

Effect of Fishmeal Supplementation on Body Weight Gain of Weaned Pigs in Eritrea

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Abstract

Two 7-week trials were carried out to examine the effect of supplementing the existing feed of weaned pigs in Eritrea with locally produced fishmeal on the body weight gain of the pigs. The diet of the weaned pigs consisted of 'bakery waste', wheat middlings and wheat bran to make 62, 22, and 15%, respectively, by air-dry weight at the beginning of the trials. In two comparative trials (Trial 1 and Trial 2), this diet was given to a group of 13 pigs as the control diet. In an attempt to improve the nutrient content of the feed, 90 grams of fishmeal per pig was added to the mixture of wheat middlings and wheat bran. The fishmeal-supplemented diet consisted of 62, 16.7, 11.1, and 10% of 'bakery waste', wheat middlings, wheat bran and fishmeal by air-dry weight, respectively. This was fed to 13 weaned pigs. The crude protein (CP), lysine, and threonine content in % and DE in MJ/kg of the control diet were 12.67, 0.41, 0.42 and 13.34, respectively. Supplementing with 90 grams of fishmeal per pig resulted in the composition of the diet to be 16.61, 0.68, 0.54% and 13.51 MJ/kg of CP, lysine, threonine and DE, respectively. Restricted feeding was practiced with the amount of wheat middlings, wheat bran and fishmeal kept constant throughout the period of the experiment with more 'bakery waste' being used to meet the increased demand of feed with increase in body weight. 10 grams of salt and 10 grams of limestone per pig were added to the feed of each group daily. In Trial 1, pigs fed the fishmeal-supplemented diet attained a growth rate of 0.29 kg per day, which was significantly ($P = 0.042$) higher than the 0.19 kg attained by the pigs fed the control diet. Similarly, in Trial 2, pigs supplemented with fishmeal attained a significantly higher ($P = 0.003$) growth rate of 0.34 kg per day compared to 0.18 kg per day for the pigs fed the control diet.

Keywords: Body weight gain, crude protein, fishmeal, lysine, pigs

Introduction

Fishmeal is a high quality animal feed used to provide a good balance of essential amino acids, energy, vitamins, minerals and trace elements for poultry, pigs and ruminants (FAO, 1986; Bimbo and Crowther, 1992; O'Connor *et al.*, 1993). However, the high cost of imported fishmeal (Balogun, 1982; Nwokoro and Olumide, 1996) has made its continued use in pig diets unattractive. This has increased the need to explore locally available sources of fishmeal either from shrimp by-catch or small pelagic fish

(Tuitoek and Ayangbile, 1994). In cases where fish waste is available in insufficient quantities for fishmeal production, the use of fish silage as pig feed has also been tried with good results (Hoffman, 1981; Machin *et al.*, 1982). Fishmeals locally produced mostly through sun-drying and grinding have been shown to have comparable nutritive values to imported fishmeals (Steiner-Asiedu, *et al.*, 1993; Eid *et al.*, 1992). Promising results have been obtained from trials carried out on poultry and pigs using locally prepared

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fishmeals (Bouzouaia and Rekhis, 1994; Tuitoek and Ayangbile, 1994; Nwokoro and Olumide, 1996; Tuitoek, 1992).

Attempts have been made to determine nutrient requirements of pigs in a tropical environment. With rations that included 70-85% maize and 8-19% groundnut cake, performances approaching that of temperate areas have been achieved (Babatunde, *et al.*, 1972; Fetuga *et al.*, 1975; Tuitoek, 1992). Usually cereal grains and protein meals that form the basis of such rations are either needed for human consumption or are too expensive to use in pig diets. Therefore, any attempt at improving pig performances in a particular area has to take the locally available feeds and management practices into consideration. The various feeds used in the tropics have a lower dietary energy than those commonly used in temperate areas. Numerous researchers have carried out trials to improve pig performance using locally available resources and obtaining decent results albeit considerably lower than results obtained in temperate areas (Hoffman, 1981; Machin *et al.*, 1982; Ayoade and Makhamera, 1984).

The objective of this experiment was to examine the effect on body weight gain of weaner pigs of supplementing the current pig diet in Eritrea with locally produced fishmeal.

