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THE ROLE OF FISH MEAL IN DIETS FOR PIGS

by

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SUMMARY

Baby Pigs - Milk Replacer Diets: The acceptability of solvent extracted fish meal to the baby pig, and the high digestibility and biological value of the fish protein, enables partial replacement of the expensive milk protein in milk replacers for baby pigs under three weeks of age without affecting performance.

Baby Pigs - Solid Diets: For the baby pig shortly before and after weaning, especially early weaning, fish meal produced from selected raw material or solvent extracted fish meal contributes essential amino acids and other important nutrients very effectively, and assists in the development of its system of protein digestion. For these reasons, inclusion of these fish meals in the diet enables optimum growth and feed conversion to be achieved, especially in early weaning systems and/or where major changes in environment occur. It also gives the baby pig a better chance of withstanding a challenge from infection.

Growing/Fattening Pigs: Trials comparing the performance of growing/fattening pigs fed diets with and without fish meal are reviewed. Those published experiments conducted mainly since 1970 indicate that out a total of 37 experiments carried out in many different countries, the majority showed an improvement in liveweight gain and feed conversion when diets containing fish meal were fed. There is some evidence that improvements is fed conversion and liveweight gain occur when fish meal is included in diets containing skimmed milk powder. The inclusion of fish meal in the growing pigs diet appears to result in a leaner carcass. Fish meal appears to be of special benefit in high nutrient dense diets for pigs.

Breeding Pigs: A comprehensive experiment with breeding sows indicates that the number of baby pigs weaned is improved when the sow's diet contains fish meal.

The improved performance of pigs fed diets containing fish meal results from better utilisation of dietary protein and energy.

Including fish meal in a pig diet may increase the cost of the diet. However, because the diet is used more efficiently as a result, actual cost of pig meat production can be reduced. This appears to be particularly true where sophisticated computer feed formulation, mixing equipment and raw material quality controls are not available, and/or the challenge from infection is high. The very young pig and breeding sow with their exacting nutritional requirements benefit particularly from receiving diets containing fish meal.

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1. INTRODUCTION

During the last decade many improvements in pig production have been made, particularly in breeding, feeding, disease control and environment control. Performance in terms of growth rate, feed utilization and reproduction has improved markedly as a result. With these improvements, requirements for nutrients in the diet, particularly protein and its constituent amino acids, have become more exacting.

For many years now it has been known that animal proteins in general, and fish protein in particular, are complementary to vegetable proteins in providing amino acids to meet the pig's requirements. What is the role of fish meal in the diet of today's high performance pig? This bulletin outlines the findings of experiments conducted mostly in the last ten years.

With the widespread use of linear programming of feed formulations by computer, most raw materials are now evaluated in terms of the nutrient data which are fed into the computer programme. The concept of linear programming assumes that these data fully reflect the nutritional value of the raw material under the circumstances in which it is to be fed, that is, in the presence of other raw materials, for the type of production, etc. As far as fish meal is concerned, do the specifications put into the computer fully account for its nutritional attributes? This bulletin reviews the experimental work which has been done to compare diets formulated with and without fish meal in terms of the effect on growth rate, feed conversion and reproductive performance.

2. FISH MEAL IN DIETS FOR BABY PIGS*

2.1. The Acceptability of Fish Meal to Baby Pigs

Recent work by Gjefsen (1) has shown that when the skimmed milk powder in a baby pig diet was completely replaced with whey powder and fish meal made from selected row material (6 to 10% fat) or solvent extracted fish meal (1% fat) feed intake by baby pigs (5 kg liveweight) was satisfactory. Feeding solvent extracted fish meal, feed intake was slightly higher than when skimmed milk powder diet was fed (table 1):

* Baby pigs – pigs up to eight weeks of age or 20 kg. liveweight.

TABLE 1

	DIET		
	Skimmed milk powder 66% in diet	Fish meal (Solvent extracted) 22% in diet	Fish meal (From specially selected raw material) 25% in diet
No. Pigs	24	24	24
Feed consumption (g/day)			
First week	111	123	111
Second week	251	260	252
First five weeks	389	413	382

Details of the diets are given in Appendix Table 1.

Gravås and Gjefsen (46) noted higher consumption by baby pigs of a creep feed containing 25% fish meal than of one (control) containing 3% fish meal (see Appendix Table 3).

2.2 The Nutritive Value of Fish Meal for Baby Pigs

Feeding baby pigs 30 to 35 days of age and liveweight 5-15 kg, Eggum (2) found fish meal protein to be highly digestible. The true digestibility of the protein was 93.2%. With the exception of phenylalanine which was 89% digestible, all the essential amino acids in fish meal had digestibility coefficients of over 93%. The biological value of the fish meal protein was high (90.1) and Eggum concluded that it was an excellent protein source for baby pigs.

It is interesting to note that Eggum's true digestibility values for fish meal protein fed to baby pigs agreed well with those determined by Dammers (3), feeding Peruvian fish meal to adult pigs. He found a true digestibility value for individual amino acids of approximately 90% or slightly above. Poppe *et al.* (4) at Bostock, East Germany, measured true digestibility values of 93.6% 95.4% and 94.9% for total nitrogen, lysine and methionine in fish meal.

2.3 Fish Meal in Practical Feeding Systems for Baby Pigs

2.3.1. Conventional Rearing

In the conventional rearing of baby pigs, they are generally offered creep feed during suckling from two weeks of age to weaning at six to eight weeks. After weaning they than receive a solid 'prestarter' diet for two to five weeks.

2.3.1.1. Fish Meal in Creep Feed

In trials with 170 pigs from 10 days to 5 weeks of age, Schröder and Werhahn (5) found they could replace skimmed milk powder (20%) with solvent extracted fish meal (6.5%) plus dried whey powder without adversely affecting live weight gain (table 2).

TABLE 2

	Control Group Skimmed milk powder diet	Trial Group Solvent extracted fish meal diet
Daily liveweight gain 10 days to 5 weeks of age (g.)	217 ± 31.8	212 ± 32.4

Details of the diets used are given in Appendix Table 2.

Increasing the fish meal in a creep feed from 3% to 25%, using a fish meal made from selected raw material at the high inclusion level, (for details of diets see Table 3), Gravås and Gjefsen (46) found

weight gain and feed conversion of baby pigs from 14-44 days of age improved from 207g and 1.88 to 282g and 1.38 respectively. Feed consumption increased from 237 to 266g/day. The experimental creep feed with 25%fish meal also contained 45% whey powder, and had a higher nutrient density than the diet with 3% fish meal (conventional creep feed).

2.3.1.2. Fish Meal in Prestarter Diets

The first solid feed the baby pig receives immediately after weaning is often referred to as a prestarter feed. This period is often a critical one for the baby pig in that it often undergoes a major change in both environment and diet, and digestive upsets can occur.

Gropp *et al* (6) carried out two trials with baby pigs (16 kg liveweight) where the environment in the first trial proved to be less than ideal. To investigate protein and methionine content of the diet, and source of protein, they used 384 baby pigs, 24 on each of eight treatments in each trial. Details of the diets and results are given in Appendix Table 8. In the second week of trial 1, severe diarrhoea occurred and losses of pigs were 7%, mainly from oedema. In trial 2 digestive upsets were less frequent and losses were under 5%. In both trials there was a marked response to fish meal in growth (+6.5%) and feed conversion (+6.0%) (see P. 9 and Appendix Table 8). This work demonstrates the value of including fish meal in baby pig diets fed immediately after weaning.

2.3.2. Early Weaning

There are various practices of early weaning in different countries, but an early weaning age of about three weeks now seems to be commonly accepted. Weaning prior to three weeks, and artificial weaning, appear to call for considerable husbandry skills, and in commercial systems have not always been successful. Few farmers wean before three weeks of age at the present time. Artificial rearing of baby pigs weaned at one to five days of age will be considered later (Section 2.3.3.).

