Shrimp By-product Feeding and Growth Performance of Growing Pigs Kept on Small Holdings in Central Vietnam

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ABSTRACT : The effect studied was that of the feeding of shrimp by-product meal, as a source of eicosapentaenoic and docosahexaenoic acid, on growth performance and fatty acid composition of adipose tissue in growing pigs kept on small holdings in Central Vietnam. Shrimp by-product meal was exchanged with ruminant meal so that the diets contained either 0, 10 or 20% shrimp by-product meal in the dry matter. The diets were fed on 6 different small-holder farms. The farmers fed a base diet according to their personal choice, but were instructed as to the use of shrimp by-product and ruminant meal. The diets were fed to the pigs from 70 to 126 days of age. There were three animals per treatment group per farm. The diets without and with 20% shrimp by-product meal on average contained 0.01 and 0.14 g docosahexaenoic acid/MJ of metabolisable energy (ME). Due to the higher contents of ash and crude fiber, the shrimp by-product meal containing diets had lower energy densities than the control diets. Eicosapentaenoic acid was not detectable in adipose tissue; the content of docosahexaenoic acid was generally increased after consumption of shrimp by-product meal. In spite of the concurrent high intakes of ash and crude fiber, the feeding of shrimp by-product meal had a general stimulatory effect on growth performance of the growing pigs. The intake of docosahexaenoic acid or its content in adipose tissue was not related with average daily gain. It is suggested that shrimp by-product meal may contain an unknown growth enhancing factor. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 7 : 1025-1029)***

Key Words : Pig, Shrimp By-product, Growth, Fatty Acids, Adipose Tissue

INTRODUCTION

High intakes of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in the form of fish oil may improve disease resistance in pigs (Fritsche et al., 1993; Calder, 2001). In a field study involving small holdings in Central Vietnam, we found that the percentage of α-linolenic acid (ALA) in adipose tissue was positively related with growth (Nguyen et al., 2002a). The content of ALA in adipose tissue of growing pigs reflects that in the diet (Nguyen et al., 2002b). In the body of the pig, ALA is converted into EPA and DHA (Innis, 1991). Possibly, the observed positive relationship between ALA in adipose tissue and growth was related to suboptimal production of EPA and DHA. Shrimp by-product meal may contain 7% fat of which 6 and 10% may be EPA and DHA, respectively. Thus, shrimp by-product meal can be used as a source of EPA and DHA so that its addition to the diet of growing-finishing pigs in small holdings in Central Vietnam could improve growth performance. This idea was tested by comparing the effect of exchanging shrimp by-product meal for ruminant meal in the diet. The farmers composed the base diets according to their personal choice, but were instructed to use shrimp by-product or ruminant meal as components.

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Received November 29, 2002; Accepted April 10, 2003

MATERIALS AND METHODS

Animals and experimental diets

Castrated, male weanling pigs (n=54) were purchased and allocated to 6 small-holdings. The piglets of a Mong cai (female)×Large White (male) cross were aged about 70 days and had a body weight of 13.2±0.54 kg (mean±SD). Each farm received 9 animals, which were housed in pens containing three piglets each. Within each farm, the three piglets in each pen had similar average body weights. Each piglet had an ear-cut number for identification. The pigs were fed a restricted amount of dry matter according to Table 1.

The shrimp by-product meal was obtained from a local company (Hue Song Huong Company, 165 Thuan An street, Hue city, Vietnam) and consisted of heads mainly. The ruminant meal was sun dried and consisted of lung/liver/blood in a 40/30/30 ratio on a wet-weight basis (collected in the slaughterhouse in Hue city). Table 2 shows the analysed composition of the two dietary variables.

The base diets were composed by the farmers according to their own choice, but the ingredient composition was rounded off to the nearest 5% and then kept constant. The ruminant and shrimp by-product meal concentrations in the final diets were 0, 10 or 20% of the dietary dry matter (Table 1). On each farm three diets were used, the ruminant/shrimp by-product meal combination being 20/0,

Table 1. Feeding schedule that was applied on each farm

	Pig body weight (kg)				
	10	20	30	40	50
	kg dry matter/day				
Base diet	0.54	0.80	1.00	1.20	1.40
Shrimp by-product meal	0/0.07/0.13	0/0.1/0.2	0/0.13/0.25	0/0.15/0.30	0/0.18/0.35
Ruminant meal	0.13/0.07/0	0.2/0.1/0	0.25/0.13/0	0.30/0.15/0	0.35/0.18/0

On each farm three diets were fed, containing either 0, 10, 20% shrimp by-product meal in total dietary matter. The compositions of the base diets used on each farm are shown in Table 3.