Materials and Methods

Composition of rations

The ingredients of the control diets (C) were 'bakery waste' collected from the students' cafeteria of the university, wheat middlings and wheat bran to make 62, 22, and 15% by air-dry weight, respectively, at the beginning of the trials. The ingredients of the fishmeal supplemented diets (FM) were 'bakery waste', wheat middlings, wheat bran and fishmeal to make 62, 17, 11 and 10% by air-dry weight, respectively, at the beginning of the trials.

Trial 1

Twenty-eight 5-week old piglets, which had just been weaned, were divided into two groups of

14, each group balanced by weight and sex. The males were castrated at 2 weeks of age. At the beginning of the experiment, there were 9 males and 5 females in Group 1 fed on the control diet (C) while there were 10 males and 4 females in Group 2 fed on the fishmeal-supplemented diet (FM). The control diet (C) consisted of 'bakery waste', wheat middling and wheat bran while FM consisted of the same ration but supplemented with locally produced fishmeal. The composition of the diets is shown in Table 1. The amount of wheat middling and wheat bran was kept constant at 225 and 150 g, respectively, for each pig fed on C throughout the experiment while the amount of wheat middling, wheat bran, and fishmeal was 171, 114, and 90 g, respectively, for the pigs fed on FM. Each pig was also provided with 10 g of salt and 10 g of limestone as an additional source of Na and Ca. As the feed intake of the pigs increased with increase in body weight, the amount of 'bakery waste' provided to them was progressively increased in equal amounts to each group. The pigs were fed as a group. Feed was provided twice a day in a semi-liquid broth form after mixing the components in a vat using water. Unfortunately, this way of providing the pigs with feeds made the measuring of feed intake impossible. Body weight of the pigs was taken every week.

The pigs were housed in two identical concrete-floored pens with an indoor sleeping area and an outdoor creep area provided with a feed trough. Straw was spread on the floor for bedding every afternoon and cleared every morning.

Trial 2

A similar experiment was conducted with 13 weaned pigs in each group, except that this time the weaners were aged 7-weeks. There were 5 males and 8 females in the control group while there were 4 males and 9 females in the fishmeal-supplemented group.

Table 1. Composition of diets in trials 1 and 2

Item	C	FM
'Bakery waste'	62.0	62.0
Wheat middlings	22.0	16.7
Wheat bran	14.6	11.1
Fishmeal	-	10.0
Salt	1.0	1.0
Crude protein	12.67	16.61
DE (MJ/kg, calculated analysis)	13.34	13.51
Arginine	0.69	0.82
Histidine	0.31	0.37
Isoleucine	0.48	0.65
Leucine	0.88	1.15
Lysine	0.41	0.68
Methionine	0.19	0.29
Methionine + cystine	0.50	0.59
Phenylalanine	0.60	0.74
Phenylalanine + tyrosine	1.00	1.29
Threonine	0.42	0.54
Tryptophan	0.21	0.27
Valine	0.62	0.81

C= Control diet; FM= Fishmeal supplemented diet

Chemical analyses

Samples of the two diets were collected at regular intervals. The contents of crude protein (Kjeldahl-N x 6.25), crude fat (HCl-ether extract), crude fibre, ash, calcium and phosphorus were determined according to standard procedures described by Association of Official Analytical Chemists (AOAC) (1990). Amino acid composition was determined according to OJEC (1998). Tryptophan was determined according to OJEC (2000).

Table 2. Weekly body weight in kg of pigs in trials 1 and 2

Age (weeks)	Trial 1		Trial 2	
	C	FM	C	FM
5	11.61 ^a	11.04 ^a		
6	12.71 ^a	13.08 ^a		
7	13.96 ^a	13.54 ^a	15.42 ^a	16.11 ^a
8	15.52 ^a	15.53 ^a	17.00 ^a	18.53 ^a
9	15.86 ^a	16.23 ^a	18.62 ^{ab}	21.88 ^b
10	17.21 ^a	18.77 ^a	20.83 ^{ab}	24.95 ^b
11	-	-	21.75 ^a	26.54 ^b
12	18.88 ^a	22.29 ^a	22.07 ^a	28.55 ^b
13			22.23 ^a	31.41 ^b

abc Means in the same row not sharing a common superscript are significantly different (P<0.05)
C= Control diet; FM= Fishmeal supplemented diet

Statistical analysis

Both trials were designed according to completely randomized design. The pig was the experimental unit. Body weights and feed intakes were analyzed using the GLM procedure of the SAS Institute, Inc. (1990). Results were presented as the least squares means (LSMEANS) of the pen in each treatment, and variance of the data was presented as standard error of the means (SEM).

