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Effects of Fish Meal from Various Origins on Growth Performance and Nutrient Digestibility in Piglets

J.H. Cho, Y.J. Choi and I.H. Kim
Department of Animal Resource and Science, Dankook University,
Cheonan, 330-714 Choongnam, Korea

Abstract: A total 100 weaned pigs [(Landrace x Yorkshire) x Duroc; 8.33 kg average initial BW] were used to evaluate the effects of fish meal from different origins on growth performance and nutrient digestibility. The dietary treatments were TLF (8 and 5% Triple Nine® low temperature fish meal in Phase 1 and 2, respectively), TF (8 and 5% Triple Nine® fish meal), FLF (8 and 5% FF Skagen® low temperature fish meal) and EF (8 and 5% El Golfo® fish meal). In Phase 1 and 2, experimental diets were fed for 10 and 14 days, respectively. In Phase 3, the same diet without fish meal was fed to evaluate after-effect of fish meal on growth performance after Phase 2. There were 5 replications with 5 pigs per pen. From days 0-10, pigs fed TF and EF diets had greater ($p<0.05$) ADG compared to pigs fed the TLF and FLF diets. Pigs fed the TF diet had improved ($p<0.05$) gain/feed ratio compared to pigs fed the FLF diet. From days 10-24, pigs fed the TLF diet had higher ($p<0.05$) ADG compared to pigs fed the FLF diet. Gain:feed ratio of the FLF group was significantly lower ($p<0.05$) than the other groups. From days 24-36, pigs fed the EF diet had greater ($p<0.05$) ADG compared to pigs fed TLF and TF diets. Pigs fed FLF and EF diets had improved ($p<0.05$) G:F ratio than pigs fed the TLF and TF diets. Overall (days 0-36), pigs fed EF diet had greater ($p<0.05$) ADG compared to pigs fed the TLF and TF diets. Pigs fed EF diet had higher ($p<0.05$) compared to pigs fed the TLF and FLF diets. With regard to nutrient digestibility, pigs fed TF diet had greater ($p<0.05$) Dry Material (DM), Nitrogen (N), Crude ash, Ca compared to pigs fed the other diets. Pigs fed TLF and EF diets had improved ($p<0.05$) P than pigs fed the FLF diet. Gross Energy (GE) of the FLF group was significantly lower ($p<0.05$) than the other groups. In conclusion, feeding nursery pigs diets containing EF can improve growth performance compared to those fed diets containing the other fish meals.

Key words: Fish meal, growth, digestibility, piglets, nursery, nutrient

INTRODUCTION

Fish meal is one of several animal proteins available for young pigs. It is rich in proteins amino acid, readily available throughout most of the world and competitively priced against other animal proteins like milk products and blood products (Ioannis, 2006; Paul Choudhury *et al*., 2002; Karimi, 2008; Adeniji, 2008). Fish meal is traditionally recognized as a very digestible protein with high contents of amino acids, vitamins and minerals (Kim and Easter, 2001; Jalal *et al*., 2000; Paul Choudhury *et al*., 2002). It is an ideal ingredient for use in pig diets, functioning primarily as a relatively inexpensive source of readily digestible, high quality protein. As a protein source, fish meal is almost ideally balanced in terms of essential amino acid ratios.

The quality of fish meal varies depending on the type and species of fish, the freshness of the fish before processing and the processing of the meal (Kjeldsen *et al*., 1984). Kim and Easter (2001) demonstrated that evaluating the nutritional value of fish meal from different sources and processing methods will improve the accuracy with which fishmeal is added to young pigs' diets.

Thus, this study was conducted to evaluate the effects of fish meal from different sources on growth performance and nutrient digestibility in weanling pig.

MATERIALS AND METHODS

The experimental protocols were approved by the Animal Care and Use Committee of Dankook University.