Early weaning of baby pigs calls for a gradual transition to a dry diet. The early consumption of a cereal based diet when the digestive tract is developing markedly improves the protein digestibility of the diet fed from weaning (7). This cereal can be introduced in the form of creep feed. The effect of creep feed intake on the growth rate of the suckled pig is well known.

In formulating a diet to be fed to early weaned pigs, two types of requirement must be met by the protein in that diet:

(i) a nutritional requirement and

(ii) a functional requirement

both aiming at optimum development of digestive function (7). The nutritional requirement is best met by using proteins of high biological value such as milk and fish protein and the functional requirement is best met by progressively increasing the proportion of conventional feeds in the diet such as fish meal, oil seed meals and cereals. For example, it has been shown by Corring *et al.* (8) that there was a specific deficiency of trypsin activity of the pancreas in baby pigs from birth, but there was a marked increase in this activity when the baby pig started to consume significant quantities of protein from creep feed, after three weeks of age.

Bayley and Holmes (10) in two experiments with pigs weaned at 10 days of age showed that skimmed milk powder (SMP) providing either 75% or 100% of dietary protein could be replaced by solvent extracted fish meal plus whey, without affecting performance. The fish meal/whey used in a ratio 3:1, was considered to be equivalent to the SMP it replaced, and superior to a soyabean protein flour. Arsenijevíc *et al.* (11) found that the growth of early weaned pigs was not affected when the 10% SMP in their commercial starter was replaced with 5% fish meal and 5% maize. The diets were equated for protein and lysine content though the fish meal treatment provided 8% more methionine. Over a 27 day period weight gain on the fish meal diet was 16% higher (488 v. 421 g/pig/day) and feed conversion was 5% better.

Gjefsen (1) compared a diet based on skimmed milk powder with one based on solvent extracted fish meal plus whey and one based on fish meal made from selected raw material plus whey at two levels of crude protein for baby pigs weaned at 21 days of age. Details of the diets and the results are given in Appendix Table 4. There were no significant differences in either liveweight gain or feed conversion in the first week, or the first five weeks, or during the interval of liveweight gain from 5 to 22 kg. The higher protein level (24%) did, however, result in a significantly higher rate of liveweight gain and the lower protein level (22%).

The effect of replacing milk protein by fish protein on the digestibility of dietary protein from 12 to 63 days of age (having weaned at 10 days) was investigated by Seve *et al.* (9) (Table 3):

TABLE 3

Composition of the dietary protein (%)			
Milk	100	66	33
Solvent extracted fish meal	0	33	66
RESULTS			
Weight gain (g/day)	317	312	277
Apparent digestibility of dietary protein (%) from:			
21 to 28 days of age	87.4	85.2	86.0
28 to 35 days of age	85.2	84.2	79.0
35 to 42 days of age	76.3	80.4	76.6

Growth and apparent digestibility were not affected when up to 33% of the milk protein was replaced with fish protein.

Investigating solid (semi-practical) diets fed to baby pigs weaned at 7 to 10 days of age, Young *et al.* (17) found that completely replacing dried skimmed milk powder with either fish meal or solvent extracted fish meal resulted in reduced growth and poorer feed conversion. However, when the solvent extracted fish meal was supplemented with soya lecithin and glucose, performance equivalent to that on the skimmed milk powder diet was achieved.

The early weaned baby pig is not able to adapt itself to all types of protein feeds supplied in high amounts. According to Aumaitre and Lambert (12), there is a limit to the amount of soyabean meal in the diet which the baby pig can effectively utilise at an early age. The results of an experiment by these workers given below, show that the protein requirement of baby pigs weaned at 35 days cannot be met satisfactorily by increasing the level of plant protein sources in the diet (Table 4):

TABLE 4

	Composition of proteins in diets (%) (equated for lysine and sulphur amino acids)		
	Diet A	**Diet B**	**Diet C**
Soyabean meal	10	20	35
Skimmed milk powder	13.5	7.8	0
Fish meal	9.7	5.7	0
Average daily gain (g/day) (from 35 days to 63 days of age)	436	390	350
Feed intake (g/day)	672	651	627
Feed conversion	1.54	1.67	1.79
Nitrogen – apparent digestibility	83.6	81.9	80.2
Nitrogen – apparent retention (g)	71.1	72.0	67.0

2.3.3. Artificial Rearing

The weaning of baby pigs from 1 to 5 days of age for artificial rearing has received much academic interest, but so far has not been adopted commercially on a large scale. The system requires liquid diets. Details of a system of artificial rearing has been given by Braude *et al.* (13).

Investigating sources of protein in the liquid diets for artificially reared pigs, Newport (14) working in Braude's group found that up to 50% of the milk protein (from dried skimmed milk) could be replaced with protein from partially hydrolysed fish protein without affecting growth. Full replacement of the milk protein with fish protein resulted in growth depression. Both Pettigrew *et al.* (15) and Pond *et al.* (16) found solvent extracted fish meal acceptable as the sole source of dietary protein for baby pigs artificially reared from 2 to 4 days of age. The latter workers found the fish protein was equivalent to casein and superior to isolated soyabean protein, but inferior to the protein in cow's milk, in terms of growth rate when these proteins formed the sole protein source in the diet.

2.4. Conclusion

The baby pig is prone to disease, especially digestive upsets, at the time of weaning, particularly if it changes farm, mixes with other pigs, changes feed and eats erratically. An animal's resistance to disease is closely associated with protein nutritional status. This in turn is dependent on the animal receiving a correct supply of amino acids at the sites of protein synthesis. The protein in fish meal, having a high digestibility and high biological value, is an effective source of essential amino acids for the baby pig. Fish meal is well accepted by the baby pig, and assists in the development of its system of protein digestion. These factors probably account for the foregoing which shows that fish meal protein is well suited for the baby pig, especially in early weaning systems and/or where major changes in environment occur. It enables optimum growth and feed conversion to be achieved, and gives the baby pig a better chance of withstanding a challenge from infection.

The value of including fish meal in creep and prestarter diets for baby pigs is widely recognised by feed formulators, and it is widely accepted in practice to incorporate fish meal in these diets. It is recommended that in diets intended for baby pigs under three weeks of age, a solvent extracted fish is used, and that in diets intended for baby pigs from three to five weeks of age fish meals made from selected raw material are used.

3. FISH MEAL IN DIETS FOR GROWING/FATTENING (FINISHING) PIGS

There are a number of trials comparing the performance of growing/fattening pigs fed diets with and without fish meal (Table 5). In most of these trials diets have been formulated with and without fish meal to equal contents of protein, and have approximately equal energy content. Most of these experiments cover the period of growth from 25 to 95 kg liveweight. Details of the treatments and results from some of these trials are shown in Appendix Tables 5 to 19. The most comprehensive series experiments were those carried out by Braude and Lerman (18), at 21 centres using 548 pigs. In Table 5 and Figure 1 results of all the experiments are summarised.

The results in Table 5 have been summarised by giving the percentage liveweight change and feed conversion change for the fish meal diet compared with the diet without fish meal. Poorer performance is indicated be a negative value. Out of a total number of 37 experiments carried out throughout the world, the majority showed an improvement in liveweight gain and feed conversion when the diets containing fish meal were fed. The size of the response was variable, and for the large co-ordinated trial carried out by Braude and Lerman the improvement was very small. However, there is some indication that the higher the levels of fish meal inclusion in grower diets the greater the response (see Figure 1).