Table 2. Analysed composition of the ruminant and shrimp by-product meal

Nutrient	Ruminant meal	Shrimp by-product meal
Macronutrients, g/kg		
Dry matter	901	930
Crude protein	744	482
Crude fat	97	75
Crude fibre	21	150
Ash	43	249
Fatty acids, g methylester/100 g methylester		
C16:0	23.7	18.4
C18:0	27.0	8.3
C18:1 n-9	20.6	19.2
C18:2 n-6	4.4	10.4
C18:3 n-3	0.9	0.6
C20:4 n-6	3.5	5.2
C20:5 n-3	0.9	5.9
C22:6 n-3	0.2	10.5

`10/10 and 0/20. It was verified that the rations contained at least 20% crude protein in the dry matter as calculated on the basis of the feed table. In our earlier study (Nguyen et al., 2002a), we found that on various small-holder farms the supply of protein was low and limited growth of the pigs. The dietary variables were supplied to the pig farms and under the supervision of students the two components were mixed with the base diets at pre-set ratios. The students recorded feed intake and the ingredient composition of the rations. Table 3 shows the ingredient composition of the diets fed on the 6 farms.

The feedstuffs supplied were weighed on a calibrated balance. The pigs were fed 2 times/day. Water was available ad libitum through nipples that were situated besides the trough in each pen. All pigs were weighed at the start and end of the experiment. The pigs were weighed individually while in a crate of known weight and using a calibrated balance.

Sample collection

Samples of the ingredients used on each farm were taken. Each new batch of feedstuff was sampled. The samples were stored at -20°C. For each farm, a composite feed sample was prepared that reflected the composition of the cumulative feed intake for the entire feeding period for each pen. Subcutaneous adipose tissue samples were taken from the pigs at the end of the experiment, when they were aged about 126 days. After disinfection and induction of local anaesthesia, a 5-10 mm incision was made in the right inguinal region. About 1 g of subcutaneous fat was removed and stored at -20°C. The skin wound was closed. No complications occurred.

Table 3. Composition of the diets fed on each farm

Farm ingredient	1	2	3	4	5	6
Rice bran	25	25	25	25	25	20
Rice	20	20	20	20	20	25
Pea by-product	10	-	5	-	-	-
Beer by-product	-	10	5	10	10	10
Commercial feed	10	10	10	10	10	10
Vegetables	15	15	15	15	15	15
Variable meal[1]	-	-	-	-	-	-

[1] The three ruminant/shrimp by-product meal combinations on each farm were 20/0, 10/10 and 0/20.

Chemical analyses

For each farm and each pen a composite feed sample was analysed. Gross energy (GE) was determined by oxygen bomb calorimetry. Dry matter (DM), crude protein, crude fat, crude fibre and ash were measured according to the Association of Official Analytical Chemists (AOAC) methods (1984). Total lipids in composite feed samples were extracted with chloroform:methanol 2:1 (Folch at al. 1957). The lipids were trans-esterified with 12% BF_3 in methanol at 80°C. The methyl esters were extracted with water and petroleum ether, taken to dryness under nitrogen, redissolved in heptane and separated and quantified by gas liquid chromatography (GC) as described (Metcalfe et al., 1966). The fat in adipose tissue or experimental fats was saponified, methylesters of fatty acids were formed and subjected to GC.

