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FISH MEAL IN DIETS FOR YOUNG PIGS

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SUMMARY AND CONCLUSIONS

Use of creep feed in the suckling period stimulates digestive enzyme induction and modifies the gut flora for better adaptation to solid dry diets. Cereal in combination with fish meal appears to improve protein digestion. Incorporation of fish meal is widely accepted in conventional creep feed. Fish meal can favourably be used in diets for pigs weaned between one and five weeks of age. Weaning at three weeks or before clearly demonstrates higher performance for diets based on milk products in combination with fish meal and cereals compared with all-vegetable diets. Fish meal is superior to isolated soyabean protein and soyabean meal as replacement for milk protein at early weaning ages. Soyabean protein in combination with fish meal and cereals are suitable when weaning at four weeks. Fish meal feeding improves performance up to ten weeks of age. Weaning from five weeks or later gives variable responses to dietary fish meal inclusion compared with other proteins, including soyabean meal. In most experiments responses were positive; in some there was no difference. Better results with early weaned pigs have been obtained when fish meal was produced from fresh selected raw material rather than from stale material.

CONTENTS

1. INTRODUCTION

Earlier weaning of pigs can improve productivity and reduce the costs of pig production. Attempts to early wean on commercial farms, for example to wean at three weeks of age, have not always been successful. Diseases, especially digestive upsets, can cause serious problems, and these may be related to feeding. Dietary protein may have an important role in this respect.

Recently, the Agricultural Research Council in the UK (1) has reviewed experiments in which nutrient requirements of pigs from three to eight weeks of age have been assessed. For protein and lysine, in relation to dietary energy, requirements were found to be high; protein– 14g per MJ DE; lysine– 0.84g per MJ DE. The protein requirement was expressed in terms of "ideal" protein providing a well balanced supply of essential amino acids.

Experiments to compare dietary proteins for the early weaned pig are few in number, yet the nature of the dietary protein is known to be important, especially as a source of essential amino acids available to the pig. Fish meal, a concentrated protein source relatively high in biological value (see IAFMM Technical Bulletin No. 1 1970) (7), had only been tested in a few experiments with early weaned pigs at the time its use as a protein source for pigs was reviewed in the IAFMM Technical Bulletin No. 6 (1979) (20). Since that time, reports of further experiments have been published comparing fish meal with other proteins, and these are reviewed in this Technical Bulletin. In particular, the value of fish meal as a replacement for milk proteins is considered.

The development of the digestive processes in the pig to three weeks of age vitally influences protein digestion. These changes should be taken into account in evaluating dietary protein sources.

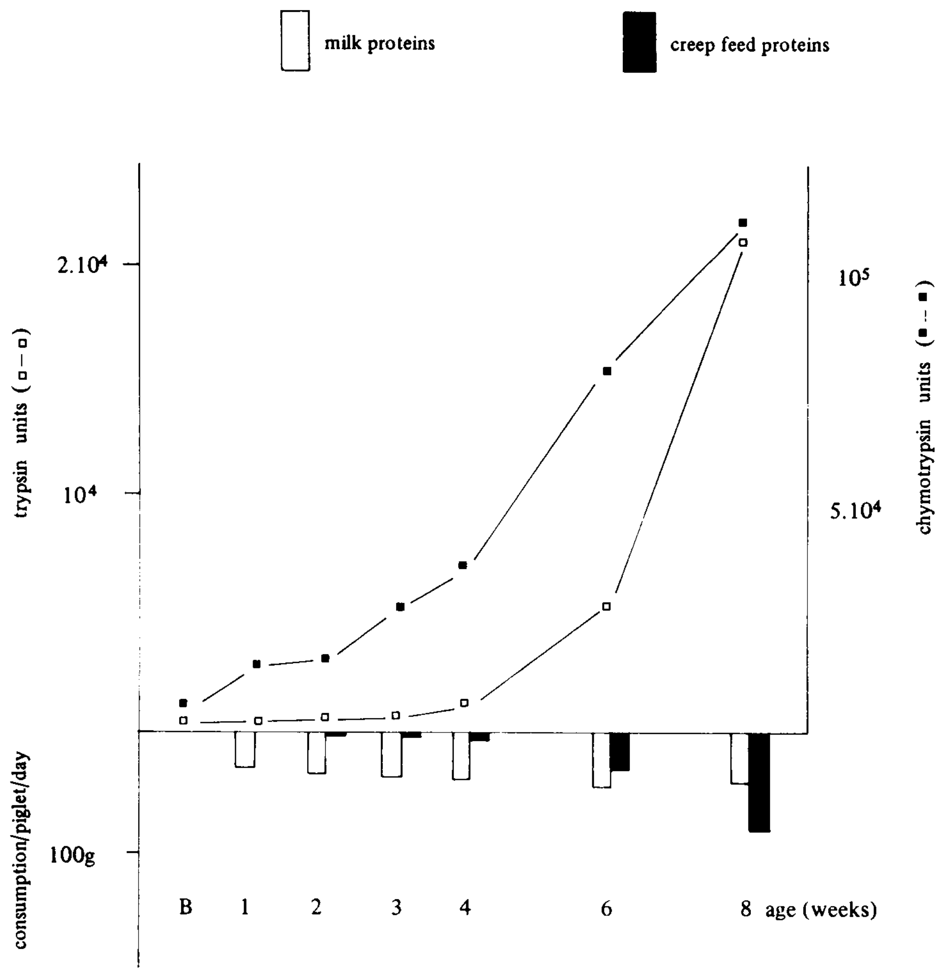
2. DIGESTIVE ENZYME DEVELOPMENT IN PIGLETS; PROTEIN DIGESTION

The digestive tract in the newborn piglet is well adapted to digest sow's milk. On a dry matter basis sow's milk is composed of about 30% protein, 25% lactose and 40% fat. Its energy value is high, due to the high fat content, and high digestibility.

The efficiency with which a substitute protein replaces that of sow's milk depends largely on the digestibility and quality of the substitute protein, but if the protein sources in addition also contain more complex starches than lactose, this could influence protein utilization. The young pig is adapted to lactose digestion, but the amylase activity in pancrease secretion develops rapidly between birth and three weeks of age (Pond *et al.* (22)). When comparing different protein sources in diets for baby pigs, the inclusion of different starches and/or lactose also will be factors to take into consideration.