In the experiments reporting carcass data (18,19,20), pigs receiving fish meal in their diets appear to have given leaner carcasses, though Salo and Laalahti (24) reported similar percentages of lean in the carcasses but slightly more fat in those of pigs receiving fish meal.

The trials carried out by Gropp *et al.* (6) differed from the other trials in that baby pigs were weaned and put on trial at 16 kg liveweight. In their first trial lasting 35 days, severe diarrhoea occured causing 7% losses, mainly due to oedema. Under these conditions, with the fish meal diet liveweight gain was improved by 4.7% (337 v 321 g/pig/day) and feed conversion by 4.9% (2.67 v 2.80 kg feed/kg gain). Taking average results for this first trial and a second trial lasting 26 days, liveweight gain was improved by 6.9% and feed conversion by 6.5% with the fish meal diet.

Matre *et al* (21) noted better growth and feed conversion with fish meal in a diet slightly lower in protein (14.9% v. 15.7%) and lysine (0.66% v. 0.73%).

Feeding diets based on cereals, alfalfa meal, and skimmed milk powder to growing pigs, Navrátil and Vlček (19) found that by replacing two-thirds fo the milk protein with protein from fish meal, growth increased from 678 g to 729 g/day and feed conversion improved from 2.94 to 2.91 (See Appendix Tables 9a and 9b). This result indicates that in diets where skimmed milk powder is used, inclusion of fish meal will improve growth and feed conversion.

4. HIGH NUTRIENT DENSE DIETS FOR PIGS

There has been renewed interest in certain countries in the past few years in so-called high nutrient dense pig diets. These are diets of higher nutrient density than conventional diets, which present the correct amount of nutrients in a smaller volume to the pigs and they are fed restricted lower quantities. They are formulated using added fat (usually 2%, to 3%), and a certain amount of maize and sometimes sorghum as part of the starch sources. Fish meal can be used in such diets as a highly concentrated form of protein, amino acids and energy. The claimed benefits of such diets are:

TABLE 5
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
SUMMARY OF RESULTS[a]

COUNTRY	FOOTNOTE/ APPENDIX TABLE NO.	LEVEL OF FISH MEAL IN FIET (%)[b]	% IMPROVEMENT IN LIVEWEIGHT FISH MEAL v NO FISH MEAL	%IMPROVEMENT IN FEED CONVERSION FISH MEAL v NO FISH MEAL	REFERENCE	(NO.)
U.K.	1/5b	5	+0.3	+0.3	Braude & Lerman (1970)	(18)
France	2/6	3.5	−0.8	+0.9	Eeckhout et al. (1973)	(22)
W. Germany	3/7	4/2	−0.2	−1.0	Pieper (1971)	(23)
W. Germany	4/8	4	+6.5	+6.0	Gropp et al. (1979)	(6)
Czechoslovakia	5/9b	7½/6/3	+5.9	+7.3	Návratil & Vlček (1971)	(19)
Finland	6/10	N.A.	+3.4	+2.9	Salo & Laalahti (1973)	(24)
Australia	7/11b	9.5	+3.5	+2.7	Williams & Natali (1972)	(25)
W. Germany	8/12	8/5	−0.2	+4.9	Agde (1973)	(26)
W. Germany	9/13	9	+8.9	+3.8	Fiedler (1975)	(27)
W. Germany	10/14	12/8	+5.9	+6.7	Büenfeld et al. (1973)	(28)
W. Germany	11/15	5/3	+1.8	+3.2	Feist et al. (1974)	(29)
W. Germany	12/16	7.5/5	+5.2	+2.2	Hoppe (1972)	(20)
Norway	13/17	2	+1.7	+1.8	Matre et al. (1976)	(21)
Norway	14/18	8	+1.1	+3.0	Homb et al. (1962)	(30)
Denmark	15/19	2	+1.7	+2.2)		
		5	+0.2	+1.6)	Hansen (1970)	(31)
		8	+5.5	+4.4)		

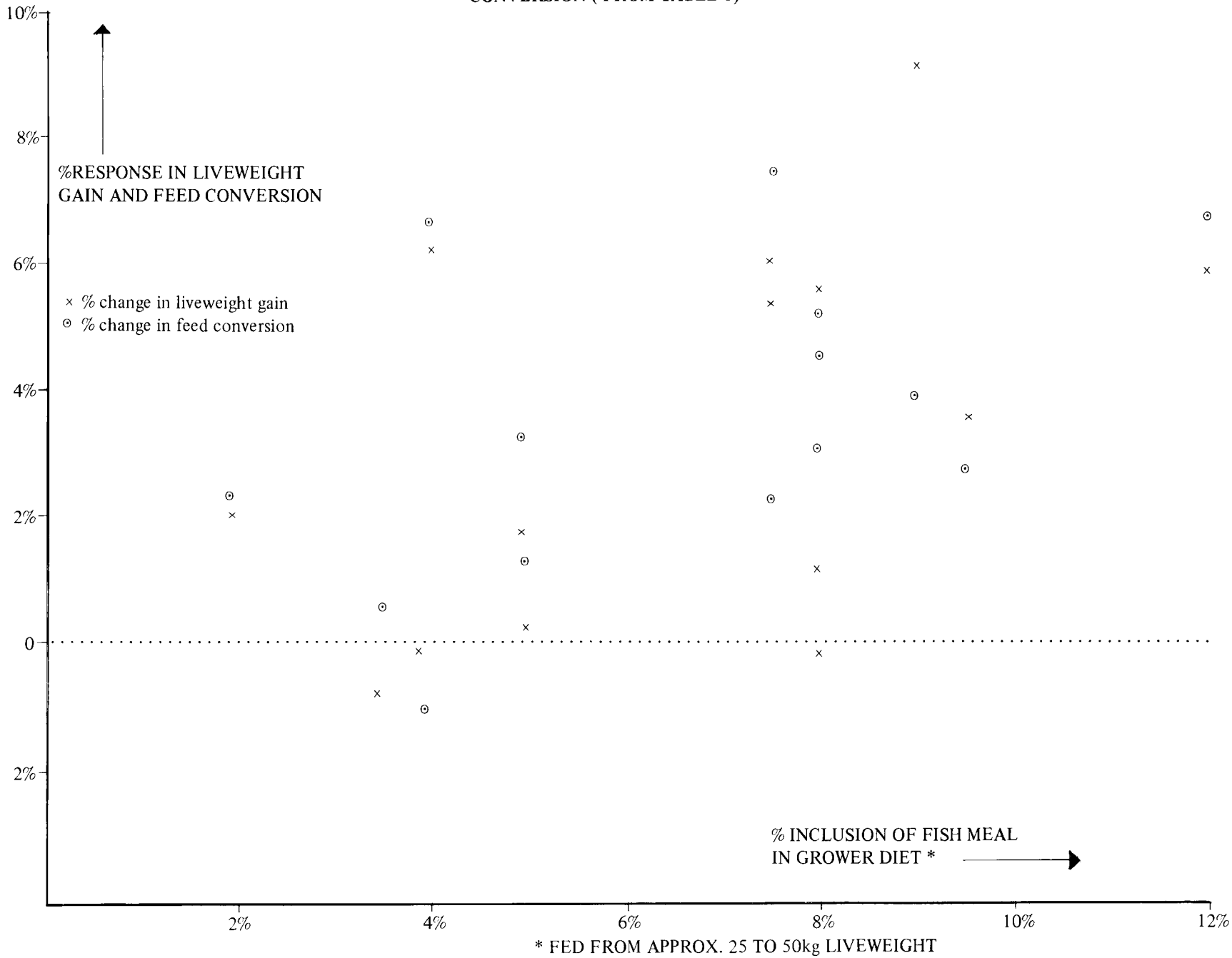
[a] Total number of experiments is 37, including the 21 carried out by Braude and Lerman in the U.K.