Statistical analysis

A pen was the experimental unit. An analysis of variance (ANOVA) was used to evaluate main effects (farm and dietary treatment) using SPSS 9.1 (Chicago, IL) according to the model:

$$Y_{ij}=\mu+farm_i+treatment_j+\varepsilon_{ij}$$

Table 4. Mean analysed macro nutrient composition of the whole diets fed

Diet[1]	1	2	3
Dry matter (%)	94.3	94.6	94.9
Crude protein (% in DM[2])	29.9	27.3	24.6
Crude fat (% in DM)	9.0	8.8	8.6
Crude fibre (% in DM)	7.3	8.6	9.9
Ash (% in DM)	7.6	9.7	11.7
ME[3] (MJ/ kg DM)	12.51	12.06	11.62

[1] Diets 1. 2 and 3 refer to the diets with 0. 10 or 20% of shrimp by-product meal, respectively.
[2] DM=dry matter.
[3] Metabolisable energy (ME) was on calculated on the basis of the measured gross energy, table values for digestibility of nutrients in the diet ingredients and by assuming that ME=0.96×digestible energy.

Where Y_{ij}=the response variable, μ=overall mean, $farm_i$=effect of farm (i=1,6), $treatment_j$=effect of dietary treatment (j=1,3) and ε_{ij}=error term. Because the small number experimental units it was not possible to test the interaction between farm and dietary treatment. In Table 5 and 6 the mean values for farms and for treatments are presented.

A pair wise T-test was used to detect differences between farms and between treatments.

A simple linear regression analysis with the model Y= Constant+β×X was used to quantify the relationship between some fatty acid in adipose tissue (Y) and fatty acid in the diet (X). The level of statistical significance was pre-set at $p<0.05$.

RESULTS

Feed composition

The macronutrient composition of the diets is shown in Table 4. The diets contained at least 24% crude protein in the dry matter. Crude fat contents of the diets were lower in diet 3 than in diet 1. Crude fiber contents of diets 2 and 3 were higher than of diet 1. The ash contents of the diets increased with increasing proportions of shrimp by-product meal. The diets without shrimp by-product meal on average contained 7.4% of ash, whereas those with 20% shrimp by-product meal contained 11.7% of ash in the dietary dry matter. Also the calculated dietary contents of metabolisable energy (ME) are given in Table 4.

Table 5 shows the fatty acid composition of the diets; the contents are expressed as g of fatty acid/ MJ ME. The levels of EPA (C20:5 n-3) and DHA (C22:6 n-3) rose with higher inclusion levels of shrimp by-product meal. Between farms, the mean dietary concentration of linoleic acid and ALA varied on average between 1.6 and 2.05 and 0.22 and 0.25 g/MJ ME, respectively.

Growth performance

Table 6 shows the average initial and final body weight and weight gain for each pen. The feeding of shrimp by-product meal instead of ruminant meal produced an increase in weight gain. During the feeding period of 56 days, the average daily weight gain for the pooled animals fed the diet without shrimp by-product meal was 0.480 kg. For the animals fed the diets with 10 and 20% shrimp by-product meal, daily weight gain was 0.505 and 0.511 kg, respectively. The analysis of variance showed that there was no significant effect of dietary treatment (p=0.055). However, the paired T-test indicated that there was a significant difference in mean daily gain between the treatment with 0% shrimp by-product meal and the

Table 5. Fatty acid composition of the whole diets fed on the farms and in adipose tissue of the pigs

Main effect	Farm						SED	P-value	Treatment			SED	P-value
	1	2	3	4	5	6			1	2	3		
	g fatty acid /MJ ME												
C18: 2n-6	1.604^{a}	2.019^{b}	1.819^{c}	2.055^{b}	2.026^{b}	1.805^{c}	0.007	<0.001	1.785^{a}	1.881^{b}	1.983^{c}	0.004	<0.001
C18: 3n-3	0.226^{a}	0.251^{b}	0.240^{c}	0.252^{b}	0.252^{b}	0.243^{c}	0.001	<0.001	0.239^{a}	0.244^{b}	0.250^{c}	0.001	<0.001
C20:5 n-3	0.046^{a}	0.047^{b}	0.047^{b}	0.047^{b}	0.047^{b}	0.047^{b}	0.0002	0.04	0.016^{a}	0.046^{b}	0.079^{c}	0.0001	<0.001
C22: 6n-3	0.075^{a}	0.078^{bc}	0.077^{c}	0.079^{b}	0.079^{b}	0.079^{b}	0.0005	<0.001	0.012^{a}	0.076^{b}	0.145^{c}	0.0003	<0.001
	Fatty acid in adipose tissue as g methylester/100 g methyl ester												
C18: 2n-6	11.67^{a}	11.19^{a}	12.41^{a}	8.07^{b}	12.32^{a}	9.45^{b}	0.60	<0.001	10.58	11.08	10.89	0.42	0.504
C18: 3n-3	0.79^{a}	1.11^{b}	1.00^{b}	1.24^{c}	1.07^{bc}	1.16^{bc}	0.08	0.004	1.07	1.04	1.08	0.06	0.760
C22: 6n-3	0.00^{a}	0.09^{b}	0.013^{a}	0.22^{c}	0.11^{b}	0.16^{bc}	0.03	<0.001^{a}	0.06^{a}	0.08^{b}	0.16	0.02	0.003