Table 3. Weekly average body weight (kg) of weaned pigs in trials 1 and 2 after excluding 3 runts from each group

Age (weeks)	Trial 1		Trial 2	
	C	FM	C	FM
5	12.2 ^a	12.0 ^a	-	-
6	13.4 ^a	14.3 ^a	-	-
7	16.5 ^a	16.3 ^a	16.7 ^a	17.0 ^a
8	16.4 ^a	17.5 ^a	18.3 ^a	19.9 ^a
9	17.1 ^a	18.6 ^a	20.1 ^a	23.1 ^a
10	18.8 ^a	20.8 ^a	21.9 ^{ab}	25.5 ^b
11	-	-	22.9 ^a	27.4 ^b
12	20.7 ^a	25.2 ^{bc}	23.9 ^{ab}	29.5 ^c
13	-	-	23.9 ^a	32.4 ^b

abc Means in the same row not sharing a common superscript are significantly different (P<0.05)
C= Control diet; FM= Fishmeal supplemented diet

Results

Analysis of rations

The chemical analysis of the control diet (C) resulted in the crude protein (CP), lysine, and threonine content in % and DE in MJ/kg to be 12.67, 0.41, 0.42 and 13.34, respectively. The chemical analysis of the fishmeal-supplemented diet (FM) resulted in the crude protein (CP), lysine, and threonine content in % and DE in MJ/kg to be 16.61, 0.68, 0.54% and 13.51, respectively (Table 1).

Trial 1

The average initial body weight of the weaners fed on C was 11.6 kg with a range of 9.4 to 14.8 kg while that for the weaners fed on FM was 11.0 kg ranging from 7.4 to 14.2 kg. The feeding trial lasted for a period of seven weeks. One pig died from each group from apparent pneumonia. At

the end of the trial, the average weight of the pigs fed on C was 18.9 kg ranging from 10 to 27 kg while it was 22.3 kg ranging from 12.8 to 32 kg for the pigs fed on FM. The difference in the final weight between the two groups was not significant at $P < 0.05$. The average daily weight gain was 150g for the pigs fed on C while it was 230 g for the pigs fed on FM.

If the three lowest weighing pigs (runts) were removed from each group, the final weight and daily weight gain would be 20.8 kg and 190 g/day, respectively, for the pigs fed on C. The respective figures for the pigs fed on FM would be 25.3 kg and 290 g/day. The final weight of the fishmeal-supplemented group was significantly higher ($P = 0.042$) than that of the control group.

Starting on the second week the pigs supplemented with fishmeal were seen to suffer from greenish diarrhoea, which lasted for about 2 weeks. They were treated with antibiotics.

Trial 2

The average initial weight of the weaners fed on C was 15.4 kg with a range of 10.0 to 21.0 kg while that for the weaners fed on FM was 16.1 kg ranging from 12.0 to 21.0 kg. The feeding trial lasted for a period of seven weeks. At the end of the trial, the average weight of the pigs fed on C was 22.2 kg ranging from 15 to 32 kg while it was 28.7 kg ranging from 13.5 to 42 kg for the pigs fed on FM. The final weight of the fishmeal-supplemented group was significantly higher than that of the control group ($P = 0.039$). The average daily weight gain was 141.9 g per day for the pigs fed on C while it was 261.3 g for the fishmeal-supplemented pigs.

If the three lowest weighing pigs (runts) were removed from each group, the final weight and daily weight gain would be 23.9 kg and 176.7 g/day, respectively, for the pigs fed on C while the respective figures for the pigs fed on FM would be 32.4 kg and 338.3 g/day. The final weight of the pigs fed on FM was significantly ($P = 0.003$) higher than the pigs fed on C.