[b] Two or more values indicate decreasing inclusion levels as the pigs got older.

Footnotes to Table 5.

1. Comparison of treatments 3 v 4, taking average values for 21 centres.
2. Average of fish meal soya treatments. Diets were not equated - soya diets had higher protein lysine, methionine + cystine contents.
3. Comparison of treatments fish meal v soya + methionine.
4. Diets with fish meal 3, 4 and 7, 8 compared with those without fish meal (with soya) 1, 2 and 5, 6. Diets were not equated in that the fish meal diets has a slightly higher amino acid content. Starting weight of pigs 16kg; Finishing weight up to 30kg.
5. Diet with fish meal compared to one in which skimmed milk powder replaced fish meal.
6. Comparison of diets with and without fish meal - group I v group II. whilst composition of diet fed is not given, protein energy, lysine, methionine + cystine, threonine and tryptophan intakes were equated.
7. From table 2 in original (p. 417) fish meal v soyabean meal treatments.
8. Comparison of diets with and without fish meal - group I v group II.
9. Comparison of diets with and without fish meal - diets 1 v 2. These diets equated for protein.
10. Treatment 1 (fish meal) v treatments 6 and 8 (soyabean meal).
11. Fish meal diet (group I) compared with diet without fish meal (group II). Fish meal diet slightly lower in protein and energy than diet without fish meal.
12. Comparison of diets with fish meal + fish solubles (F) compared with diets without fish meal (V).
13. Diets with and without fish meal not equated for protein and lysine.
14. From Table 3 in orinigal (p9) herring meal v soyabean meal treatments.
15. Diet without fish meal compared with diets with 2%, 5%, and 8% fish meal

FIG 1 EFFECT OF FISH MEAL INCLUSION IN PIG DIETS ON LIVEWEIGHT GAIN AND FEED CONVERSION (FROM TABLE 1)



1. In the early stages of growth when appetite can be a limiting factor such diets enable pigs to consume a greater quantity of nutrients.

2. From approximately 45 to 95 kg liveweight such diets generally give lower feed costs per kg liveweight gain.

3. An improvement in killing-out percentage of around 2% to 4%.

Although high nutrient dense (HND) diets are more expensive to formulate per ton of feed, in many situations they will give cheaper meat production. Because they are more concentrated, they reduce transport costs. Work at Wye College (University of London) by Curran (32) also reported by Cooke and Trapnell (33) in which HND and conventional diets were compared, showed better feed conversion and similar liveweight gain with 2% to 4% improvement in killing out percentage with HND diets.

The HND diet used by Curran (32) was 20% more concentrated than the conventional diet, with metabolisable energy content of 3120 kcal per kg (TDN approximately 78), crude protein content of 18.5%, and lysine content of 1%. Smith (34) compared an HND diet containing 7.5% fat with a conventional pig diet, the former having a 10% higher energy concentration. Weight gain per unit of digestible energy was 3.4% higher with HND diet. Although the nutritional reasons for the improved killing out percentage are not completely clear, it is likely that the HND diet will be used more efficiently per unit of digestible or metabolisable energy because the fat will have a greater net energy value to a pig than an equivalent amount of digestible or metabolisable energy from carbohydrate (35). The additional fat in HND diets replaces carbohydrates. Furthermore, if the fat consists of a mixture of saturated and unsaturated fatty acids then it is likely, according to Lewis and Wiseman (35), that the mixture will have a higher energy value than the sum of the energy values of the individual fats.

5. FISH MEAL IN DIETS FOR BREEDING PIGS (SOWS)

Experiments with sows to compare diets with and without fish meal are few in number. The most comprehensive trial reported appears to be that by Palmer *et al.* (37) in the U.S.A. who found more piglets born to sows fed diets based on corn-soya with 6% fish meal, compared with straight corn-soya diets. The experimental diets were fed over two full reproductive cycles (see Table 6). The results from

TABLE 6

	LOT 2 – 6% FISH MEAL[1]			LOT 1 – 0% FISH MEAL[1]		
	1st Farrow	2nd Farrow	Average	1st Farrow	2nd Farrow	Average
No. Farrowed	44	30		41	24	
Gestation wt. gain (kg/day)	0.28	0.48	0.38	0.25	0.46	0.36
Lactation wt. loss (kg/lactation)	5. 6	10.6	8.1	5.2	17.7	11.5
Live piglets born/ (litter/kg)	8.0	8.6	8.3	7.5	7.4	7.4
Av. litter birth wt. (kg)	9.47	11.64	10.55	8.43	9.48	8.96
No. piglets/litter – at weaning	7.1	7.0	7.1	6.5	6.4	6.5
Av. piglets weaning wt. (kg)	10.15	10.19	10.17	10.32	10.17	10.24

[1] Basal diet – corn/soya.

this experiment are in line with earlier results in Europe (38). A later Experiment by Baker in Illinois (39) showed no differences in reproductive performance of sows fed diets containing fish meal during pregnancy compared with those sows receiving a corn-soya diet throughout pregnancy. In this trial all sows received corn-soya diets during lactation. Unlike Palmer's trial, this trial considered feeding in gestation only for the treatment period. In view of the sow's higher nutritional requirement during lactation, it is more likely that any benefits from fish meal feeding would be seen in lactation. Responses in either gestation or lactation to protein supply in the diet are dependent upon nutrition in the preceding phase of the reproductive cycle. For example, Pike (40, 41) fed a high protein diet (19.5% crude protein) containing 15% white fish meal or a low protein diet (10.5% crude protein) containing only cereal protein during pregnancy of 48 sows, which all received the same diet in lactation (16% crude protein, 5% white fish meal). He found similar numbers of pigs born, but on the high protein diet containing fish meal significantly more pigs were alive at three weeks of age, and more pigs weaned at eight weeks of age. It has since been shown that satisfactory reproduction of sows can be obtained feeding much less protein (11.5% in prenancy diet and 13.5% in lactation diet) (42). However, in both diets, part of the protein was supplied by fish meal. The pregnancy and lactation diets contained 2.4% and 4.3% of white fish meal respectively. It is likely that if satisfactory reproductive performance of the sow is to be achieved feeding low protein diets, then the source of the protein will be important.

Although the experiments with sows are limited in number, there is evidence that the inclusion of fish meal in the diet over the whole reproductive cycle may result in better reproductive performance.

6. POSSIBLE EXPLANATIONS FOR THE PRODUCTION RESPONSE WITH FISH MEAL

From the foregoing there is good evidence that the inclusion of fish meal in the diet for pigs results in improved performance. In other words, the nutrient specifications used in formulating the diet in some way underestimated the full nutritional contribution of the fish meal. What, therefore, is the explanation for this? Fish meal contains a high proportion (60% to 75%) of protein of high feeding value because of its content of those essential amino acids which, if deficient in the diet, are most likely to limit growth. A few years ago attention was paid only to lysine because it was the first limiting amino acid in diets based on the feeds available. But the possible use of synthetic lysine and of lowering total protein levels leads to the necessity of considering also the second and possibly third limiting amino acid. Therefore attention must also be given to threonine, tryptophan and methionine plus cystine (43,44). The better the different essential amino acids can be balanced, the more the total protein content of the diet can be reduced. Finally, the situation should be reached where, with perfect amino acid balance, a true minimum protein need is reached which encompasses both the essential and non-essential amino acids. The balancing process can be achieved by adjusting the proportions of various natural sources of amino acids in both cereals and the high protein feeds, and by the use of synthetic amino acids when these are available at competitive prices.

The availability of the amino acids in dietary protein has a most important bearing on the utilisation of that protein. With modern processing and handling techniques the availability of the amino acids in fish meal proteins is high. This will tend to compensate for the lower availability of the amino acids in cereals, in particular lysine and trytophan.