Experimental fish meals: Fish meals vary according to processing, origin, fish species used and manufacturer. Fishmeal processed using low temperature drying is referred to as low temperature or super prime fishmeal. A standard fishmeal drying phase is generally conducted

Corresponding Author: I.H. Kim, Department of Animal Resource and Science Dankook University, #29 Anseodong, Cheonan, 330-714 Choognam, Korea

Table 1: Formulation and chemical composition of the experimental diets (Phase 1)

Items	Phase 1 (days 0~10)			
	TLF[1]	TF[1]	FLF[1]	EF[1]
Ingredient (%)				
Corn	46.355	46.781	46.937	46.651
Wheat bran	3.000	3.000	3.000	3.000
Soy bean meal	15.760	15.320	15.360	15.750
Triple Nine® low temperature fish meal	8.000	-	-	-
Triple Nine® fish meal	-	8.000	-	-
FF Skagen® low temperature fish meal	-	-	8.000	-
El Golfo® fish meal	-	-	-	8.000
Soy oil	3.535	3.490	3.391	3.380
Whey	20.000	20.000	20.000	20.000
Limestone	0.700	0.600	0.600	0.400
Mono-calcium phosphate	0.900	0.900	0.800	0.900
Zinc oxide	0.280	0.280	0.280	0.280
HCl-L-Lysine	0.205	0.287	0.289	0.267
DL-Methionine	0.080	0.114	0.115	0.107
L-Threonine	0.013	0.049	0.049	0.045
L-Tryptophan	0.359	0.365	0.365	0.408
Vitamin/Mineral premix[2]	0.340	0.340	0.340	0.340
Choline	0.173	0.174	0.174	0.172
Avilalmycine	0.200	0.200	0.200	0.200
Tylosin	0.100	0.100	0.100	0.100
Chemical composition[3]				
Digestible energy (kcal kg^{-1})	3650.00	3652.00	3649.00	3652.000
Crude protein (%)	20.00	20.00	20.00	20.000
Calcium (%)	0.80	0.79	0.81	0.790
Phosphorus (%)	0.75	0.75	0.75	0.750
Lysine (%)	1.45	1.45	1.45	1.450
Available lysine (%)	1.32	1.32	1.32	1.320
Available Methionine (%)	0.46	0.46	0.46	0.460
Available Met+cys (%)	0.74	0.72	0.72	0.730

[1]TLF (Triple Nine® Low temperature Fish meal); TF (Triple Nine® Fish meal); FLF n (FF Skagen® Low temperature Fish meal); EF (El Golfo® Fish meal). [2]Provided per kg of complex diet: 20,000 IU of Vitamin A; 4,000 IU of Vitamin D_3; 80 IU of Vitamin E; 16 mg of Vitamin K_3; 4 mg of thiamin; 20 mg of rivoflavin; 6 mg of pyridoxine. 0.08 mg of Vitamin B_{12}; 120 mg of niacine; 50 mg of Ca-pantothenate; 2 mg of folic acid; 0.08 mg of biotin; 70 mg of Fe; 0.4 mg of Co; 0.15 mg of Se and 0.5 mg of I; [3]Calculated values were derived from the NRC (1998)

Table 2: Formulation and chemical composition of the experimental diets (Phase 2)

Items	Phase 2 (days 10~24)			
	TLF[1]	TF[1]	FLF[1]	EF[1]
Ingredient (%)				
Corn	56.597	56.862	57.334	56.830
Wheat bran	3.00	3.00	3.00	2.800
Soy bean meal	27.30	27.00	26.70	27.500
Triple Nine® low temperature fish meal	5.00	-	-	-
Triple Nine® fish meal	-	5.00	-	-
FF Skagen® low temperature fish meal	-	-	5.00	-
El Golfo® fish meal	-	-	-	5.000
Soy oil	4.467	4.425	4.354	4.353
Limestone	0.900	0.900	0.800	0.700
Mono-calcium phosphate	1.600	1.600	1.600	1.600
Salt	0.211	0.211	0.194	0.242
Zinc oxide	0.280	0.280	0.280	0.280
HCl-L-Lysine	0.084	0.138	0.149	0.119
DL-Methionine	0.043	0.065	0.067	0.059
L-Threonine			0.002	
Vitamin/Mineral premix[2]	0.320	0.320	0.320	0.320
Choline	0.109	0.110	0.111	0.108
Fenbendazole	0.050	0.050	0.050	0.050
Tiamuline	0.039	0.039	0.039	0.039
Chemical composition[3]				
Digestible energy (kcal kg^{-1})	3601.000	3599.000	3599.000	3602.000
Crude protein (%)	20.820	20.810	20.690	20.870
Calcium (%)	0.800	0.810	0.800	0.780
Phosphorus (%)	0.790	0.790	0.810	0.790
Lysine (%)	1.300	1.300	1.300	1.300
Available lysine (%)	1.150	1.160	1.160	1.150
Available methionine (%)	0.400	0.400	0.400	0.400
Available Met+cys (%)	0.690	0.680	0.680	0.680