The natural development of the digestive enzyme system in the young pig is considerable in the first few weeks of life. Creep feeding and weaning age can influence this development. Suckling piglets under three weeks of age have weak hydrochloric acid and pepsin secretion, but an important clotting effect of the milk protein occurs in the gastric section. This clotting slows down the rate of passage of the milk, allowing more time for digestion. Pancreatic trypsin and chymotrypsin activity is weak from birth, but a marked increase was shown to occur after three weeks of age when the dietary protein source was changed to include non milk proteins in creepfeed as shown in a figure by Seve & Aumaitre (24) (Figure 1):

Fig. 1 – Total enzymatic activities of chymotrypsin and trypsin, in the piglet, from birth till the 8th week of age (24)



Earlier weaning may improve protein digestibility (Seve *et al* (25)). According to Shields *et al.* (26), both pigs with access to creep feed or weaned at two weeks of age had higher protease activity at four weeks of age compared with a group that did not receive creep or solid feed.

Advising on the optimal utilisation of sources of protein according to age at weaning Seve and Aumaitre (24) recommended inclusion of highly digestible proteins such as skimmed milk powder, dried whey, fish meal and soluble fish protein concentrate, rather than less digestible vegetable proteins such as soyabean meal, when weaning before 35 days of age (Table 1).

TABLE 1 (from (24))

% of diet	Weaning at: 12 days	21 days	35 days
Skim-milk powder	25-50	10-15	0-5
Dried whey	0-15	0-15	0-15
Fish meal	0-5	5-10	2-5
Soluble F.P.C.	10-20	0-10	0-5
Soyabean oil meal	5-10	10-15	15-20

In summary, digestive enzyme development can be stimulated by introducing small quantities of non-milk proteins and cereals into the diet of the young pig, particularly from three weeks of age. The non-milk proteins fed should be those which are more digestible, such as fish meal.

Currently pig diets are formulated on the basis of the chemically determined total amino acids. A part of the amino acids is indigestible. Some indication of the digestibility of amino acids has been obtained from analysis of feed and faeces, to obtain faecal digestibility. However, these figures can be misleading. Fermentation in the hind-gut can result in amino acid breakdown followed by microbial synthesis. Catabolism and anabolism of amino acids in the hind gut will vary, resulting in a variable effect on the faecal content of an amino acid and its faecal digestibility. By establishing a cannula at the end of the small intestine (ileum) several workers have determined ileal digestibility of amino acids from various protein sources.

Fuller *et al.* (8) and Brundza *et al.* (3) have shown amino acids from fish meal to have generally higher ileal digestibilities than amino acids from vegetable proteins (see Appendix tables 1 and 2). This could be important with respect to lysine and threonine as these could be limiting amino acids in diets based on vegetable proteins and barley.

3. THE NUTRITIVE VALUE OF FISH MEAL FOR PIGLETS

The main components in fish meal, and the range of their contents in commercially available fish meal, are protein – 60% to 72%, fat – 5% to 12%, ash 12% to 20% and the balance as moisture. The ash contributes substantial quantities of calcium and phosphorus which are highly available to the young pig. Fish meal also contains water soluble vitamins. However, its major function is to provide protein and the constituent amino acids. Eggum (5) working with young pigs (30 to 35 days of age), found the essential amino acids in fish meal highly digestible (about 90%). Most fish meals, with the exception of those with a high content of offal, contain about 7.5% lysine in the protein and between 5.0 and 5.4% lysine as fed (see Technical Bulletin No. 1) (7). Lysine is generally the first limiting acid in pig diets. For each % of fish meal included in diets for young pigs, contribution of lysine required from other sources is reduced by approximately 5%.

Leibholz (15) reported that for four concentrated protein sources the apparent protein digestibility in pigs between 9 and 28 days of age decreased in the following order, casein, isolated soyabean protein (ISP), fish meal and soyabean meal. Apparently nitrogen digestibility in fish meal was calculated to be 87% (Table 2):

TABLE 2 (from (15)) [1,2]

	DIET			
Protein source	**Casein**	**ISP**	**Fish meal**	**Soya bean meal**
Apparent nitrogen digestibility, %[1]				
9-14 days of age	94.6	91.2	86.6	83.1
23-28 days of age	96.9	90.7	87.6	87.8

1) Standard error of mean, diet 0,0039[xx], age 0,0035[x], diet & age 0,0048.
(x $P < 0.05$, xx $P < 0.01$)

2) For details of diets used, see appendix Table 3.

Gjefsen and Opstvedt (9) measured protein digestibility and nitrogen balance in pigs over two periods, i.e. from 31 to 36 and from 60 to 64 days of age:

TABLE 3 (from (9))

Protein in diets (%)	6	12	18	24
		Digestibility %		
Dried skim milk diets				
31 to 36 days of age				
AD[1]	87.6±5.4	92.5±2.4	96.4±0.4	96.9±1.0
TD[2]	99.2±5.5	99.8±1.6	100.3±0.8	100.0±1.0
60 to 64 days of age				
AD	87.3±5.7	92.4±1.5	96.3±1.1	97.4±0.5
TD	97.6±5.1	98.9±1.5	100.5±1.1	100.5±0.5
Fish meal (80)/ whey powder (20) diets:				
31 to 36 days of age				
AD	81.3±3.2	88.1±1.2	91.7±6.4	94.2±2.2
TD	92.8±3.0	93.6±1.2	94.2±3.7	97.3±2.2
60 to 64 days of age				
AD	82.1±3.3	90.8±2.5	90.6±2.2	93.0±2.4
TD	93.5±3.3	95.7±2.4	94.8±2.2	96.1±2.4

1) Apparent protein digestibility

2) True nitrogen digestibility.

Dried skim milk or a mixture of selected Norwegian Herring type fish meal and whey powder (80:20) was incorporated as the sole protein source to give 6, 12, 18 and 24% dietary protein (Appendix Table 3). The true digestibility (TD) for the dried skim milk protein was 99.6% while that of fish meal – whey powder diets was 94.8%. The latter agrees closely with the value of 93.8% TD of fish protein obtained by Eggum (5).