Pigs fed on FM, in Trial 2 had higher daily body weight gains than pigs fed on FM in Trial 1. Trial 1 was carried out in the months of January and February while Trial 2 was done in April and May. No mortality or diarrhoea incidents were noted in Trial 2 for any of the groups.

Discussion

The pigs fed on the fishmeal supplemented diet (FM) with a 16.67% CP, showed a marked increase in daily gain to 0.28 and 0.34 kg per day in the first and second trials, respectively. Babatunde *et al.* (1972) obtained a daily weight gain of 0.29 kg on weaners fed a diet containing 18% CP, and Balogun (1982) obtained average daily weight gain of 0.28 and 0.35 kg/day on 16–35 kg pigs fed on diets with 18 and 20% crude protein levels, respectively, in the humid tropics. The results obtained in the present study seem to be better taking into consideration the superior basal diets used by both groups of workers which consisted of maize (70-85%) and groundnut cake (8 -19%) and higher CP levels. The less harsh environment of the highlands in Eritrea could be one reason because the above-mentioned authors indicated the depressing effect of high ambient tropical temperatures on appetite to be the cause of the lower feed consumption they had observed in the trials. The positive effects of fishmeal shown by numerous studies (Laksevela, 1961; Pike *et al.*, 1984; Stoner *et al.*, 1990), that it generally improves growth and performance of starter and grower pigs could also be another reason to explain the difference. Pike (1979) suggests explanations for the positive responses to fishmeal to be a better amino acid supply and balance, an under-estimation of the energy contribution of fishmeal, and the contribution of selenium within the fishmeal. There were also some reporters who obtained better growth rates than those obtained in the present study with diets having a similar or lower level of protein. Fetuga *et al.* (1975) obtained a daily live-weight gain of 443.5 g on weaners of a weight class interval of 13-34 kg fed on a diet of 16% CP. This was higher than the gain obtained in this study using a similar CP level. The reason for this could be the superior basal diet used by Fetuga *et al.* (1975) which consisted of yellow maize (75%), ground nut cake, fishmeal, blood meal, etc. providing DE of 15.65 MJ/kg and a better amino acid balance, particularly lysine than the fishmeal-supplemented diet used in the present study. Tuitoek (1992) obtained average daily gain of 831 g on growing pigs with an initial body weight of 23.0 kg fed for 30 days using a diet with a CP content of only 15.5%. The diet contained 90.85% of barley and 7.6% local (omena) fishmeal. The better performance

obtained by Tuitoek (1992) could be due to the higher energy of the diet, as well as the variation that exists in the quality of the different fishmeals.

The nutrient composition of the control diet (C) and fishmeal-supplemented diet (FM) is shown in Table I. The control diet (C), while being marginally deficient in energy, was severely deficient in CP (12.27%), and as a result also deficient in lysine and other amino acids. Eusebio (1980) recommends 17% CP and a DE of 14.64 MJ/kg for pigs of 10-30 kg live weight to achieve a daily gain of 0.32 kg. In the present trials, supplementing with fishmeal resulted in the improvement of CP level to 16.67%, which is within the recommended level, while the DE remained being marginally deficient at 13.51 MJ/kg. Some authors have also recommended higher CP levels. Serres (1992) recommended 18% CP for pigs of 10-20 kg liveweight to achieve a daily live-weight gain of 454 g. The growth rate of pigs fed on C of 0.19 kg per day is low but similar to growth rates obtained on pigs fed on similarly inadequate diets. Hoffman (1981) fed 9-week old pigs on locally available feeds such as coconut meal, breadfruit flour and fish silage and obtained growth rates which ranged from 186 to 409 g/d. Babatunde *et al.* (1972) obtained average daily gains of 0.10 and 0.16 kg for weaners fed dietary crude protein levels of 12 and 14%, respectively. The slightly lower daily gains obtained by Babatunde *et al.* (1972) than those obtained in the present study could be due to the adverse effect of the humid environment in which they worked.