[1]TLF (Triple Nine® Low temperature Fish meal); TF (Triple Nine® Fish meal); FLF (FF Skagen® Low temperature Fish meal); EF (El Golfo® Fish meal); [2]Provided per kg of complex diet: 20,000 IU of Vitamin A; 4,000 IU of Vitamin D_3; 80 IU of Vitamin E; 16 mg of Vitamin K_3; 4 mg of thiamin; 20 mg of rivoflavin; 6 mg of pyridoxine. 0.08 mg of Vitamin B_{12}; 120 mg of niacine; 50 mg of Ca-pantothenate; 2 mg of folic acid; 0.08 mg of biotin; 70 mg of Fe; 0.4 mg of Co; 0.15 mg of Se and 0.5 mg of I. [3]Calculated values were derived from the NRC (1998)

using hot air. The protein digestibility of low temperature fish meal is higher than that of standard fishmeal. However, it is very difficult to get information from fish meal producers about their specific processing equipment and fish species content in order to assess several fishmeal quality assurances. Table 1 shows the process characteristics and Table 2 shows the amino acid composition of four fish meals.

Triple Nine® low temperature fish meal. This fish meal is made from fresh fish and is produced in Denmark under very mild conditions (dried at 70°C). Sand eel is the major raw material in this fishmeal, it comprises about 60% of the company's annual catches. Sprat, Blue Whiting and Norway Pout are the secondary fish species used for this fishmeal with minimal Horse mackerel being used. These three species make up about 40% of the company's annual catches. The manufacturers of Triple Nine® use waste material from the fish trimming process for fishmeal production but only trimmings from wild caught fish like herring and mackerel are used.

Triple Nine® prime quality fish meal. This fish meal is produced by the same company in Denmark and is divided with standard fishmeal. However, the content of this fish meal is made of unspecified fish and the drying phase is usually completed with hot air dried at 90°C.

FF Skagen® low temperature fish meal. This fish meal is a low temperature fish meal that is produced by gentle drying at about 70°C in Denmark. The fish species mainly used for this fish meal include herring, blue whiting and sand eel. El Golfo® fish meal. This South American fishmeal is divided with super prime fishmeal. Anchovy and sardine are identified as the major components of this fish meal.

Table 3: Formulation and chemical composition of the experimental diet (Phase 3)[1]

Items	Phase 3 (days 24~35)
Ingredients (%)	
Corn (USA)	50.53
Wheat (Soft)	5.00
Soybean meal (CP 44%)	33.21
Animal fat	6.10
Molasses	2.50
Limestone	0.51
Tri-calcium phosphate	1.28
Salt	0.38
HCl-L-lysine (LYS: 79.24%)	0.09
Vitamin/mineral premix[2]	0.30
Tylosin	0.10
Chemical composition	
Digestible energy (kcal kg^{-1})	3650.00
Crude protein (%)	20.00
Lysine (%)	1.20
Crude ash (%)	5.10
Calcium (%)	0.80
Phosphorus (%)	0.60

[1]Calculated values were derived from the NRC (1998). [2]Provided per kg of complex diet: 20,000 IU of Vitamin A; 4,000 IU of Vitamin D_3; 80 IU of Vitamin E; 16 mg of Vitamin K_3; 4 mg of thiamin; 20 mg of rivoflavin; 6 mg of pyridoxine. 0.08 mg of Vitamin B_{12}; 120 mg of niacine; 50 mg of Ca-pantothenate; 2 mg of folic acid; 0.08 mg of biotin; 70 mg of Fe;0.4 mg of Co; 0.15 mg of Se and 0.5 mg of I

Table 4: Characteristics of fish meals

	Fish meal			
Items	TLF	TF	FLF	EF
Species	Sand eel and sprat	Sand eel and sprat	Herring and sand eel	Anchovy and sardine
Origin	Denmark	Denmark	Denmark	Chile
Drying temperature (°C)[1]	70	90	70	Unknown
Drying type	Indirect hot air dryer	Vacuum steam dryer	Indirect hot air dryer	Unknown

[1]Approximate temperature

Table 5: Amino acids profiles of experimental fish meal based on dry material[1]