3.1 Conventional rearing/creep feed

Creep feed is normally made available to suckling piglets from the second week of life to weaning as a supplement to the sow's milk. The protein level can therefore be lower than that in a complete feed, but the protein must be of high quality. The palatability of creep feed is an important factor, and this can be influenced by the make-up, and particularly the quality of ingredients such as proteins. Although the amount of creep feed consumed by individual piglets is relatively small, the nutrients in the creep feed are used more effectively than the same nutrients if they were fed to the sow to convert into milk for the baby pig (Lucas and Lodge) (16). Quite small intakes of creep feed can induce digestive enzyme activity (see pages 2 & 3), and modification of the gut flora which may smooth the dietary changes upon weaning.

Gråvas and Gjefsen (11) reported higher performance when using increased protein (27%) and fish meal (24%) levels in creep feed compared with a conventional creep feed containing 18% protein and 3% fish meal plus 15% soyabean meal (Appendix Table 4). In the period from two weeks of age and to weaning at six weeks of age, the growth performance was improved from 207 g/day to 282 g/day and feed conversion was reduced from 1.88 to 1.38. Conventional creep feed in Norway now includes 11% fish meal made from selected raw material (Appendix Table 5). Economically, the price of fish meal is the factor which tends to limit higher inclusion.

3.2 Artificial rearing

Artificial rearing is defined as rearing of piglets weaned within a few days of birth. Pond *et al* (22) found fish protein concentrate equal to casein and superior to isolated soyabean protein when used as the sole protein source in liquid diets for pigs artificially reared from 2 to 4 days of age. (For details of diets used see Appendix Table 6). Newport (17, 18) found higher growth rate using fish protein concentrate and whey powder as a replacement for 50% of the dried skim milk in liquid diets to pigs weaned at 2 days of age:

TABLE 4 (from (17))

Protein source	Milk[1]	50% Milk 50% Fish[2]	Fish
Daily gain, g	216	249	130

1) From dried skim milk

2) From fish protein concentrate

The crude protein level was 3% higher in the fish protein diet, and this might explain the better growth compared with dried skim milk. Total replacement of dried skim milk markedly reduced performance and increased scouring and mortality.

The experiments demonstrated that fish proteins can be used as partial replacement of milk protein in liquid diets to pigs weaned during the first week of life. Furthermore fish protein appears to be more suitable than soyabean protein for this purpose.

3.3 Weaning between one and three weeks of age

Seve *et al.* (25) replaced 33%, 66% and 100% of skim milk protein by fish protein in pelletized diets from weaning at twelve days of age and up to 63 days of age. High inclusion of fish protein concentrate (66% or 100%) decreased digestibility and growth. A combination of 33% fish protein and 67% skim milk protein did not affect growth and apparent digestibility compared with 100% skim milk protein.

Leibholz (15) observed 5% lower gain when fish meal supplied 50% of the total dietary protein instead of milk protein (casein) (details of diets are given in Appendix Table 7). Fish meal was superior to soyabean meal and isolated soya bean meal (ISP) in promoting growth and better feed conversion:

TABLE 5 (from (15))

	DIET					
Protein source	**Casein**	**ISP**	**Fish Meal**	**Soya bean meal**	**S.E. of mean Diet**	**Age**
Weight gain (g/day)						
7 to 14 days of age	89	103	95	80		
14 to 21 days of age	212	163	197	189	9.51*	8.24**
21 to 28 days of age	332	374	309	304		
7 to 28 days of age	211	180	200	191	6.65**	
Feed intake (g/day)						
7 to 28 days of age	177	209	185	210	7.54**	
Feed conversion[1]						
7 to 28 days of age	0.84	1.16	0.93	1.10	0.00039**	

1) Feed conversion: Feed intake/weight gain (g/g)
* $P < 0.05$ **$P < 0.01$

Roderiques and Young (23) working with pigs weaned at 1 week, replaced protein from milk products (buttermilk casein) with herring meal protein (0%, 20%, 40% and 60% replacement). Average daily gains (g) over four weeks were respectively 223, 207 206 and 184 g/day. Feed intake decreased with increasing amount of fish protein. Adjusted daily gain per unit food intake did not vary, which indicates similar feed conversion.

In summary, partial replacement of milk protein with fish meal was successful for replacement of up to half the milk protein. Fish protein is preferable to vegetable protein such as soya bean meal for pigs weaned before three weeks of age.

3.4 Weaning from three to five weeks of age

Okai *et al.* (19) conducted an experiment pre-weaning and post weaning 36 litters, each adjusted to seven or eight piglets. Piglets were given no creep feed, a simple one of cereals and soya, one containing also tallow (semi-complex), or a complex one without cereals but based on dried milk products, starch, sugars, soyabean and herring meals. Details of the diets are given in Appendix Table 8. At weaning at 21 days of age pigs were re-allocated for four weeks more to one of the three diets given before weaning. Before weaning creep intake was small and there was no significant difference between the groups, suggesting adequate intake of sows milk. In the post weaning period, dietary substitution of soyabean meal with herring meal and dried skimmed milk improved weight gain ($P < 0.001$) and feed conversion (not significant):

TABLE 6 (from (21))

Treatments	Diet: Simple	Semi-complex	Complex	Significance
% fish meal	0	6.4	11.0	
No. of pigs [1]	72(4)	72(3)	72(1)	
Mean 3 weeks (weaning) wt (kg)	5.14	5.21	5.01	NS[2]
Mean 7 weeks wt (kg)	12.60[a]	13.74	14.46[b]	xxx
Mean daily gain, 3 to 7 weeks (kg)	0.27[a]	0.31[b]	0.34[c]	xxx
Mean daily intake, 3 to 7 weeks (kg)	0.44[a]	0.48[b]	0.54[c]	xxx
Feed conversion [3] 3 to 7 weeks	1.63	1.54	1.59	NS
Digestibility coefficients				
Energy (%)	86.0[a]	86.5[a]	93.2[b]	xx
Nitrogen (%)	87.1[ab]	85.1[a]	90.5[b]	x