The rate of absorption of available amino acids from the intestine and transport to site of protein synthesis varies depending on the source of that amino acid. It has been found, for example, that synthetic amino acids are absorbed much more quickly than the same amino acids from natural protein (45). As a result, the utilisation of amino acids supplied in the diet in synthetic form could well be adversly influenced. It could be, for example, that there is a temporary amino acid imbalance at the site of protein synthesis when synthetic amino acids are used in certain situations.

About a third of the energy content of fish meal is contained in its fat content. It has been demonstrated for poultry that the metabolisable energy from fat is used with a much higher degree of efficiency than metabolisable energy from carbohydrate or protein. That is, for fat, metabolisable energy systems do not fully reflect the high efficiency with which the energy it provides is used for growth, especially where the fat consists of saturated and unsaturated fatty acids (see section 4). It is quite likely that a similar effect occurs in pigs (35).

In some pig diets supplementary selenium is not added. Some countries do not permit its addition to animal feeds, although it is an essential trace element. Because of the relatively high selenium content of fish meal in relation to other raw materials, its inclusion in pig diets will increase the selenium content of the finished diet. This may result in improved performance where supplementary selenium is not added.

The 37 experiments carried out in different parts of the world with growing/fattening pigs (table 5) represent very different conditions of pig rearing. In some of these experiments, the formulation of the diet and the mixing were carried out with considerable precision, and there was extensive quality control of raw materials. Many pig farmers in Europe mix their feeds on farm, buying in protein concentrate and mixing it with cereals, or in some cases use protein feeds, e.g. fish meal and soya, direct. In such cases there is little, if any, opportunity for quality control on the raw materials. Furthermore, mixing facilities may be limited and thus the inclusion of trace nutrients such as the B vitamins, lysine, methionine and selenium, etc. and the uniform mixing into the feed may not be possible. In such situations, inclusion of fish meal, not only a rich source of high quality protein, but a unique blend of minerals and vitamins, can offer some degree of insurance against shortcomings of feed formulations and mixing etc. Degree of quality control, nutritional expertise and mixing facilities used in most trials are generally very much better than those for on-farm mixing. It is unlikely that farm mixing would achieve the precision, for example, of the large co-ordinated trial of Braude and Lerman. In the experiments by Fiedler (27), Buenfeld *et al.* (28), Gropp *et al.* (6), and Navrátil and Vlček (19), there was a very marked improvement in performance with diets containing fish meal. It may be that these experiments were more like commercial farm feeding of pigs, with on-farm mixing, than was the large co-ordinated trial of Braude and Lerman.

It is likely that the variable improvement in performance resulting from fish meal inclusion in the diet, as seen in Table 5, reflects differing mixing and quality control facilities for diets and/or the challenge from infection, with the larger responses occurring where mixing and quality control facilities were limited and/or the challenge from infection was high.

7. CONCLUSIONS

In milk replacers for baby pigs under three weeks of age partial replacement of expensive milk protein with solvent extracted fish meal will not affect performance. In most cases it will reduce diet cost, thereby reducing production cost.

Shortly before and after weaning of the baby pig, especially the early weaned pig, can be a very critical period. Fish meal included in diets fed during this period serves an important role in enabling optimum growth and feed conversion to be achieved.

Including fish meal in a pig diet may increase the cost of the diet. However, the actual cost of pig meat production can often be reduced because the diet is used more efficiently. This appears to be even more apparent where sophisticated computer feed formulation, mixing equipment and raw material quality control are not available. The very young pig and the breeding sow with their exacting nutritional requirements appear to benefit particularly from receiving diets containing fish meal.

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APPENDIX TABLE 1
FISH MEAL IN DIETS FOR BABY PIGS
From Gjefsen (1)

DIET COMPOSITION %	DIETARY TREATMENT		
	Skimmed Milk Powder	Solvent Extracted Fish Meal	Fish * Meal
Skimmed milk powder	66.0	–	–
Solvent extracted fish meal	–	22.4	–
Fish meal *	–	–	24.7
Whey powder	–	43.7	41.4
Maize meal	–	–	–
Maize starch	28.6	24.6	27.1
Oat hull	2.2	2.1	2.2
Maize oil	1.2	5.2	2.7
Minerals, vitamins etc.	2.0	2.0	1.9
CALCULATED ANALYSIS			
Crude protein %	22.9	22.9	22.9
Metabolisable energy kcal/kg	3,630	3,630	3,630

*Produce from selected raw material

APPENDIX TABLE 2
FISH MEAL IN DIETS FOR BABY PIGS
From Schröder and Werhahn (5)
Details of Experimental Diets

DIET COMPOSITION %	Control Diet, (with skimmed milk powder)	Trial Diet (with solvent extracted fish meal)
Skimmed milk powder	20.0	–
Solvent extracted fish meal	8.5	15.0
Dried whey powder	–	10.0
Oat groats	11.5	15.0
Maize	25.0	25.0
Wheat	15.0	15.0
Wheat bran	6.5	6.5
Sugar	4.0	4.0
Ext. soya	3.0	3.0
Fat	2.0	2.0
Molasses	1.0	1.0
Mineral + vitamins	3.5	3.5
CALCULATED ANALYSIS %		
Crude protein	17.7	16.0
Energy TDN	77	78

APPENDIX TABLE 3
FISH MEAL IN DIETS FOR BABY PIGS
From Gravås and Gjefsen (46)

Creep Feed Composition %			
Conventional Creep Feed		Experimental Creep Feed	
Herring type fish meal	3.00	Herring type fish meal*	23.8
		Whey powder	45.0
Soyabean meal, extracted	14.60	Oats, ground	7.2
Wheat middlings	8.90	Maize starch	10.5
Barley, ground	47.0	Lard	5.0
Oats, ground	7.4	Sunflower oil	1.0
Sorghum, ground	10.0	Glucose	3.45
Molasses	1.0	Mineral mixture	2.50
Dried milk	2.0	Limestone meal	1.50
Sugar	2.0	Vitamins[2]	0.05
Lysine	0.08		
Vitamins[1]	0.25		
Citric acid	0.30		
Ferrous sulphate	0.30		
Limestone meal	1.90		
Calcium phosphate	0.80		
Magnesium oxide	0.04		
Salt	0.30		
Micromineral mixture	0.11		

* Produced from selected raw material.

1 Added per kg: vit. A: 5000 IE, vit. D_3: 700 IE, vit. E: 20 mg, riboflavin: 5 mg, vit. B_{12}: 0.012 mg.

2 Added per kg : vit. A: 5000 IE, vit. D_3 : 700 IE, vit. E: 20 mg.

APPENDIX TABLE 4
FISH MEAL IN DIETS FOR BABY PIGS
From Gjefsen (1)

Protein source:	Skim milk powder		Solvent extracted Fish Meal		Fish Meal*	
Protein in diet, %	22	24	22	24	22	24
No. of animals	12	12	12	12	12	12
Diets:						
Composition, %:						
Skim milk powder	63.0	69.0	–	–	–	–
Solvent extracted Fish Meal	–	–	21.4	23.2	–	–
Fish Meal*	–	–	–	–	23.7	25.7
Dried whey	–	–	41.6	45.7	39.4	43.3
Maize starch	31.7	25.5	27.8	21.5	30.2	24.1
Fat, minerals & vitamins	5.7	5.5	9.2	9.5	6.7	6.9
Calculated analysis:						
ME, kcal/kg	3,630	3,630	3,630	3,630	3,630	3,630
Crude protein %	21.9	23.9	21.9	23.9	21.9	23.9
Results						
Live weight, kg:						
At start	5.7	5.6	5.3	5.6	5.5	5.4
After 5 weeks	14.6	14.7	13.3	15.6	13.9	14.7
At end of exp.	22.1	22.1	22.3	22.4	22.1	22.5
Daily live weight gain g/						
First week	7.1	21.3	16.7	35.5	4.9	22.7
First 5 weeks	257.5	259.5	227.7	287.1	241.3	264.4
Whole experiment	329.1	332.0	318.6	358.0	322.0	358.6
Kg feed/kg gain:						
First 5 weeks	1.5	1.5	1.6	1.6	1.5	1.5
Whole experiment	1.6	1.6	1.7	1.8	1.6	1.7

* Produced from selected raw material.

