TRA CATFISH *(PANGASIUS HYPOPHTHALMUS)* RESIDUE MEALS AS PROTEIN SOURCES FOR GROWING PIGS

by

Tran Trung Tuan

Institutionen for husdjurens utfodring och vård
SLU
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Dedication

To My parents, my wife Nguyen Huynh Bich Phuong
My daughter Tran Thien Thanh and my son Tran Thiện Thanh

Tra catfish *(Pangasius hypophthalmus)* residue meals as protein sources for growing pigs

Tran Trung Tuan

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Abstract

Two experiments were conducted to determine the effect of diets containing Tra catfish residue meals on total tract apparent digestibility and performance of growing pigs.

Four diets were tested, based on cassava root meal as the energy source: The control diet (Diet FM) was a basal diet plus marine fish meal; Diet BM was the basal diet plus broken meat catfish by-product meal; Diet OE was the basal diet plus oil extracted catfish by-product meal, and Diet BH was the basal diet plus bone and head catfish by-product meal. In Experiment I, total tract digestibility was determined in four growing pigs in a 4x4 Latin Square design. In the second experiment, the same four diets were fed to 24 growing pigs in a Randomized Complete Block design with four treatments and six replications.

In Experiment I, there were differences among the diets in the coefficients of apparent digestibility of dry matter, crude protein, ether extract and ash, that were the highest in diet BM and lowest in diet BH ($P<0.05$). Apparent digestibility of organic matter was highest in diet BH ($P<0.05$). In Experiment II, there were differences in the average daily gain (ADG), feed conversion ratio (FCR) and back-fat thickness among diets, with a descending trend from diets BM, OE, FM and BH ($P<0.05$). FCR in diets BM and OE was lower than in diet FM ($P<0.05$). However, FCR in diet BH was higher than in diet FM ($P<0.05$). Back-fat thickness in diets BM and OE was higher than in diet FM ($P<0.05$), while diet BH was lower than in diet FM ($P<0.05$). The iodine number in diet BM was higher than in diet FM ($P<0.05$), but on diet BH was lower than on diet FM ($P<0.05$). The feed cost per kg weight gain of diet BM was the lowest when compared to the other treatments ($P<0.05$). The gross income and net benefit per pig on diet BM were higher than in the other treatments ($P<0.05$).

It can be concluded that there were differences in the total tract digestibility of dry matter, crude protein and ether extract among the protein sources, with the best values in the diet BM and the worst in diet BH. The ADG, FCR and economic benefits of diet BM were highest, followed by OE, FM and BH.

Key words*: Catfish by-product meals, carcass quality, digestibility, economic benefits, growing pigs, performance*

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Appendix

This thesis is based on the following papers, which are referred to in the text by their Roman numerals I and II

I. Tran Trung Tuan and Brian Ogle. Evaluation of the apparent digestibility of diets containing fish meal and Tra catfish by-product residue meals in growing pigs

II. Tran Trung Tuan and Brian Ogle. Effects on performance of replacing fish meal by Tra catfish by products in the diets of growing pigs

List of Abbreviations

AOAC	Association of Official Analytical Chemists
CF	Crude fibre
CP	Crude Protein
CTTAD	Coefficient of Total Tract Apparent Digestibility
DM	Dry matter
ME	Metabolizable Energy

1. Introduction

In Vietnam, pig production accounted for 27 % of total agricultural production in 2008, and increased 1.5 times as compared to 2000. Pig production is one of the most important activities for development in rural areas of Vietnam, where small farmers lack access to agricultural technologies and have low incomes. The pig population in Vietnam has increased by 6.2 % annually from 2000 to 2006. However, pig numbers declined by 0.29 % in 2008 (Vietnam Statistical Yearbook, 2008). Smallholders are faced with problems of low profits and incomes because of increasing animal feed prices. Lapar *et al* (2003) reported that around 80 % of the total pig population in Vietnam were raised in traditional smallholder systems, with diets based on rice bran, broken rice, maize, vegetables, and by-products from agriculture, such as cassava residue meal (Loc *et al* 1996), and rice distiller's waste (hem) (Luu Huu Manh *et al* 2003).