Items (%)	TLF	TF	FLF	EF
Lysine	7.9	7.3	6.6	7.6
Methionine	3.0	2.8	2.7	2.8
Cystine	1.0	0.9	0.82	0.9
Threonine	4.3	4.1	3.6	3.8
Tryptophan	1.3	1.1	0.93	0.9
Isoleucine	4.7	4.4	3.9	4.2
Leucine	7.5	7.2	6.2	6.8
Histidine	2.3	2.2	2.1	2.0
Phenylalaine	4.0	3.8	3.4	3.6
Tyrosine	3.3	2.9	2.9	2.9
Valine	5.5	5.2	4.7	4.9
Aspartic acid	9.5	9.0	7.7	8.0
Serine	4.4	4.1	3.6	3.9
Glutamic acid	13.6	13.3	10.6	10.2
Proline	3.8	3.8	3.5	3.6
Glycine	5.6	5.9	4.4	4.7
Alanine	6.0	6.1	4.8	5.0
Arginine	5.8	5.6	4.8	5.1

[1]TLF (Triple Nine® Low temperature Fish meal), TF (Triple Nine® Fish meal), FLF (FF Skagen® Low temperature Fish meal), EF (El Golfo® Fish meal)

Table 6: Comparative chemical composition of experimental fish meals[1]

Items (%)	TLF[2]	TF[2]	FLF[2]	EF[2]
Dry Matter	91.19	92.57	91.26	90.41
Crude protein, Kjeldahl	70.63	70.62	72.16	68.83
Crude fat	10.01	10.05	7.11	11.10
Crude fiber	0.60	0.45	0.51	0.36
Crude ash	12.75	12.58	13.37	14.96
Calcium	2.43	2.21	2.25	3.58
Phosphorus	1.81	1.75	1.97	2.18
Cd (ppm)	0.13	0.43	0.19	1.07
Cr (ppm)	2.37	2.22	2.38	3.02

[1]Values expressed on an as-fed basis. [2]TLF (Triple Nine® Low temperature Fish meal), TF (Triple Nine® Fish meal), FLF (FF Skagen® Low temperature Fish meal), EF (El Golfo® Fish meal)

Experimental design, animals and diets: A total of 100 weaned pigs [(Landrace x Yorkshire) x Duroc] with an initial BW of 8.33±1.05 kg were used to evaluate the effects of fish meal from different origins on growth performance and nutrient digestibility. Pigs were blocked by initial body weight and then randomly allocated to 1 of 4 treatments in a randomized complete block design. There were 5 replications with 5 pigs per pen. The dietary treatments were as follows: TLF (8 and 5% Triple Nine® low temperature fish meal in Phase 1 and 2, respectively), TF (8 and 5% Triple Nine® fish meal), FLF (8 and 5% FF Skagen® low temperature fish meal) and EF (8 and 5% El Golfo® fish meal). In Phase 1 and 2, experimental diets were fed for 10 and 14 days, respectively.

In Phase 3, the same diet without fish meal was fed to evaluate growth performance after Phase 2. The diets (Table 3-5) were formulated to meet or exceed the nutrient requirements established by the NRC (1998). All pigs were housed in an environmentally controlled room with a 1-slatted plastic floor in 25 adjacent pens. Each pen was equipped with a 1-sided self-feeder and a nipple waterer to allow the pig *ad libitum* access to feed and water throughout the experimental period. The temperature of the room that all pigs were housed in was maintained at 32°C for the 1st week and then decreased by 1-2°C every week to be reached around for 26°C. Pigs BW were measured at days 10, 24 and 36 of the experimental period and feed consumption was recorded on a pen basis during the experiment to calculate ADG, ADFI and G:F ratio (Table 6).

Sampling and analysis: Chromic oxide (Cr_2O_3) was added to the diet as an indigestible marker at 0.20% of the diet for 7 days before fecal collection and at day 24 (end of the Phase 2) to calculate the DM, N, ash, Ca, P and energy digestibility. Fecal grab samples were collected at random from at least 2 pigs in each pen. All feed and feces samples were immediately stored at -20°C until analysis.

Fecal samples were dried at 70°C for 72 h and then finely ground to pass through a 1 mm screen. The procedures used for the determination of DM, N, ash, Ca, P and energy digestibility were in accordance with the methods established by the AOAC (1984). Chromium concentrations were determined via UV absorption spectrophotometry (UV-1201, Shimadzu, Kyoto, Japan) and the Apparent Total Tract Digestibility (ATTD) of DM, N, ash, Ca, P and energy were calculated using indirect methods as described by Fenton and Fenton (1979). In addition, the GE of the feed and feces was determined using an oxygen bomb calorimeter (Parr Instruments Inc., 6100, USA).

