ab}	0.00^{a}	0.02^{b}	0.02^{ab}	0.0040	<0.001
C18:2tc	0.00	0.00	0.00	0.00	0.000	NS
C18:2ccω6	20.19^{a}	20.74^{a}	26.42^{b}	29.18^{c}	0.386	<0.001
C18:3γω6	0.02^{ab}	0.04^{b}	0.01^{a}	0.01^{a}	0.0068	<0.01
C18:3αω3	1.37^{a}	1.49^{a}	1.92^{b}	2.06^{b}	0.034	<0.001
C20:0	0.12^{a}	0.18^{ab}	0.22^{b}	0.19^{b}	0.024	<0.05
C20:4ω6	0.10	0.13	0.13	0.13	0.016	NS
C22:0	0.00	0.00	0.00	0.00	0.000	NS
C20:5ω3	0.01	0.00	0.01	0.00	0.004	NS
C22:4ω6	0.01	0.02	0.02	0.01	0.006	NS
C22:6ω4	0.08^{b}	0.04^{a}	0.05^{a}	0.05^{a}	0.011	<0.05

Table 6 The effect of gender on fatty acid profile of samples of lean meat

	Gender			
	Boars	Gilts	s.e.m.	P
C14:0	1.97	1.87	0.045	NS
C14:1	0.99	1.05	0.083	NS
C16:0	22.40	22.57	0.136	NS
C16:1ω7	2.30	2.48	0.057	<0.05
C17:0	0.35	0.37	0.036	NS
C18:0	10.12	10.10	0.118	NS
C18:1ω9	28.35	29.61	0.369	<0.05
C18:1ω7	2.43	2.53	0.058	NS
C18:2tt	0.01	0.02	0.003	NS
C18:2ct	0.01	0.00	0.006	NS
C18:2tc	0.00	0.00	0.000	NS
C18:2ccω6	25.80	24.43	0.365	<0.01
C18:3γω6	0.03	0.03	0.007	NS
C18:3αω3	1.20	1.08	0.067	NS
C20:0	0.03	0.05	0.009	<0.05
C18:4ω3	0.29	0.29	0.034	NS
C20:4ω6	3.29	3.06	0.184	NS
C22:0	0.00	0. 00	0.000	NS
C20:5ω3	0.08	0.08	0.013	NS
C22:4ω6	0.11	0.09	0.017	NS
C22:6ω4	0.23	0.26	0.044	NS

Table 7 The effect of gender on fatty acid profile of samples of fat

	Gender			
	Boars	Gilts	s.e.m.	P
C14:0	1.77	1.71	0.041	NS
C14:1	0.07	0.06	0.007	NS
C16:0	21.35	21.34	0.101	NS
C16:1ω7	1.79	1.83	0.032	NS
C17:0	0.46	0.38	0.014	<0.001
C18:0	11.79	11.61	0.145	NS
C18:1ω9	33.02	35.09	0.213	<0.001
C18:1ω7	1.63	1.81	0.050	<0.05
C18:2tt	0.03	0.04	0.005	<0.05
C18:2ct	0.01	0.01	0.003	NS
C18:2tc	0.00	0.00	0.000	NS
C18:2ccω6	25.07	23.19	0.273	<0.001
C18:3γω6	0.02	0.02	0.005	NS
C18:3αω3	1.79	1.62	0.024	<0.001
C20:0	0.17	0.19	0.017	NS
C20:4ω6	0.12	0.12	0.011	NS
C22:0	0.00	0.00	0.000	NS
C20:5ω3	0.00	0.01	0.003	NS
C22:4ω6	0.01	0.01	0.004	NS
C22:6ω4	0.05	0.06	0.008	NS

APPENDIX 2 EXPLANATION OF STATISTICAL TERMS

Example 1: P_2 measurements for 3 treatments

	Treatment 1	Treatment 2	Treatment 3	s.e.m.	P
P_2 (mm)	10^{a}	15^{ab}	20^{b}	2.0	<0.05
Days	70	73	69	5.0	NS

Means with a common superscript are not significantly different

s.e.m.
Data are presented with standard error of the means (s.e.m.) and probability values (P). Obviously not all pigs had a P_2 of 10 mm in Treatment 1. The s.e.m. is a measure of the variability associated with each result presented.

P
The probability value (P) describes the probability that the difference being assessed was due to random variation (chance). Figures used are $P<0.05$, $P<0.01$ or $P<0.001$ and implies that the probability of the result obtained being due to random variation was less than 5%, 1% or 0.1%. Therefore a probability of $P<0.001$ is a very highly significant result in statistical terms. NS means that the values are not significantly different, i.e. the results obtained were more than 5% due to random variation. Lack of significance does not necessarily mean that there was no treatment effect at all, rather, if it did exist, it was too small to distinguish from random variation.

Superscripts
The superscripts a, ab and b etc are used to distinguish between values which are significantly different. For example, in the table above, 10 and 20 are significantly different because they have different superscripts. However, 10 is not significantly different from 15, nor is 15 significantly different from 20.

Interactions
A significant gender x treatment interaction implies that the effect of slaughter weight differs in boars and gilts as shown in the table below. In this example, the values for boars are increasing while those for gilts are decreasing.

Example 2: A significant gender x treatment interaction

	Boars	Gilts	s.e.m.	P
Treatment 1	100^{c}	100^{c}	1.5	<0.05
Treatment 2	103^{c}	95^{bc}		
Treatment 3	110^{d}	90^{b}		
Treatment 4	117^{c}	60^{a}		