Table 1: Livestock population in Vietnam, 2000 – 2008 (million heads)

	2000	2006	2007	2008
Pigs	20.2	26.9	26.6	26.7
Cattle	4.1	6.5	6.7	6.3
Buffaloes	2.9	2.9	3.0	2.9
Poultry	196.1	214.6	226.0	247.3

Source: Vietnam Statistical Yearbook, 2008

Table 2: Pig population in the Mekong Delta, 2000 – 20008 (thousand heads)

	2000	2006	2007	2008
Mekong Delta	2976.6	3982.0	3784.8	3630.1
Angiang province	186.1	190.9	175.6	169.3
Cantho province	242.6	167.3	142.9	125.1
Dongthap province	186.5	322.4	310.6	299.5
Kiengiang province	277.0	350.8	357.6	331.7

Source: Angiang Statistical Yearbook, 2008

Table 3: Cassava production in Vietnam, 2000 – 2008 (thousand tons)

	2000	2006	2007	2008
Vietnam	1986.3	7782.5	8192.8	9395.8
Mekong Delta	68.2	64.2	72.9	106.8
Angiang	8.1	18.2	16.1	23.9
Cantho	0.4	0.1	-	0.2
Kiengiang	5.3	6.5	11.3	19.4

Source: Vietnam Statistical Yearbook, 2008

The Mekong Delta is the main catfish producing region in Vietnam, in which Angiang and Dongthap Province and Cantho City accounted for most of the intensive catfish production (Chau Thi Da *et al* 2010). The development of Tra (*Pangasius hypophthalmus*) and Basa (*Pangasius bocourti)* catfish production is seen in both the number of ponds and stocking density, with highly intensive culture systems developing in the frontiers of the Mekong Delta in recent years. The increase of fillet production for export, which is a high value product, has increased the living standard of people in the Mekong Delta in the Southern part of Vietnam (Pham Van Khanh 2004). The industrial catfish farms have been rapidly developing, and are the most important form of aquaculture. Recently, catfish production was over one million tons from 6,000 ha of water area in the Mekong Delta in 2009, and this is expected to increase to up to 1.5 million tons from 8,600 ha in 2010, and is predicted to be up to 11,000 and 13,000 ha by 2015 and 2020, respectively (Chau Thi Da *et al* 2010).

The by-products of catfish processing include heads, skin and viscera, which are the main products, and account for almost 60 % of the volume that enters the processing factories. This means that catfish by-product is an important potential source of nutrients of high value for livestock feed (Lovell 1980). According to Nguyen Thi Thuy *et al* (2007), the by-products (head and bone, broken meat and skin) from the fillet processing factories in Angiang province account for 65 % of the volume, which means that this has a great potential as a source of protein for animal feeds.

Objectives

The objective of this research was to study if *Tra* catfish residue meal can replace traditional fish meal in diets for growing pigs without affecting the diet digestibility and the growth performance, and with economic benefits to producers.

The experiments were conducted with growing pigs to:

- Determine the apparent digestibility of dry matter, crude protein, ether extract, and ash in *Tra* catfish residue meals.

- Determine the live weight gain, feed conversion ratio, back-fat thickness and economic benefits of feeding catfish by-products.

2. General discussion

In the Mekong Delta, where a major part of farmers are growing paddy rice for sale, pig diets are usually based on rice bran, broken rice, maize and cassava root meal as the main ingredients to supply dietary energy. These are mixed with sources of protein, such as commercial concentrates, marine fish meal and soybean meal, in home-made concentrate diets for pigs, and/or complete commercial feeds. In recent years, use of commercial feed has been increasing, and the price of marine fish meal has also been increasing as a result of the increasing cost of oil. Moreover, pig diets are based on rice bran, vegetable and agricultural by-products such as sweet potato vine, cassava residue and hulled groundnut cake, and therefore containing high fibre, and low protein and energy levels (Loc *et al*, 1996). It is very important to efficiently utilize locally available feed resources to raise pigs. Several studies have been done on the effect of using local feeds such as catfish oil in diets for fattening pig (Le Thi Men *et al*, 2003), and Tra catfish residue meal as a protein source for pigs (Le Thi Men *et al*, 2005). Other studies in the Mekong Delta have focused on catfish oil combined with water spinach for finishing pigs (Le Thi Men *et al*, 2005), catfish by-product meals for pigs (Nguyen Thi Thuy *et al*, 2007) and catfish by-product meal and silage for growing pigs (Nguyen Thi Thuy *et al*, 2010). This study was concerned with evaluating locally available protein feed sources: broken meat, oil extracted, bone and head catfish by-products mixed with cassava root meal.