1) Number of pigs that died during the experiment is shown in brackets
2) NS, not significant (P > 0.05)
x Significant treatment difference (P < 0.05)
xx Significant treatment difference (P < 0.01)
xxx Significant treatment difference (P < 0.001)
a-c Means within a row with same letter are not significantly different (P > 0.05)
3) Feed conversion: Feed intake/weight gain (g/g)

Increased weight gains may have resulted from an effect of increased energy and lysine concentrations, but the greatest nitrogen digestion was also obtained with the complex diet where herring meal provided 33% of the total protein inclusion. When Okai *et al.* (19) weaned piglets at five weeks of age, no significant differences were obtained on liveweight gain and feed intake up to eight weeks of age. The results indicate that complex diets containing large amounts of milk and fish meal protein and processed carbohydrates are superior to diets based on cereals and soyabean meal as the major source of energy and protein when weaning at about three weeks of age. At five weeks of age no difference in weight gain was obtained between complex and simple diets based mostly on cereals and soyabean meal.

De Moura and Fowler (4) compared four diets fed to piglets from weaning at three weeks of age until they reached 25kg liveweight. A control diet of white fish meal and milk was compared with three diets containing soyabean protein as the main protein from soyabean meal extracted or with soya oil (S+O) or without soya oil (S) full fat soyabean meal (FFS). All diets had the same ratios of crude protein and lysine per unit of digestible energy (MJ). The growth of piglets on the white fish meal and milk diet (C) was outstanding, daily gains being 484g/day in the first two weeks and 534g/day in the first five weeks. Comparable pairs of daily gains for the other three treatments were 361g and 447g for S + O, 351g and 447g for S and 375g and 474g for FFS. In comparison with the fish meal plus milk diet, the soyabean diets resulted in daily gains at least 22% less from three to five weeks of age and at least 11% less from three to eight weeks of age. It was concluded that the better response of pigs on the fish meal plus milk protein diet was due to the suitability of this protein fraction to the digestive capacity of the immature digestive tract of the young pig.

Pike *et al.* (21) examined the response of different nutrient density diets with or without fish meal inclusion for the first two weeks following weaning at 3 to 4 weeks of age. On conventional diets (digestible energy 15.1 MJ/kg dry matter (DM), crude protein 188g/kg DM), both growth rate and feed conversion up to 8 weeks of age were significantly higher with fish meal inclusion. On high density diets (digestible energy 17.7 MJ/kg DM, crude protein 209g/kg DM) fishmeal improved growth rate and feed conversion numerically, though the difference was not significant. The growth rate on both high density diets was not significantly higher than on the conventional diet with fish meal inclusion. Incorporation of fish meal in the conventional weaning diet favourably increased pig performance, and this positive effect remained up to slaughter at 90kg liveweight.

Gjefsen *et al.* (11) compared dried skim milk with two combinations of fish meal and whey powder as protein sources at two dietary protein levels (22% and 24%) in diets for pigs weaned at three weeks of age (for details) of the diets and results see Table 7). The growth experiment was conducted from weaning up to 22kg liveweight. There were no significant differences between weight gain and feed conversion comparing dry skim milk or fish meal diets, but significantly higher liveweight gain was obtained with 24% compared with 22% dietary protein:

TABLE 7 (from (11))

Treatments

Protein source:	**Skim milk powder**		**Fish meal[1]**		**Fish meal[2]**		
Protein in diet, %	22	24	22	24	22	24	
No. of animals	12	12	12	12	12	12	
Dietary Ingredients: (%)							
Skim milk powder	63.0	69.0	–	–	–	–	
Fish meal	–	–	21.4	23.3	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, MJ	15.2	15.2	15.2	15.2	15.2	15.2	
Crude protein %	22.0	24.0	22.0	24.0	22.0	24.0	
Results:							
Live weight, kg:							**S.E. of mean**
At start	5.7	5.6	5.3	5.6	5.5	5.4	0.27
Daily live weight gain, g							
First 5 weeks	256	260	227	287	241	264	11.8
Whole experiment	329	332	319	358	322	359	9.0
Feed conversion[3]:							
First 5 weeks	1.5	1.5	1.6	1.6	1.5	1.5	0.044
Whole experiment	1.6	1.6	1.7	1.8	1.6	1.7	0.066

1) Produced from selected raw material, solvent extracted
2) Produced from selected raw material
3) Feed Conversion: Feed intake/weight gain (g/g)

Fish meal in diets based on soyabean meal plus cereals for pigs from weaning at four weeks to ten weeks of age was examined by Kjeldsen *et al.* (14).

TABLE 8 (from (14))

	Diet					
	1	2	3	4	5	6
Fish meal inclusion, (%)	0	4	8	12	16	20
Number of pigs	20	20	20	20	20	20
Average weight, kg at:						
4 weeks	7.5	7.5	7.5	7.5	7.5	7.5
6 weeks	8.6	9.2	9.1	9.5	9.5	9.2
8 weeks	14.3	15.6	15.7	16.5	15.9	16.2
10 weeks	23.1	24.9	24.8	25.9	24.6	24.9
Daily gain, g	370	413	412	438	407	413

(Diet composition is shown in Appendix Table 9)

Lysine and methionine content increased slightly with increasing amount of fish meal inclusion. The increase in lysine content may have influenced the result, as lysine may have been limiting in the diets, but the effect is likely to have been small, and would certainly not account for the size of the differences between the treatments. During the first two weeks of the experiment the piglets receiving fish meal diets gained 0.5kg to 0.9kg more than piglets given the diet without fish meal. In the whole period daily weight gain was improved from 370 g/day to an average of 416 g/day with fish meal inclusion. Increasing the content of fish meal up to 12% inclusion resulted in increased feed consumption and daily gain. Costings made at the time showed that when prevailing prices of fish meal were approximately double soya bean meal, the optimum fish meal level in the diet was 8% to 9%.