Statistical analyses: In this experiment, all data were analyzed as a randomized complete block design using GLM procedures of SAS (1996) with each pen being used as an experimental unit. The means of the treatments were also compared by Duncan's multiple range test (Duncan, 1955). Variability in the data was expressed as the Standard Error of Mean (SEM) and the selected level of significance was set at $p<0.05$.

RESULTS AND DISCUSSION

Growth performance: Growth performance is shown in Table 7. From d 0-10, there was no significant difference in the ADFI after weaning among treatments. Pigs fed TF and EF diets had greater ($p<0.05$) ADG compared to pigs fed the TLF and FLF diets.

Pigs fed the TF diet had improved ($p<0.05$) G:F ratio compared to pigs fed the FLF diet. From days 10-24, pigs fed the TLF diet had higher ($p<0.05$) ADG compared to pigs fed the FLF diet. G:F ratio of the FLF group was significantly lower ($p<0.05$) than the other groups. There were no significant differences in ADFI after weaning among the treatments. From days 24-36, pigs fed the EF diet had greater ($p<0.05$) ADG compared to pigs fed TLF and TF diets. Pigs fed FLF and EF diets had improved ($p<0.05$) G:F ratio than pigs fed the TLF and TF diets. Overall (days 0-36), pigs fed the EF diet had greater ($p<0.05$) ADG compared to pigs fed the TLF and TF diets. Pigs fed the EF diet had higher ($p<0.05$) G:F ratio compared to pigs fed the TLF and FLF diets.

Nutrient digestibility: Nutrient digestibility is shown in Table 8. At days 24 after weaning, pigs fed the TF diet had greater ($p<0.05$) DM, N, Ash, Ca compared to pigs fed the other diets. Pigs fed TLF and EF diets had improved ($p<0.05$) P digestibility compared to pigs fed the FLF diet. GE of the FLF group was significantly lower ($p<0.05$) than the other groups.

Table 7: Effect of various fish meals on growth performance in weanling pigs[1]

Items	TLF[2]	TF[2]	FLF[2]	EF[2]	SE[3]
Phase 1 (0~10 days)					
Average daily gain (g)	423.00^{b}	446.00^{a}	424.00^{b}	448.00^{a}	10.00
Average daily feed intake (g)	514.00	502.00	550.00	519.00	30.00
Gain/Feed	0.82^{ab}	0.89^{a}	0.77^{b}	0.86^{ab}	0.05
Phase 2 (10~24 days)					
Average daily gain (g)	540.00^{a}	511.00^{ab}	501.00^{b}	515.00^{ab}	10.00
Average daily feed intake (g)	892.00	839.00	868.00	824.00	50.00
Gain/Feed	0.61^{a}	0.61^{a}	0.58^{b}	0.63^{a}	0.03
Phase 3 (24~36 days)					
Average daily gain (g)	692.00^{c}	708.00^{bc}	748.00^{ab}	757.00^{a}	10.00
Average daily feed intake (g)	1272.00	1277.00	1259.00	1275.00	50.00
Gain/Feed	0.54^{b}	0.55^{b}	0.59^{a}	0.59^{a}	0.03
Overall (0~36 days)					
Average daily gain (g)	558.00^{b}	559.00^{b}	562.00^{ab}	577.00^{a}	10.00
Average daily feed intake (g)	914.00	891.00	910.00	890.00	20.00
Gain/Feed	0.61^{b}	0.63^{ab}	0.62^{b}	0.65^{a}	0.01

Table 8: Effect of various fish meals on nutrient digestibility in weanling pigs[1] (24 days)

Items (%)	TLF[2]	TF[2]	FLF[2]	EF[2]	SE[3]
Dry matter	77.36^{b}	80.99^{a}	77.24^{b}	78.80^{b}	0.61
Nitrogen	76.37^{b}	81.18^{a}	75.30^{b}	76.54^{b}	0.98
Ash	40.84^{b}	50.56^{a}	43.06^{b}	44.89^{b}	1.84
Calcium	53.58^{b}	53.95^{a}	53.70^{b}	53.62^{b}	0.04
Phosphorus	44.99^{a}	41.17^{ab}	38.20^{b}	46.17^{a}	1.66
Gross energy	79.43^{a}	79.65^{a}	75.80^{b}	77.86^{a}	0.69

[1]Each mean represents 5 pens of 5 pigs. [2]TLF (Triple Nine® Low temperature Fish meal); TF (Triple Nine® Fish meal); FLF (FF Skagen® low temperature Fish meal); EF (El Golfo® Fish meal). [3]Standard error. $^{a, b}$ Means in the same row with different superscripts differ ($p<0.05$)

Fish meal is widely used in the diets of young pigs as a relatively inexpensive source of readily digestible, high quality protein. However, fish meal is made from a variety of fish species depending on the location of production. Limited information is available about the effects of various fish meal in pigs.