The amino acid composition of both diets is shown in Table I. The amino acids most limiting in cereal grains for swine are lysine, threonine, tryptophan and histidine (Lewis, 1985). The control diet is severely limited by lysine and to some extent by threonine, but is also short in histidine while the contents of tryptophan and methionine seem to be adequate. Even though, supplementation with fishmeal improved the overall amino acid balance of the diet, the level of some amino acids, particularly lysine and to a smaller extent threonine, still fell short of the recommended levels. The lysine level was raised from 0.41% in C to 0.68% in FM. The recommended amino acid level for lysine for pigs weighing 20-50 kg ranges from 0.76-1.09% for different types of diets (NRC, 1998). The e level was likewise increased from 0.42

to 0.54% after supplementation with fishmeal. The threonine requirement recommended by different authors ranges from 0.54 – 0.75% for pigs weighing from 5 – 50 kg and fed different diets (NRC, 1998) while ARC (1981) suggests 0.37 – 0.6% threonine to be adequate for pigs weighing 10 to 55 kg. The histidine content was increased from 0.31% in C to 0.37% in FM, thus meeting the NRC (1998) recommendation of 0.36%. All other essential amino acids were adequate in C and supplementation with fishmeal further increased their levels as can be seen from Table I.

Other changes that occurred in the diet as a result of addition of fishmeal could also have partially contributed to the improvement in performance of the pigs fed on FM. The higher CP content of FM and the inclusion of fishmeal in itself could have increased the feed intake of the pigs fed this diet compared to those pigs fed on C. Although in the present study, it was not possible to measure feed intake, many workers have found an increase in daily feed consumption with increase in dietary protein levels and improvement of quality by inclusion of fishmeal (Babatunde, *et al.*, 1972; Stoner *et al.*, 1990). Protein quality and quantity are among the important factors regulating feed intake in animals (Pond *et al.*, 1965; D'Mello, 1992).

The inclusion of fishmeal slightly increased the calculated DE in MJ/kg from 13.34 to 13.51, while lowering the CF content from 3.0% in C to 2.3% in FM. The reduction in CF came about because the addition of fishmeal was followed by a proportional reduction in the amounts of wheat bran and wheat middlings, which were the main sources of fibre. The more fibrous and abrasive the feed, the greater the associated metabolic faecal loss and the lower the digestibility of the protein (Whittemore and Elsley, 1976).

The improvement in the amino-acid balance due to addition of fishmeal in the present study, could partially explain the improved performance of the weaners fed the fishmeal-supplemented diets in both trials. However, supplementation with 90 g of fishmeal per pig per day could not satisfy the lysine requirement. Raising the level of fishmeal to 15% of the dry matter would increase the protein level to 18.87% and the lysine content of the diet to 0.85%. Fetuga *et al.* (1975) obtained improved growth rate and feed efficiency on pigs from 8 to 50 kg

live weight fed diets with a common energy level of 15.65 MJ/kg of DE as the protein levels were increased from 16 up to 20%. Furthermore, 16 and 18% protein diets showed significant responses to additional lysine. Babatunde *et al.* (1972) found average daily gain increased from 0.28 to 0.39 kg as the dietary crude protein levels increased from 16 to 20%. However, the above experiments were carried out in the humid tropics and the dietary energy of the diets was much higher than that of the present study. Increasing the level of fishmeal in order to increase the amount of lysine only while keeping the same marginal dietary energy could lead to a reduction of ME. Almost all other amino acids were balanced or already in excess with the addition of 90 g of fishmeal per pig per day.

It has been mentioned that weaners in Trial 2 performed better than those in Trial 1 for the fishmeal-supplemented groups. This could be due to three reasons. The first is that during the first trial an incidence of greenish diarrhoea was observed which affected several pigs only in the fishmeal-supplemented group. Even though the affected pigs were treated with antibiotics, the weakening effect of the diarrhoea continued for a few weeks and this could partially explain the poorer performance of the fish-meal supplemented pigs in Trial 1 than their counterparts in Trial 2. The problem of diarrhoea was not manifested in Trial 2. Overall, pigs supplemented with fishmeal seemed healthier than the control group. This confirms the fact that animals fed inadequate protein diets are usually more susceptible to disease infections than those fed more adequate protein diets, as revealed in the work of Hill *et al.* (1962). The second cause for the difference could be due to the better weather conditions that were prevalent during the months when Trial 2 was carried out compared to Trial 1. The first trial was carried out during the months of January and February. In Asmara, Eritrea, which has an altitude of about 2300 metres above sea level, these months could be quite cold with occasional frost. The weaner pigs in both groups seemed to suffer with pneumonia-like symptoms and were seen coughing frequently. Trial 2 was carried out in the months of April and May by which time weather conditions were mild and no incidences of pneumonia-like symptoms were noticed. The third reason could be that the weaners in Trial 2 were about 10–14 days older and slightly heavier

compared to the weaners in Trial 1. This could have enabled them to better withstand the stressful time of weaning.