Gulbrandsen (12) studied the effect of whey powder inclusion in diets for piglets weaned at three weeks of age. All diets contained 27.9% protein of which herring type fish meal based on selected raw material provided 73% of the total protein. Further protein was supplied with variable levels of whey powder and cereals (Appendix Table 10). High whey powder inclusion (26%) was preferable the first two weeks after weaning, but later on diets with higher amounts of cereals gave the best performance (Table 9). This development seems natural according to the piglets enzymatic adaptation to digest lactose in early stages of life. Digestibility of more complex carbohydrates is limited during the early weeks of life, but starch digestibility increases relatively rapidly after weaning between three and five weeks of age (see p2):

TABLE 9 (from (12))

	Diet					
	1	2	3	4	5	6
Whey powder (g/kg of diet)	432	346	260	173	87	0
Barley/wheat (g/kg of diet)	0	83	174	260	346	432
Number of experiments	5	5	5	5	5	5
Total number of pigs	25	25	25	25	25	25
Start weight, kg	6.4	6.2	6.6	6.4	6.1	6.5
Weight gain, g/day						
From 21 to 28 days of age	71	77	102	70	55	33
From 28 to 35 days of age	229	256	251	228	227	209
From 35 to 42 days of age	325	337	362	333	349	307
Average up to 22 kg liveweight	366	384	386	382	377	365
Feed conversion[1] (up to 22kg liveweight)	1.34	1.31	1.33	1.34	1.37	1.37

[1]Feed conversion – feed intake/weight gain (g/g)

Bouard *et al.* (2) found no favourable effect of 5% fish meal inclusion in cereal/soya diets to pigs between five and ten weeks of age (9kg to 25kg liveweight). English *et al* (6) evaluated diets varying in source and concentration of protein and energy for pigs from 8kg to 24kg liveweight. Diets with proteins derived from cereals, milk, fish meal and soyabean meal were compared with diets based on cereals and soya proteins. The diets also gave two energy concentrations (see Appendix Table 11 for diet composition). All diets contained equal lysine to protein and protein to energy ratios, and the pigs were fed *ad lib.* The cereal based diets supplemented with protein from milk, herring meal and soyabean meal supported the best performance in terms of growth and feed efficiency (Table 10). Of these two diets the lower energy diet resulted in increased feed intake and a non-significant increase in liveweight gain:

TABLE 10 (from (6))

	Diet				
	A	B	C	D	
Results:					S.E. of Difference
Liveweight (kg)					
Start	8.18	8.08	8.04	8.15	
Finish	22.85	21.97	23.61	22.13	0.56
Feed intake per day (g)	773	802	832	790	15.5
Liveweight gain per day (g)	390	375	417	375	15.3
Gain: feed ratio (kg:kg)	0.499	0.466	0.505	0.457	0.016
Deaths					
Number	2	1	3	6	
Percent	1.6	0.8	2.3	4.7	

In summary these investigations have shown that fish meal in combination with dried skim milk products and cereals markedly improve performance compared with cereal and soyabean meal diets without animal protein supplement, when weaning at three weeks of age. Piglets at this age or younger have not developed sufficient enzymatic capacity to digest complex vegetable proteins and carbohydrates; the highly digestible fish meal together with milk products are more suitable. When weaning at four weeks of age, investigations show that dried milk products can be replaced successfully by a mixture of fish meal, cereals and soyabean meals. Exclusion of fish meal in these diets reduces performance. Optimal performance was obtained with 12% fish meal inclusion together with about 60% cereals and 13% soyabean meal as the main constituents. Pigs weaned at five weeks of age or later appear to show variable responses to dietary fish meal inclusion. Most trials show better results with fish meal in diets, though the size of the response varies.

4. QUALITY OF FISH MEAL FOR YOUNG PIGS

Kjeldsen *et al.* (13) working with pigs weaned at four weeks of age, examined dietary inclusion of 12% fish meal manufactured from fish with different degrees of freshness (i.e. total volatile nitrogen (TVN) in the raw material). A diet without fish meal was used as a control; for details of the fish meal qualities and diets see Appendix Table 12. The results from the feeding experiments with pigs between four and ten weeks of age are shown in Table 11:

TABLE 11 (from (13))

	Treatments					
	1	2	3	4	5	6
Fish meal type	control – no fishmeal	whole meal	whole meal	pressed cake meal	whole meal	whole meal
TVN (mgN/100g) in fish meal	–	< 70	<70	<60	<120	<140
No. of pigs	20	20	20	20	20	20
Average weight at:						
4 weeks, kg	7.3	7.2	7.2	7.2	7.2	7.3
10 weeks, kg	22.0^{c}	24.5^{ab}	25.7^{a}	23.9^{b}	23.9^{b}	24.1^{b}
Daily gain, g	350^{c}	412^{ab}	442^{a}	398^{b}	398^{b}	400^{b}
Fup/kg gain[1]	2.36^{c}	2.14^{a}	2.05^{a}	2.17^{ab}	2.28^{bc}	2.14^{a}

Values with different superscripts are significantly different ($P < 0.05$)

1) Fup = Feed units for pigs

All diets containing fish meal resulted in better performance than that achieved by the control group. Daily gain was significantly better in the fish meal groups compared with the control group. Whole fish meals prepared from raw material with lowest TVN content gave best growth and best feed utilisation. Presscake meal resulted in poorer performance than expected from the raw material quality; daily gain was similar to that achieved feeding fish meal produced from raw material of lower quality. Total lysine contents of the meals (see Appendix Table 12) are surprising; presscake meal normally has a higher lysine content than whole fish meal due to the lower lysine content of the protein in solubles added back to produce whole fish meal. Protein digestibilities of the fish meal diets were also determined. The digestibility was influenced by the fish meal quality in the same way as performance for the growth experiment. An economical calculation based on the current feed prices and on the achieved feed consumption and daily gain showed a difference of 13 Danish Kroner (US $ 1.4) in net profit per ten week old pig when using a high quality fish meal compared with a low quality meal.