APPENDIX TABLE 5a
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Braude and Lerman (18)

DIET COMPOSITION (%)	TREATMENT			
	ARC* Diet 5% WHF*	Standard Diet 7% WFM	Standard Diet + Lysine 7% WFM	Standard Diet + Lysine 0% WFM
Up to 54 kg liveweight				
Barley	61.2	66.6	66.6	61.2
Wheat offals	25.0	25.0	25.0	25.0
WHF*	5.0	7.0	7.0	–
Soyabean meal	7.0	–	–	11.0
Minerals/vits.	1.8	1.43	1.43	2.9
Lysine	–	–	0.1	0.1
Methionine	0.1	0.1	0.1	0.1
From 54 kg to 96 kg liveweight				
Barley	67.2	70.2	70.2	68.2
Wheat offals	25.0	25.0	25.0	25.0
WFM*	2.5	3.0	3.0	–
Soyabean meal	3.5	–	–	4.5
Minerals/vits	1.8	1.8	1.8	2.3
Lysine	–	–	0.07	0.07
Methionine	0.1	0.1	0.1	0.1
DIET ANALYSIS (%)				
Up to 54 kg liveweight				
Crude protein	17.6	16.2	16.2	16.2
Lysine	0.82	0.72	0.82	0.82
TDN (approx. calculated value)	68	68	68	68
From 54 kg to 96 kg liveweight				
Crude protein	15.0	14.0	14.0	14.0
Lysine	0.64	0.57	0.63	0.63
TDN (approx. calculated value)	69	69	69	69

* WFM – White fish meal. ARC – Agricultural Research Council (U.K.)

APPENDIX TABLE 5b
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Braude and Lerman (18)

RESULTS:	TREATMENT				
	1 ARC[1] Diet 5% WFM[2]	2 Standard Diet 7% WFM	3 Standard Diet + Lysine 7% WFM	4 Standard Diet + Lysine 0% WFM	S.E. of treatment means
	RESULTS				
Growth rate (g/day)					
Start to 54 kg	539	522	536	528	4.54
56 kg to slaughter	715	701	710	718	5.35
Overall	616	596	613	611	4.08
Feed Conversion					
Start to 54 kg	2.87	2.99	2.89	2.93	0.025
54 kg to slaughter	3.75	3.82	3.74	3.70	0.025
Overall	3.32	3.40	3.32	3.33	0.022
Carcase data					
Length mm.	811.0	810.2	810.0	809.7	1.6
Shoulder fat mm (max.)	43.0	44.0	44.2	42.7	0.30
Mid back fat mm (min.)	20.5	21.2	21.0	20.1	0.25
Loin fat mm (min.)	22.3	23.0	22.6	22.2	0.28
Width of eye muscle mm	81.2	80.3	80.8	81.7	0.44
Depth of eye muscle mm	50.4	49.3	49.9	49.5	0.37
Fat over eye muscle (C) mm	18.3	18.7	18.8	18.0	0.29

[1]WFM = White fish meal [2]ARC – Agricultural Research Council (UK).

APPENDIX TABLE 6
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Eeckhout *et al.* (22)

DIET COMPOSITION %	FISH MEAL			SOYA		
	FF_1	FF_2	FF_3	FS_1	FS_2	FS_3
Maize	10.0	10.0	10.0	10.0	10.0	10.0
Milo	46.7	46.7	46.7	46.0	46.0	46.0
Barley	15.0	15.0	15.0	15.0	15.0	15.0
Bran	11.5	11.5	11.5	7.5	7.5	7.5
Soya	10.0	10.0	10.0	17.5	17.5	17.5
Fish meal	3.5	3.5	3.5	–	–	–
Mineral + Vit.	3.25	3.25	3.25	4.0	4.0	4.0
1-Lysine HCl	–	0.10	0.20	–	0.1	0.1
dl-methionine	–	0.05	0.10	–	0.05	0.05
DIET ANALYSIS:						
Crude protein	–	15.4	–	–	15.9	–
Lysine	0.74	0.82	0.90	0.77	0.85	0.93
Methionine + cystine	0.50	0.55	0.60	0.53	0.58	0.63

RESULTS:	FF_1	FF_2	FF_3	AVE-RAGE	FS_1	FS_2	FS_3	AVE-RAGE
Liveweight gain								
25 - 60 kg	871	896	930	899	892	916	905	905
60 - 95 kg	1024	960	910	965	1043	951	924	973
25 - 95 kg	941	921	917	926	957	931	913	934
Feed conversion								
25 - 60 kg	2.99	2.79	2.73	2.84	2.96	2.83	2.78	2.86
60 - 95 kg	3.46	3.53	3.69	3.56	3.36	3.60	3.70	3.55
95 - 100 kg	3.23	3.16	3.20	3.20	3.22	3.23	3.24	3.23

APPENDIX TABLE 7
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Pieper (23)

COMPOSITION DIET (%):	A Soya + Fishmeal		B Soya		C Soya + methionine	
Liveweight	30-60 kg	60-100 kg	30-60 kg	60-100 kg	3060 kg	60-100 kg
Maize	50	50	50	50	50	50
Barley	9	16	6	14	6	14
Wheat bran	15	20	15	20	15	20
Soya	20	10	26	14	26	14
Fish Meal	4	2	–	–	–	–
Minerals	2	2	3	2	3	2
DIET ANALYSIS:						
Dig. protein %	16.2	12.2	16.0	12.4	16.0	12.4
TDN	71.7	71.1	71.0	70.8	71.0	70.8
RESULTS:						
Liveweight gain						
g/day 30-60 kg	753		723		759	
60-100 kg	774		778		769	
30-100 kg	763		753		765	
Feed conversion						
30-60 kg	2.35		2.47		2.32	
60-100 kg	3.42		3.35		3.35	
30-100 kg	2.96		2.97		2.93	

APPENDIX TABLE 8
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Gropp *et al.* (6)

TREATMENTS	Low Proteins 1,2	Low Proteins 3,4	High Proteins 5,6	High Proteins 7,8
DIET COMPOSITION %				
Barley	44.5	46.0	34.0	36.0
Wheat	20.0	20.0	20.0	20.0
Maize	20.0	20.0	20.0	20.0
Soya	12.5	7.0	23.0	17.0
Fishmeal	0	4.0	0	4.0
Minerals + Vitamins	3.0	3.0	3.0	3.0
NET ANALYSIS: (%)				
C. Protein Trial 1	13.1	14.0	17.1	17.1
Trial 2	13.8	14.2	17.7	17.2
Lysine	0.64	0.71	0.91	0.96
Methionine + cystine	0.49	0.54	0.58	0.63
Threonine	0.53	0.56	0.68	0.70
RESULTS:				
Cumulative daily gain (g)	Low Protein Soya	Low Protein Fish meal	High Protein Soya	High Protein Fish Meal
Trial 1	284	311	352	374
Trial 2	334	372	442	455
Average	309	336	397	415
Feed conversion				
Trial 1	3.30	3.01	2.43	2.32
Trial 2	3.21	2.86	2.40	2.32
Average	3.26	2.93	2.42	2.32