Economic considerations

Finished pigs were being sold at 16 nakfa (~1.6 USD) per kg of live-weight at the time when the trials were conducted. The cost of fishmeal was 4 nakfa (~0.4 USD) per kg. The extra cost due to fishmeal supplementation was 17.64 nakfa per pig. At the end of Trial 1, pigs fed on FM were on average 4.6 kg heavier than pigs fed on C. The extra gain due to fishmeal supplementation of 73.6 nakfa (4.6x16) more than covered for the extra cost of fishmeal. Similarly, for Experiment 2 the added cost of fishmeal per pig was 17.28 nakfa while the extra gain of 6.42 kg was worth 102.72 nakfa. In both trials supplementing with fishmeal increased the profitability sharply.

Conclusions

Current nutrient recommendations for weaner or grower pigs are designed to meet a given weight gain under conditions found mostly in temperate countries. It is futile to try to achieve such weight gains in the tropics where the right feeds are either not available or are too expensive. It is rather advisable to try to improve performance of pigs using existing feed resources in a particular area. One such unexploited feed resource that could go a long way in improving pig performance in Eritrea is fishmeal. Fishmeal, locally produced by simple sun-drying and grinding, used as a supplement to local pig diets in Eritrea has the potential to improve pig performance and production profitability. There were indications that a higher level of fishmeal than the one used in the present study could result in an even better performance. Therefore, further studies are recommended to establish the highest economically reasonable level of incorporating fishmeal in the diets of weaners and growers. The possible use of other sources of protein such as blood meal and synthetic amino acids should also be explored.

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References

- ARC (Agricultural Research Council), 1981. The nutrient requirement of pigs. C.A.B., England.
- AOAC (Association of Official Analytical Chemists), 1990. Official Methods of Analysis. 15th ed., Washington, DC, USA.
- Ayoade, J.A. and Makhambura, T.P.E., 1984. Alternative to maize in pig diets. 1. Replacing maize with bean pods in the diets of growing-fattening pigs in the tropics. *Trop. Anim. Prod.* 9, 200-202.
- Babatunde, G.M., Olomu, M.J. and Oyenuga, V.A., 1972. Determination of the optimum crude protein requirement of pigs in a tropical environment. *Anim. Prod.* 14, 57-67.
- Balogun, T.F., 1982. The effect of dietary protein level and blood meal supplementation on the performance of growing Large White and Landrace pigs in Nigeria. *Trop. Anim. Prod.* 7, 14-19.
- Bimbo, A.P. and Crowther, J.B., 1992. Fishmeal and Oil: Current Uses. *JAOCs*, 69, 221-227.
- Bouzouaia, M. and Rekhis, J., 1994. Trials of meals from animal origin in broilers in Tunisia. *Revue Méd. Vét.* 145, 7, 581-585.
- D'Mello, J. P. F., 1992. Amino acid imbalances, antagonisms and toxicities. In: D'Mello, J.P.F. (ed.) *Amino Acids in Farm Animal Nutrition*, Wallingford, CAB International, UK, pp. 63-97.
- Eid, N., Dashiti, B. and Sawaya, W., 1992. Chemical and physical characterization of shrimp by-catch of the Arabian Gulf. *Food. Research International* 25, 181-186.
- Eusebio, J.A., 1980. Pig production in the tropics. Intermediate Tropical Agriculture Series. Longman Group Ltd., UK.
- FAO (Food and Agriculture Organisation), 1986. The production of fishmeal and oil. FAO Fisheries Technical Paper, 142 (Rev. 1), Fisheries Industries Division, FAO, Rome.
- Fetuga, B.L., Babatunde, G.M. and Oyenuga, V.A., 1975. Protein levels in diets for European pigs in the tropics. *Anim. Prod.* 20, 133-146.
- Hill, G.H., Colburn, R.W. and Schneider, H.A., 1962. The relative roles of vitamins, protein, and the salmonellosis-resistance factor in the natural resistance of mice to salmonellosis. *J. Nutr.* 78, 424-430.
- Hoffman, A., 1981. The use of coconut cake and fish silage as pig feed in the Seychelles. *Trop. Anim. Prod.* 6, 76-77.
- Laksevela, B., 1961. Graded levels of herringmeal to bacon pigs, effect on growth rate, feed efficiency and bacon quality. *J. Agric. Sci.* 56, 307-315.
- Lewis, A. J., 1985. Use of synthetic amino acids in practical rations. In *Proceedings of the Carolina Swine Nutrition Conference*. Raleigh, North Carolina State University, USA, pp. 32-45.
- Machin, D.H., Young, R.H. and Crean, K., 1982. The use of formic acid prepared fish silage made from shrimp by-catch in the diets of fattening pigs. *Trop. Anim. Prod.* 7, 120-126.
- NRC (National Research Council), 1998. *Nutrient Requirements of Swine*. Tenth Revised Edition, National Academy Press, Washington, DC, USA.
- Nwokoro, S.O. and Olumide, T.O., 1996. Utilisation of fishmeal, blood meal and chicken offal meal as methionine and lysine supplements in oilseed cake based diets by growing finishing cockerels. *Bull. Anim. Hlth. Prod. Afri.* 44, 197-200.
- O'Connor, J.D., Sniffen, C.J., Fox, D.G. and Chalupa, W., 1993. A net carbohydrate and protein system for evaluating cattle diets: IV. Predicting amino acid adequacy. *J. Anim. Sci.* 71, 1298-1311.