REFERENCES

1. *Agricultural Research Council.* 1981 The Nutrient Requirements of Pigs. Technical Review by an Agricultural Research Council Working Party. Commonwealth Agricultural Bureau Farnham Royal, Slough SL2 3BN, England.
2. *Bouard, J.P., Castaing, J. and Fekete, J.* (1979). Journees Rech. Porcine en France 197-202.
3. *Brundza, L., Zebrowska, T., Savic, S., Teodorovic, M. and Latkouska, M.* 1981. 'Zbornikradova' br 1I/12. Institut zu stocarstvo, Nov Sad.
4. *De Moura, M.P. and Fowler, V.R.* 1983. Anim. Prod. **36**, 3:523. (Abst.)
5. *Eggum, B.O.* (1973). 406 beretning fra Førsogslaboratoriet, København.
6. *English, P.R., Davidson, F.M., Dias, M.F.M., Smith, W.J., Tan, M.H.B.T. and Fowler, V.R.* (1979). Anim. Prod **28**, 3:437 (Abst.)
7. *Food and Agriculture Organisation* (1970). Available Amino Acid Content of Fish Meals. Technical Bulletin No. 1. IAFMM, Hoval House, Mutton Lane, Potters Bar, Herts, EN6 3AR, UK.
8. *Fuller, M.F., Cadenhead, A., Chin, K.H., Milne, T. and Brown, D.* **(1983). VI**th Int. Symp. Protein Metabolism and Nutrition. III 285. INRA.
9. *Gjefsen T. and Opstvedt, J.* (1980). Acta Agric. Scand. **30** 175-182.
10. *Gjefsen, T., Gulbrandsen, K.E. and Opstvedt, J.* (1980) Acta Agric. Scand. **30**, 157-167.
11. *Gråvas, L. and Gjefsen, T.* (1978). Forsøk med forautomater og til skuddsfôr til smågris. Stensiltrykk nr. 152. Institutt for bygningsteknikk, Norges Landbrukshøgskole.
12. *Gulbrandsen, K.E.* To be published.
13. *Kjeldsen. N.J., Danielsen, V., Just, A., Nielsen, H.E. and Eggum, B.O.* 1983. National Institute of Animal Science, Copenhagen. Newsletter No. 449.
14. *Kjeldsen, N.J., Danielsen, V., Nielsen, H.E. and Eggum, B.O.* (1981). National Institute of Animal Science, Copenhagen. Newsletter No. 390.
15. *Leibholz, J.* (1982). Anim. Prod. **34**, 9-12.
16. *Lucas, I.A.M. and Lodge, G.A.* 1961. The Nutrition of the Young Pig. Tech. Comm. 22. Commonwealth Agricultural Bureau, Farnham Royal, England.
17. *Newport, M.J.* (1979). Br. J. Nutr. **41**, 103.
18. *Newport, M.J. and Keal, H.D.* (1983). Br. J. Nutr. **49** 43-50.
19. *Okai, D.B., Aherne, F.X. and Hardin, R.T.* 1976. Can. J. Anim. Sci. **56** 573-586.
20. *Pike I.H.* (1979). 'The role of fish meal in diets for pigs'. Technical Bulletin No. 6. IAFMM, Hoval House, Mutton Lane, Potters Bar, Herts EN6 3AR, UK.
21. *Pike, I.H., Curran, M.K., Edge, M., and Anne Harvey.* 1983 Anim. Prod. **36**, 3:523 (Abst).
22. *Pond, W.G., Snyder, W., Walker Jr. E.F., Stilling, B.R. and Sidwell, V.* (1971). J.Anim. Sci. **33** 587-591.
23. *Roderiques, J.P. and Young, L.G.* (1980). J. Anim. Sci. **51** Suppl. 1, 218.
24. *Seve, B. and Aumaitre, A.* (1978). World Review of Animal Production, **XIV**, No. 2. 25-31.
25. *Seve, R., Aumaitre, A., Tord, P.* (1975). Ann. Zootech. **24**, 21-42.
26. *Shields, R.G., Ekstrom, K.E. and Maham, D.C.* (1980). J. Anim. Sci. **50**, 257-265.

APPENDIX TABLE 1
DIGESTIBILITY OF N AND OF AMINO ACIDS IN SEVEN PROTEIN SOURCES, ESTIMATED FROM ANALYSIS OF DIGESTA FROM THE TERMINAL ILEUM
From Fuller ět *al.* (8)

SOURCE	COPRA	FISH MEAL: SAND EEL	FISH MEAL: HERRING	POULTRY OFFAL	SUNFLOWER	MAIZE GLUTEN	SESAME	SEM	SIGNIFICANCE OF DIFFERENCE BETWEEN DIETS
Nitrogen	0.52	0.79	0.78	0.57	0.66	0.61	0.76	0.025	$p < 0.001$
Threonine	0.49	0.80	0.79	0.55	0.60	0.60	0.66	0.029	$p < 0.001$
Valine	0.70	0.86	0.85	0.72	0.72	0.73	0.80	0.019	$p < 0.001$
Iso-leucine	0.65	0.88	0.87	0.76	0.75	0.72	0.79	0.022	
Leucine	0.70	0.89	0.88	0.73	0.75	0.84	0.82	0.019	$p < 0.001$
Tyrosine	0.78	0.88	0.89	0.68	0.78	0.83	0.86	0.018	$p < 0.001$
Phenylalanine	0.76	0.87	0.86	0.74	0.78	0.79	0.85	0.017	$p < 0.001$
Lysine	0.53	0.91	0.89	0.61	0.65	0.69	0.71	0.036	$p < 0.001$

APPENDIX TABLE 2
APPARENT DIGESTIBILITY OF AMINO ACIDS IN THE SMALL INTESTINE
From Brundza *et al.* (3)

	DIETARY TREATMENT GROUP: MAIZE/ SOYABEAN MEAL	MAIZE/ FISHMEAL	MAIZE/ SUNFLOWER MEAL	MAIZE/ SKIMMED MILK POWDER
Aspartic acid	77.9^a	74.7^a	63.8^b	69.3^c
Threonine	64.8^a	71.5^b	65.2^c	70.7^b
Serine	74.7^a	73.7^a	58.6^b	66.5^c
Glutamic acid	72.3^a	72.3^a	65.8^b	74.4^a
Proline	73.5^b	67.2^a	70.2^a	85.4^c
Glycine	45.3^a	70.4^b	57.0^c	59.7^c
Alanine	76.9^a	79.9^a	71.9^b	72.7^b
Valine	65.7^b	74.5^a	59.4^c	70.4^a
Iso-leucine	75.6^a	67.8^b	72.4^a	72.4^a
Leucine	87.2^b	81.7^a	71.9^c	81.7^a
Tyrosine	77.9^a	91.1^b	79.7^c	88.3^b
Phenylalanine	79.6^a	80.4^a	79.5^a	84.3^b
Lysine	71.1^a	79.9^b	59.1^c	77.6^b
Histidine	76.4^a	79.0^a	70.6^b	77.5^a
Arginine	86.0^a	86.0^a	85.1^a	81.7^b