Trial 1 – duration 35 days (starting at weaning – 16 kg liveweight)
Trial 2 – duration 26 days " " " "

APPENDIX TABLE 9a
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Navrátil and Vlček (19)

LIVEWEIGHT GROUP	Up to 35kg				35 to 55kg				55 to 95kg			
TREATMENT[1]	1	2	3	4	1	2	3	4	1	2	3	4
DIET COMPOSITION (%)	FM	2/3FM 1/3SMP	1/3FM 2/3SMP	SMP	FM	2/3FM 1/3SMP	1/3FM 2/3SMP	SMP	FM	2/3FM 1/3SMP	1/3FM 2/3SMP	SMP
Barley	56	56	56	56	48	48	48	48	45	45	45	45
Wheat	30.2	27.2	24.2	21.2	39.6	37.2	34.8	32.4	45.6	44.4	43.2	42
Alfalfa meal	5	5	5	5	5	5	5	5	5	5	5	5
Fish meal	7.5	5	2.5	–	6	4	2	–	3	2	1	–
Skimmed milk powder	–	5.5	11.0	16.5	–	4.4	18.8	13.2	–	2.2	4.4	6.6
Vit. & Min. Suppl.	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
DIET ANALYSIS: (%)												
Dry-matter	90.6	91.1	90.8	91.2	91.1	90.9	91.1	91.3	90.1	90.2	90.2	90.2
Crude protein	13.6	14.0	13.5	13.8	13.5	13.3	13.4	13.7	11.3	11.3	11.3	11.2
Lysine	0.69	0.69	0.69	0.69	0.63	0.63	0.63	0.63	0.51	0.51	0.51	0.51
Energy (TDN)	74.7	74.8	74.9	75.2	75.5	75.1	75.3	74.4	77.4	77.4	77.5	77.5

FM - Fish Meal SMP – skimmed milk powder

1. Treatments repeated with 0.4% added lysine.

APPENDIX TABLE 9b
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Navrátil and Vlček (19)

TREATMENT	PROTEIN SUPPLEMENT				ADDED LYSINE	
RESULTS:	FM	2/3 FM 1/3 SMP	1/3 FM 2/3 SMP	SMP	0	0.4%
Growth g/day	718^{b}	729^{b}	690^{ab}	678^{a}	666^{a}	742^{b}
Feed conversion	2.94	2.91	3.16	3.17	3.27	2.83
Weight of ½ carcass (kg)	36.6	36.4	36.2	36.5	36.5	36.4
Carcass length (cm)	77.5	77.8	77.0	76.9	77.1	77.4
Eye muscle area (cm^2) (longissimus dorsi)	30.9^{b}	29.5^{ab}	28.2^{a}	29.1^{a}	28.0^{a}	30.9^{b}
Backfat thickness at rump (cm)	3.00^{a}	3.12^{a}	3.28^{b}	3.32^{b}	3.25	3.11

FM – Fish Meal SMP – Skimmed Milk Powder
(values with a common letter are not significantly different $P < 0.05$)

APPENDIX TABLE 10
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Salo and Laalahti (24)

DIETS:

	Rates of feeding of dietary Ingredients: (g. air dried feed/pig/day)					
	Group I			Group II		
Wt. of pig (kg)	Barley	Vegetable mixture[1]	Mineral Supplement	Barley	Fish Meal	Mineral Supplement
20	960	260	40	1050	160	40
25	1060	"	"	1150	"	"
30	1260	"	"	1350	"	"
35	1410	"	"	1500	"	"
40	1610	250	50	1700	150	50
45	1810	"	"	1900	"	"
50	2010	"	"	2100	"	"
55	2210	"	"	2300	"	"
60-90	2410	"	"	2490	115	"

ANALYSIS OF DIET INGREDIENTS:

	C. Protein	Energy (Feed units)
Barley	12.3	0.9
Fish Meal	72.0	1.1
Vegetable mixture[1]	47.4	1.0

Diets were equated for energy protein, lysine, methionine + cystine, threonine and tryptophan etc.

RESULTS:	Group I	Group II
Daily live weight gain (g)	641	663
Feed energy conversion (feed units/wt gain)	2.71	2.63
Back fat mm	26.0	27.2
Side fat mm	22.8	24.5
Long dorsi cm^2	29.9	28.9
Carcass length cm.	98.0	97.5
Lean meat % carcass	45.7	45.6

1 Consisted of 60% soyabean meal, 15% turnip rape meal, 25% Torula yeast and 1% lysine.

APPENDIX TABLE 11a
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Williams and Natali (25)

Dry matter, crude protein, amino acid and digestible energy contents of the major dietary constituents (As per cent of diet)

Attribute	Grains*		Protein Concentrates*				
			Soybean meal	Fish-meal	Whale solubles	Soybean meal + whale solubles	Recommended levels‡
Inclusion level	80	80	12.5	9.5	6.7	9.6	–
Dry matter inclusion level	71.8	69.6	15.0†	14.8†	15.1†	15.0†	–
Crude protein	10.6	10.6	6.3	6.0	6.0	6.1	16
Lysine	0.34	0.20	0.43	0.53	0.42	0.43	0.7
Methionine	0.13	0.13	0.09	0.18	0.07	0.08	0.5
Cystine	0.14	0.14	0.08	0.05	0.06	0.08	0.5
Tryptophan $	0.14	0.07	0.08	0.07	0.03	0.06	0.13
Digestible energy (kJ/100 g) $	967	1,105	243†	239†	257†	250†	1,381

* The total percentage of any attribute for each diet is given by adding the values in the respective grain and protein concentrate columns.

‡ Sago contribution included, making protein concentrate up to approxamately 15% of diet.

† For pigs 20-35 kg liveweight (National Research Council 1968).

$ Estimated data used in computing these are given in text.

APPENDIX TABLE (11 b)
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Williams and Natali (25)

Average daily gains, feed and energy conversion ratios and carcass measurements for grain and protein concentrate comparisons.

Parameters measured	Grain		Protein concentrate				± SE*
	Barley	Sorghum	SBM	FM +3.5	WS	SBM + WS	
Average daily gain (g/day) 18.4 – 81.2 kg liveweight	469a	452b	479a	496a	414c	453b	4.4
Feed conversion ratio (g feed/g gain) 18.4 – 81.2kg liveweight	3.09a	3.18a	3.01a	2.93a	3.44c	3.17b	0.06
Energy conversion ratio (kJ DE/g gain) 18.4 – 81.2 kg liveweight	37.48a	42.96b	38.53a	37.30a	44.39c	40.67b	0.76
Eye muscle index (mm^2)	379Ba	3504b	3827ab	3973a	3231c	3574b	162
Backfat (mm)	18.1a	21.0b	18.1a	18.8a	21.5a	19.7a	1.6

SBM – Soybean meal. FM – fishmeal. WS – Whale solubles.

* Average standard error of the 8 diet means.

Within treatment comaprisons, means containing a common letter are not significantly different from each other. P 0.05.