- OJEC (Official Journal of the European Communities), 1998. Commission Directive 98/64/EC of 3 September 1998 establishing Community methods of analysis for the determination of amino acids, crude oils and fats, and olaquinox in feedingstuffs and amending Directive 71/393/EC. L 257, 19, pp.16-23.
- OJEC (Official Journal of the European Communities), 2000. Commission Directive 2000/45/EC of 6 July 2000 establishing Community methods of analysis for the determination of vitamin A, vitamin E and tryptophan in feedstuffs. L 174, pp. 45-50.
- Pike, I.H., 1979. The role of fishmeal in diets for pigs. Tech. Bull. Int. Assoc. Fishmeal Manuf. No. 6.
- Pike, I.H., Curran, M.D., Edge, M. and Harvey, A., 1984. Effect of nutrient density, presence of fishmeal and method of feeding of unmedicated diets on early-weaned pigs. Anim. Prod. 39, 291-299.
- Pond, W., Barnes, G.R.H., Bradfield, R.B., Kwong, E. and Krook, L., 1965. Effect of dietary energy intake on protein deficiency symptoms and body composition of baby pigs fed equalized but sub-optimal amounts of protein. J. Nutr. 85, 57-66.
- SAS Institute, Inc. 1990. SAS user's guide. SAS Institute, Inc., Cary, NC, USA.
- Serres, H., 1992. Manual of pig production in the tropics. C.A.B. International, Walling for, UK.
- Steiner-Asiedu, M., Lied, E., Lie, Ø. and Nilsen, R., 1993. The nutritive value of sun-dried pelagic fish from the Rift Valley in Africa. J. Sci. Food Agric. 63, 439-443.
- Stoner, G.R., Allee, G.L., Nelssen, J.L., Johnston, M.E. and Goodband, R.D., 1990. Effect of select menhaden fishmeal in starter diets for pigs. J. Anim. Sci. 68, 2729-2735.
- Tuitoek, J.K., 1992. Pelagic whole fish (*Rastriobola argenteus*) as a protein source for pigs. Trop. Anim. Hlth. Prod. 24, 251-255.
- Tuitoek, J.K. and Ayangbile, A.O., 1994. Small pelagic fish and fermented blood as complementary protein supplements for poultry. Bull. Anim. Hlth. Prod. Afr. 42, 135-140.
- Whittemore, C.T. and Elsley, F.W.H., 1976. Practical pig nutrition. Farming Press Ltd., Suffolk, UK.