[1] Diets 1. 2 and 3 refer to the diets with 0, 10 or 20% of shrimp by-product meal, respectively.

Table 6. Mean values of initial and final body weight and daily weight gain for farms and diets

Main effect	Farm						SED	P-value	Treatment			SED	P-value
	1	2	3	4	5	6			1	2	3		
Initial weight (kg)	13.2	13.1	13.6	13.0	13.1	13.1	0.3	0.413	13.3	13.3	13.0	0.2	0.315
Final weight (kg)	43.0	41.0	41.2	39.4	39.8	42.0	1.1	0.070	40.1	41.5	41.6	0.8	0.158
Daily gain (kg/d)	0.532^{a}	0.498^{ac}	0.494^{bcd}	0.472^{bc}	0.479^{bc}	0.516^{ad}	0.017	0.040	0.480^{a}	0.505^{ab}	0.511^{b}	0.012	0.055

Diets 1. 2 and 3 refer to the diets with 0, 10 or 20% of shrimp by-product meal, respectively.

Table 7. Linear relationships between some fatty acids in the diet and in the diet and in the adipose tissue on the basis of pen means (n=16)

Y	=β × X	+Constant	R^2
% LA in adipose tissue	=-1.62×LA in diet (g/MJ ME)	+13.91	0.026
% ALA in adipose tissue	=10.8×ALA in diet (g/MJ ME)	-1.57	0.435
% DHA in adipose tissue	=0.764×DHA in diet (g/MJ ME)	+0.04	0.194

treatment with 20% shrimp by-product meal.

Fatty acid composition of adipose tissue

In adipose tissue, EPA was not detectable. The relative percentage of DHA increased when shrimp by-product meal was included in the diet (Table 5). The percentage of DHA on average was 0.06% for pigs fed the diets without shrimp by-product meal and 0.16% for their counterparts given diets with 20% shrimp by-product meal. The adipose tissue contents of linoleic acid and ALA were influenced by the different diets fed on each farm, the range being 8.09 to 12.41% and 0.79 to 1.24% of total fatty acids.

Correlations on a pen basis

For all pen mean data combined, linear correlation coefficients were calculated between the dietary contents of DHA, ALA and linoleic acid and those of adipose tissue. Dietary fatty acids were expressed as g/MJ ME. Adipose tissue fatty acids were expressed as % of total fatty acids. The linear correlation coefficients (r) were found to be 0.44, 0.66 and 0.029 for DHA, ALA and linoleic acid, respectively. The results are shown in Table 7.

There were no significant correlations between the intakes of DHA, ALA or linoleic acid and growth, nor between the contents of DHA, ALA or linoleic acid in adipose tissue and growth.

DISCUSSION

This study confirms earlier work (Nguyen et al., 2002b) in that the fatty acid composition of the diet affects the fatty acid composition of adipose tissue in growing swine. Because the farmers were allowed to compose the base diet according to their own preferences, there were between-farm differences in diet composition, including the content of ALA. There was a direct relationship between ALA intake and its percentage in adipose tissue (Table 7). The incorporation of shrimp by-product meal into the diet raised the intake of EPA and DHA. When the diets contained 20% shrimp by-product meal, the average dietary DHA content was 0.14 g/MJ ME. In the pigs fed shrimp by-product meal, the adipose tissue generally was enriched with DHA, but EPA remained undetectable.