APPENDIX TABLE 12
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Agde (26)

DIET COMPOSITION (%)	GROUP			
	I		II	
	Starter	Finisher	Starter	Finisher
Fish meal	8.1	5.4		
Soyabean meal	8.1	5.4	20.0	12.0
Barley	82.0	88.0	77.0	85,0
Minerals	1.8	1.2	3.0	3.0
DIET ANALYSIS (%):				
Digestible crude protein	15.3	13.3	14.7	13.3
TDN	72.1	72.3	71.7	71.5
RESULTS:				
Daily liveweight gain (g)		902		904
Feed conversion		3.10		3.26
Days to 100 kg		158.8		157.10

APPENDIX TABLE 13
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Fiedler (27)

DIET[1] (Protein Source)		LIVEWEIGHT GAIN (g/day)	FEED CONVERSION
9% Fishmeal + 8% Soyabean meal[2]	Diet 1	769	3.25
24% soyabean meal[2]	Diet 2	706	3.38
28% soyabean meal[3]	Diet 3	723	3.35

1 Full details of diets are not given.

2 These diets had similar energy protein and lysine contents.

3 This diet had similar energy content but more protein and lysine than the other diets.

APPENDIX TABLE 14
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Büenfeld *et al.* (28)

	GROUP															
	1		2		3		4		5		6		7		8	
	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Fish meal	12	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Soyabean meal (from Brasil)	–	–	–	–	9	6	13	14	19	12	22	14	20	12	20	12
Protein concentrate†	–	–	18	12	10	6	–	–	–	–	–	–	–	–	–	–
Meat & bone meal	–	–	–	–	–	–	6	–	–	–	–	–	–	–	–	–
Yeast	–	–	–	–	–	–	–	–	3	2	–	–	–	–	–	–
Barley	87	91	82	88	90	87	79	83	75	83	75	83	77	85	77	85
Mineral mixture	1	1	1	1	1	1	2	3	3	3	3	3	3	3	3	3
÷ contains 45% fish meal	† contains 45% fish meal								–		†† U.S. soyabean meal.					
DIET ANALYSIS (%)																
Digestible crude protein	13.8	11.8	14.1	12.1	14.2	11.9	14.4	12.3	14.9	12.3	14.9	12.3	15.3	12.2	15.3	12.2
TDN	68	69	69	69	69	69	69	68	68	68	68	68	68	69	68	69

RESULTS	GROUP								Limit difference 5%
	1	2	3	4	5	6	7	8	
Daily weight gain g.	772	745	745	749	729	726	735	731	22
Feed conversion	2.92	3.01	3.04	3.05	3.13	3.11	3.10	3.14	0.09
Carcass weight (cold kg)	76.06	76.37	76.31	76.06	75.11	74.97	74.73	75.17	1.02

S = Starter diet (30-50kg liveweight) F = Finisher diet (50-100kg liveweight)

APPENDIX TABLE 15
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Feist *et al.* (29)

DIET COMPOSITION (%):	Group I	Group II	Group III
Starter/grower diet			
Fish meal	5	2.5	–
Bean meal	–	15	30
Wheat middlings	26	13	–
Minerals	–	0.5	1.0
Finisher diet			
Fish meal	3	1.5	–
Bean meal (field beans)	–	10	20
Wheat middlings	17.5	8.75	–
Minerals	–	0.25	0.5
Diet Analysis (%):			
Starter/grower diet			
C. Protein	15.5	15.9	16.2
TDN	660	671	682
Finisher diet			
C. Protein	12.7	13.0	13.3
TDN	671	679	687
Results:			
Daily liveweight gain (g)	736	732	723
Feed Conversion	3.1	3.1	3.2

Only those components of diet which were varied are given.

APPENDIX TABLE 16
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Hoppe (20)

TREATMENT				
Growth Phase	30 - 50 kg		50 - 105 kg	
Group	V	F	V	F
No. Pigs	9	9	9	9
DIET COMPOSITION (%) PROTEINS				
Fish Meal	–	7.5	–	5.0
Fish solubles (concentrated)	–	1.1	–	0.75
Soya (44% C.P.)	–	4.7	–	6.1
Soya (50% C.P.)	8.4	–	10.3	–
Maize Gluten	4.6	–	1.5	–
DIET ANALYSIS %:				
Crude Protein	16.0	16.1	15.2	15.1
TDN	72.1	72.0	71.1	72.0
Lysine	0.80	0.82	0.72	0.71
Threonine	0.60	0.66	0.57	0.61
Meth + cyst.	0.56	0.57	0.52	0.52
RESULTS:				
			V	F
Average daily weight gain (g)			678	713
Feed conversion			3.238	3.166
Carcass quality classes*	1		–	1
(no. in class)	2		7	10
	3		9	5
	4		2	2

* highest class (1) represents leanest carcass, with progressively increasing fat content down classes.

APPENDIX TABLE 17
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Matre *et al.* (21)

EXPERIMENT	SV 113		SV 125			
GROUP	1	2	1	2	4	5
No. of animals	8	8	14	15	14	15
DIET COMPOSITION (%):						
Herring meal	–	2.0	–	2.0	–	2.0
Soyameal	12.3	7.8	13.0	8.0	16.0	11.0
Barley	68.2	64.0	84.5	87.5	61.5	64.5
Oats	3.0	5.0	–	–	–	–
Molasses	2.0	2.0	–	–	–	–
Meat + bone meal	1.5	1.5	–	–	–	–
Manioc	–	–	–	–	20.5	20.5
Minerals	2.5	2.3	2.5	2.5	2.5	2.5
DIET ANALYSIS (%):						
Dry matter	87.8	87.3	87.5	87.9	87.4	87.8
Crude protein	15.7	14.9	16.0	15.5	15.0	14.0
Lysine	5.1	5.0	4.5	4.6	5.3	5.3
RESULTS:						
Experiment:	SV 113		SV 125			
Treatments:						
Fish Meal:	0	2	0		2	
Daily corrected liveweight[1] gain (g)	713	709	651		667	
Feed conversion (F.F.U. 2kg corrected liveweight gain)[1]	3.09	3.07	3.30		3.22	
Killing out % [2]	70.6	71.5	72.2		73.3	

1 F.F.U. Fattening feed units.
2 Corrected to a killing out % of 73%.

APPENDIX TABLE 18
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Homb *et al.* (30)

TREATMENT	Vegetable Protein	Fish Meal
No. of pigs	4	4
DIET COMPOSITION %		
Barley	37.1	37.3
Maize	29.7	29.8
Manioc	12.4	17.3
Wheat meddlings	7.4	7.4
Soybean meal	13.4	–
Fish meal herring	–	8.2
Average daily consumption:		
Fattening feed units (F.F.U.)	1.97	1.94
Digestible crude protein, g	178	178
RESULTS:		
Corrected[1] live weight gain (C. lwg.) g/d	537	543
Feed conversion (F.F.U./kg C lwg.)	3.68	3.57
Lean score[2]	11.7	12.1
Thickness of back fat, mm	38.0	34.8
Thickness of belly, mm	32.7	34.8

1 Liveweight gain corrected to a killing out % of 73% (C. lwg.)
2 Increasing number indicates increasing quality.

APPENDIX TABLE 19
FISH MEAL IN DIETS FOR GROWING/FATTENING PIGS
From Hansen (31)

DIET COMPOSITION(%):	1	2	3	4
Herring meal(1)	0	2.0	5.0	8.0
Soyabean meal	18.0	14.0	8.0	2.0
Barley	79.7	82.0	85.4	89.4
Mineral/vits.	2.3	2.0	1.6	0.9
DIET ANALYSIS (%):(2)				
Crude Protein	16.3	16.4	16.4	16.4
RESULTS:				
Daily liveweight gain (g)	604	614	605	637
Feed conversion (kg feed units/kg gain)	3.17	3.09	3.12	3.03

(1) Defatted herring meal
(2) Details of amino acid content of diets not given

FISH MEAL SCIENTIFIC ADVISORY SERVICE

The International Association of Fish Meal Manufacturers (IAFMM) announces the establishment of a permanent Scientific Advisory Service mainly for Feed Compounders and Concentrate Manufacturers and Agricultural Institutions. The staff of the IAFMM, in conjunction with its Scientific Committee, representing an international group of experts in nutrition, bacteriology, engineering and product development, will provide up-to-date information on any aspect of Fish Meal and its uses. All enquiries should be directed to:

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International Association of Fish Meal Manufacturers,