Values with same superscripts do not differ significantly

APPENDIX TABLE 3
DIET COMPOSITION
From Gjefsen & Opstvedt (9)

	Experiment 1				Experiment 2			
	Protein in diets (%)				Protein in diets (%)			
Ingredients (%)	6	12	18	24	6	12	18	24
Dried skim milk	17.23	34.55	51.82	69.10				
Norseamink[1)]	–	–	–	–	6.10	12.15	18.20	24.30
Whey powder	–	–	–	–	10.28	20.45	30.63	40.90
Lactose	27.44	18.28	9.14	–	28.88	21.25	13.60	5.90
Glucose	22.95	16.95	10.98	5.00	5.00	5.00	5.00	5.00
Salt	1.29	0.99	0.69	0.39	1.01	0.75	0.49	0.23
Calcium carbonate	0.36	0.36	0.36	0.36	0.55	0.58	0.62	0.65
Dicalciumphosphate	2.88	1.92	0.96	–	2.91	1.94	0.98	–
Magnesiumoxide	0.11	0.07	0.04	–	0.13	0.09	0.04	–
DL-methionine	0.04	0.08	0.12	0.15	0.03	0.05	0.08	0.10
Fat, ground oat hulls, zincbacitracin, ethoxyquin, vitamins and minerals	6.08	6.08	6.08	6.08	6.08	6.08	6.08	6.08
Maize starch	to 100%							

1) Produced from selected raw material.

APPENDIX TABLE 4
CREEP FEED COMPOSITION
From Gråvas & Gjefsen (11)

Conventional Creep Feed		Experimental Creep Feed	
Ingredients	%	Ingredients	%
Herring type fish meal	3.0	Herring type fish meal	23.8
Soyabean meal – extracted	14.60	Whey powder	45.0
Wheat middings	8.90	Oats, ground	7.2
Barley, ground	47.0	Maize starch	10.5
Oats, ground	7.4	Lard	5.0
Sorghum, ground	10.0	Sunflower oil	1.0
Molasses	1.0	Glucose	3.45
Dried milk	2.0	Vitamins & minerals	4.05
Sugar	2.0		
Lysine	0.08		
Vitamins & minerals	4.0		

1 Produced from selected raw material.

APPENDIX TABLE 5
CONVENTIONAL CREEP FEED COMPOSITION
AS USED IN NORWAY

Ingredients:	g/kg
Fish meal, NorSeaMink[1]	110
Soyabean meal, extracted	105
Dried whole milk	20
Barley, ground	297
Oats, ground	57
Wheat, ground	100
Sorghum, ground	103
Maize, ground	100
Sugar	20
Hydrogenated marine fat	37
Dried apple powder	20
Lysine	0.3
Methionine	0.1
Ascorbic acid	5.0
Ferrous fumarate	0.5
Chalk	7.0
Salt	1.8
Dicalciumphosphate	10.7
Microminerals	0.55
Vitamins	3.00

1) Special quality of Norwegian herring meal.

APPENDIX TABLE 6
COMPOSITION OF LIQUID DIETS FOR BABY PIGS
From Pond *et al.* (22)

Ingredients	%	g/litre
Protein source[1]	33.0	66.00
Glucose (Cerelose)	39.32	78.64
Minerals	5.68	11.36
Vitamins premix	1.00	1.00
Lard	20.00	40.00
Soya lecithin	1.00	2.00
Total	100.00	200.00

1) Fish protein concentrate A (FPC-A), fish protein concentrate B (FPC–B), casein, or isolated soyabean protein (ISP)

APPENDIX TABLE 7
DIET COMPOSITION
From Leibholz (15)

Variable ingredients (g/kg)	Diets: Casein	ISP	Fish meal	Soyabean meal
Casein	253	–	–	–
Isolate soyabean protein (ISP)[1]	–	237	–	–
Fish meal	–	–	358	–
Soyabean meal	–	–	–	505
Lactose	540	549	435	281
Lysine	–	3	–	3
Methionine	–	4	–	4
Chemical composition (g/kg dry matter)				
Crude protein	273	278	271	276
Lysine	21.0	20.9	22.2	20.9
Methionine	7.7	7.0	6.6	7.1

1) In this and following Tables, Supro 610, Ralston Purina, St. Louis, Mo.

APPENDIX TABLE 8
DIET COMPOSITION
From Okai *et al.* (19)

Ingredients (%)	Diets: Simple	Semi-complex	Complex
Wheat	45.0	25.0	–
Barley	13.5	15.0	–
Oat groats	–	25.0	–
Dextrose	–	–	10.0
Sucrose	–	–	7.0
Corn starch	–	–	17.5
Tallow	3.0	2.0	1.0
Soybean meal (45,8%)	34.0	13.0	13.0
Herring meal (70,6%)	–	6.4	11.0
Dried skim milk	–	10.0	20.0
Dried whey	–	–	15.0
Vermiculite [1]	–	–	3.0
Iodized salt	0.5	0.4	0.5
Calcium phosphate	1.5	1.0	0.5
Calcium carbonate	1.0	0.7	–
Vitamin mineral mix.	1.5	1.5	1.5
Composition: (analyzed)			
Moisture (%)	7.7	7.3	4.8
Crude protein (%)	23.8	22.5	23.4
Gross energy (Mcal/kg)	4,055	4,188	3,801
Crude fibre (%)	4.2	3.1	0.9
Digestible energy (Mcal/kg)	3.49	3.62	3.56
Amino acid levels (calculated)			
Lysine (%)	1.2	1.3	1.7
Methionine & cystine (%)	0.8	0.8	0.9

1) Vermiculite, a fine aggregate form. Vermiculite is expanded or exfoliated mica, relatively inert chemically.