Fish meals usually are divided into 3 fishmeal types. The first type is herring type meal, the second type is South American type meal and then finally white type fish meal (FAO, 1986). TLF, TF and FLF fish meals are classified as herring type fish meals while EF fish meal comprises a South American type fish meal and is made from whole anchovies and sardines (FAO, 1986).

Fish is generally considered to be a food source associated with health advantages. As well as positive nutritive value, the lipid fraction of fish shows an interesting fatty acid profile with a significant percentage of n-3 Polyunsaturated Fatty Acids (PUFA), the health benefits of which have been widely studied. Omega-3 fatty acids improve the functioning of the immune system and reduce inflammation in the body (Korver and Klasing, 1997).

The fatty acid composition of fish oil is dominated by two members of the n-3 PUFA family: 20:5, n-3 Eicoosapentaenoic Acid (EPA) and 22:6, n-3 Docosahexaenoic Acid (DHA). Most fish oils contain 18

EPA and 12% DHA, or a total of 30% n-3 fatty acids (Kris-Etherton *et al*., 2002). The total amount of fatty acid content may vary according to the species of fish. Anchovy and sardine oils contain more n-3 fatty acids (EPA and DHA) compared to other fish oils (INRA, 2004).

Turan *et al*. (2007) demonstrated that EPA and DHA contents of anchovy meal were between 7.52 and 8.36% and form 17.44-19.16%, respectively. Barlow and Pike (1977) reported that the content of n-3 polyunsaturated fatty acids (34.3%) in anchovy meal was higher than the content of n-6 Polyunsaturated fatty acids (4.1%).

Cho and Kim (2011) reported that EPA and DHA are the most effective polyunsaturated fatty acids in term of assisting the immune system in defending against disease agents and reducing the bodily stress response.

Fishmeal supplies a number of n-3 (omega-3) essential polyunsaturated fatty acids including EPA and DHA which can be precursors to important metabolic regulators such as the prostagladins and leukotrienes.

Sorigure *et al*. (1997) also reported that anchovy oil is rich in long-chained double bonded (n-3) fatty acids. Turan *et al*. (2007) demonstrated that anchovy meal contains high n-3 fatty acids. As show in Table 6, pigs fed EF had greater ($p<0.05$) ADG compared to those fed the TLF or TF diets. Also, G:F ratio of the EF group was higher ($p<0.05$) than either the TLF or FLF group during the entire experimental period.

In the study, the Phase 3 diets were the same and without fish meal supplementation in all treatments. Researchers used this diet to investigate if there was any after-effect of fish meal dietary supplementation. The results demonstrated that FLF treatment has lower growth performance in Phase 1 and 2 but it could catch up with other treatments in Phase 3 as fish meal was withdrawn, it was meant that no significant growth improve effect of fish meal could carry over to Phase 3. A lower GE digestibility of the FLF treatment may result in the lower growth performance relative to other treatments during Phase 1 and 2 and in Phase 3 had compensation growth effect.

According to Table 5-7 although, EF treatment have lower crude protein contents than other treatments but still have the best growth performance. This may due to its higher crude fat and minerals. We even make the hypothesis that EF has higher amino acid utilization efficiency but this need a further study to prove it.

CONCLUSION

In this study, although, the present study did not show the fatty acid profiles for each fish meal, the EF meal produced from anchovy and sardine containing an abundant amount of long chain fatty acid groups (EPA and DHA) was shown to improve growth performance in piglets compared to those fed the other fish meals.

IMPLICATIONS

The results of the current study indicate that South American fish meal has similar effects on piglet growth performance compared to European low temperature fish meals. This may suggest that South American fish meal could replace the more expensive European standard fish meal for piglet diets without detriment. Further researches are necessary to determine the effects of various fish meals in piglet diet.

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