The question addressed in this study was whether the feeding of extra EPA and DHA in the form of shrimp by-product meal would enhance growth. The diets were formulated so that protein supply was abundant and would not limit growth. The proximate analysis of the shrimp by-product meal was in line with that of fresh shrimp by-product meal as reported by Ngoan et al., 2000. The shrimp by-product meal in the present experiment contained 6- and 7-fold more ash and crude fiber than did the ruminant meal. As a result, the shrimp by-prodcut meal containing diets contained more ash and fiber and had lower energy densities than the control diet. These characteristics of the shrimp by-prodcut diets by itself would depress body-weight gain. Nevertheless, there was a general stimulatory effect of shrimp by-product meal on growth, but there was no relationship between the intake of DHA or DHA in adipose tissue and daily gain. It follows that the intake of DHA was not limiting growth, but that another component of the shrimp by-product meal acted as a powerful determinant of growth. The identity of the component is unknown.

This positive effect of shrimp by-product meal on growth is in contrast with the results of Ngoan et al. (2001). They showed a depressed growth rate by replacing fish meal with ensiled shrimp by-product. The reduction in daily gain was caused by a low dry matter intake on the diet with ensiled shrimp by-product. It is well known that the process of ensiling the shrimp by-product depressed dry matter intake much more than the shrimp by-product it self (Ngoan and Lindberg, 20001).

An other possible explanation for the presented results is the relatively high protein content of the control diet. The excretion of nitrogen on the diet with an excess of protein can reduce the energy available for growth.

In conclusion, the intake of shrimp by-product meal at the expense of ruminant meal stimulated growth of swine kept in small holdings in Central Vietnam. The data indicate that the extra intake of EPA and DHA associated with the shrimp by-product meal did not cause the increase in average daily weight gain.

ACKNOWLEDGEMENTS

We thank Robert Hovenier and Jan van der Kuilen for chemical analyses. L. Q. Nguyen was supported by the Utrecht Scholarship Programme and The Netherlands Foundation for Nutrition and Health Research.

REFERENCES

AOAC, 1984. Official Methods of Analysis. 12th edition.

Association of Official Analytical Chemists, Washington, DC.

Calder, P. C. 2001. Polyunsaturated fatty acids, inflammation, and immunity. Lipids, 36:1007-1024.

Fritsche, K. L., D. W. Alexander, N. A. Cassity and Shu-cai Huang (1993). Maternally supplied fish oil alters piglet immune cell fatty acid profile and eicosanoid production. Lipids 28:677-682.

Folch, J., M. Lees, G. H. Sloane Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. Journal of Biological Chemistry, 226, 497-509.

Innis, S. M. 1991. Essential fatty acids in growth and development. Progress in Lipid Research, 30: 39-103.

Metcalfe, L. D., A. A. Schmitz, J. R. Pekka. 1966. Rapid preparation of fatty acid esters from lipids for gas chromatographic analysis. Analytical Chemistry, 18, 514-516.

Ngoan, L. D., J. E. Lindberg, B. Ogle, S. Thomke. 2000. Anatomical proportions and chemical and amino acid composition of common shrimps species in Central Vietnam. Asian-Aust. J. Anim. Sci. 13:1422-1428

Ngoan, L. D., J. E. Lindberg. 2001. Ileal and total tract digestibility in growing pigs fed cassava root meal and rice bran diet with inclusion of fish meal and fresh or ensiled shrimp by-products. Asian-Aust. J. Anim. Sci. 14:216-223.

Ngoan, L. D., B. Ogle, J. E. Lindberg. 2001. Effects of repalcing fish meal with ensiled shrimp by-product on the performance and caracass characteristics of growing pigs. Asian-Aust. J. Anim. Sci. 14:82-87.

Nguyen, L. Q., H. Everts, A. C. Beynen,. 2002a. Intake of essential fatty acids by growing-finishing pigs kept on small holdings in Central Vietnam. Tropical Animal Health and Production (submitted).

Nguyen, L. Q., M. C. G. A. Nuijens, H. Everts, N. Salden,. A. C. Beynen. 2002b. Mathematical relationships between the intake of n-6 and n-3 polyunsaturated fatty acids and their contents in adipose tissue of growing pigs. Meat Science (submitted)