APPENDIX TABLE 9
DIET COMPOSITION
From Kjeldsen *et al.* (14)

Ingredients kg.	Diet 1	2	3	4	5	6	
Fish meal	0	40	80	120	160	200	
Soya bean meal	340	270	205	135	67	0	
Barley	318	352	381	415	447	478	
Wheat	200	200	200	200	200	200	
Dried yeast	50	50	50	50	50	50	
Animal fat	50	50	50	50	50	50	
Dicalcium phosphate	21	19	15	13	10	7	
Chalk	10	8	8	6	5	4	
Salt	3	3	3	3	3	3	
Vitamin – micromineral-mix	8	8	8	8	8	8	
Total	1000	1000	1000	1000	1000	1000	
Chemical analyses: g/kg							Fish meal
Dry matter,	873	880	881	882	878	886	916
(Dry matter basis):							
Crude protein	272	276	274	274	281	283	763
Crude fat (Soxhl.)	78	85	87	92	97	101	103
Ash	67	67	65	65	64	62	136
Ca	11.5	11.1	10.1	9.6	9.2	8.5	14.7
P	8.3	8.5	8.3	8.5	8.7	8.6	21.4
Lysine	14.1	14.4	14.6	14.8	15.2	15.7	51.3
Methionine	4.1	4.4	4.7	5.4	5.7	6.4	21.1
Cystine	4.3	4.1	3.8	3.6	3.4	3.3	5.9

APPENDIX TABLE 10
DIET COMPOSITION
From Gulbrandsen (12)

Ingredients kg	Diet 1	2	3	4	5	6
Whey powder	100	80	60	40	20	0
Barley/wheat	0	20	40	60	80	100
NorSeaMink[1)]	290	291	293	295	297	299
Whey powder	432	346	260	173	87	–
Barley	–	43	87	130	173	216
Wheat	–	43	87	130	173	216
Maize	118	118	118	118	118	118
Oats	92	92	92	92	92	92
Glucose	28	31	32	36	39	43
Sun flower oil	10	10	10	10	10	10
Vitamin–Mineral mix.	5	5	5	5	5	5
DL-methionine	1	1	1	1	1	1
Lard	24	20	15	10	5	–
Chemical content g/kg:						
Crude protein	279	279	279	275	277	279
Crude fat (Soxhl.)	67	65	62	59	57	55
Ash	72	65	63	57	55	48
DE,MJ/kg (calculated)	17.8	17.7	17.6	17.4	17.3	17.1

1) Special quality of Norwegian herring meal.

APPENDIX TABLE 11
DIET COMPOSITION
From English *et al.* (6)

	Diets			
Ingredients (%)	A	B	C	D
Barley	41	34.5	73	66.5
Maize	30	30		
Soya Bean Meal	12	32	10	30
Denatured skim milk (Brand 1A)	10		10	
Herring Meal	5		5	
Dicalcium phosphate	1	2	1	2
Limestone flour	0.33	0.5	0.33	0.5
Salt	0.5	0.75	0.5	0.75
Vitamins/trace minerals	0.35	0.25	0.25	0.25
Chemical analysis (air dry basis):				
Dry matter (g/kg)	903	893	906	892
Crude protein (g/kg)	202	204	199	199
Crude fibre (g/kg)	24.2	41.5	32.8	40.9
Crude fat (g/kg)	51.7	33.8	31.6	25.1
Calculated values				
Energy content (MJ DE per kg)	14.7	14.12	13.64	13.59
Protein to Energy (g crude protein per MJDE)	14.3	14.4	14.6	14.6
Lysine in protein (g/16g N)	7.7	7.7	7.8	7.8
Calcium (g/kg)	7.5	7.6	7.6	7.7
Phosophorus (g/kg)	7.3	7.5	7.3	7.8
Salt (g/kg)	8.1	8.3	8.2	8.3

All diets were pelleted.

APPENDIX TABLE 12
DESCRIPTION OF FISH MEAL QUALITIES
From Kjeldsen *et al.* (13)

	Diets				
	1	2	3	4	5
TVN in raw material					
TVN in raw material (mg/N/100g)	< 70	< 70	<60	< 120	< 140
Meal type	wholemeal	wholemeal	presscakemeal	wholemeal	wholemeal
Analyses of Fish Meal (%)					
Moisture	6.7	4.6	6.3	2.6	6.8
Fat (Soxhlet)	5.7	6.4	10.1	13.6	9.6
Crude protein	70.4	76.4	71.8	66.0	72.8
Ash	19.4	15.2	11.9	16.8	12.3
DBC (mmol/16gN)	94	91	90	92	84
TVN (%N of total N)	1.46	1.20	0.98	2.41	2.76
Lysine (g/16gN)	8.17	7.85	7.49	7.57	7.17
Meth. & Cystine (g/16gN)	4.20	3.95	3.95	3.80	3.71

Feed composition (%)	Diets	
	Coı Control	1–5
Fish meal	0.0	12.0
Soya bean meal	34.0	13.5
Barley	31.8	41.5
Wheat	20.0	20.0
Dried yeast	5.0	5.0
Animal fat	5.0	5.0
Vitamins and minerals	4.2	3.0
	100.0	100.0

Chemical analysis of diets:	Control	1	2	3	4	5
In dry matter:						
Crude protein	26.4	26.3	27.1	26.8	26.0	26.8
Fat(Stoldt)	8.3	8.8	9.2	9.8	9.8	9.7
Ash	7.0	7.5	7.1	6.3	7.0	6.8
Lysine (g/16gN)	5.25	5.70	5.78	5.60	5.68	5.40
Meth. & Cystine (g/15gN)	3.02	3.37	3.39	3.30	3.38	3.16
FFA (% of fat)	12-	13	11	11	16	13
Peroxid (mekv/kg fat)	1.0	1.4	2.3	1.2	1.7	1.7
TVN (% N of total N)	93	83	86	84	82	82

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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:

Dr. S. M. Barlow
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