In Vietnam, cassava is the second crop after paddy rice, with 9395.8 thousand tons produced in 2008 (Vietnam Statistical Yearbook, 2008). Le Van An *et al* (2004) reported that cassava root meal contained 89.3 % DM, in which almost all is organic matter (98.3 %). The contents of crude protein, ether extract, crude fibre, neutral detergent fiber and acid detergent fiber were 2.9, 1.9, 3.2, 9.3 and 3.6%, respectively.

2.1 Methods for processing catfish by-products

According to Nguyen Thi Thuy *et al* (2007), the processing of catfish by-products is performed by several methods, but the basic principle is grinding and boiling. Depending on the objective for the products, they are divided into wet or dry catfish residue meals, or oil extracted products. Normally, a product with low crude protein contains added cassava root meal. In contrast, a residue containing high CP will be without cassava root meal. Then the products are dried or not, depending on the immediate use, or stored (Figure 1).

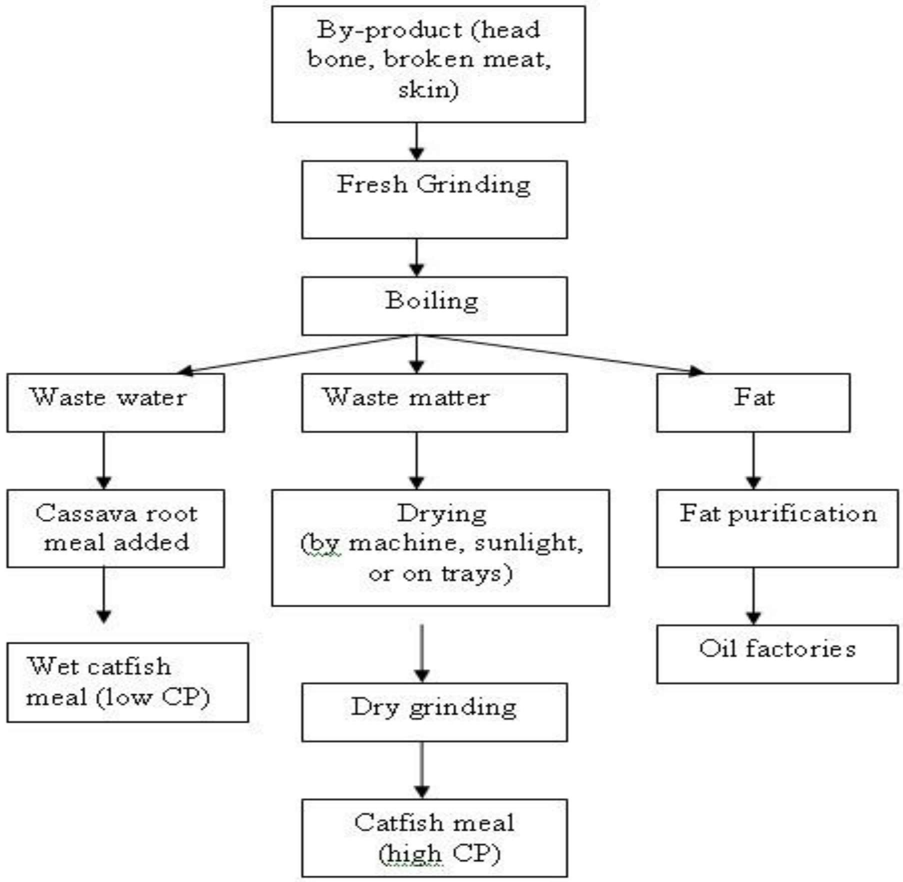

Figure 1. Catfish by-product processing methods

2.2 Nutritive value of catfish by-products

Nguyen Thi Thuy *et al* (2007) reported that catfish by-product meal was classified into three groups: head and bone, broken meat and skin, and waste water and waste matter. Of these, broken meat and skin contained the highest level of crude protein and ether extract, and the lowest contents of ash, crude fibre, calcium, phosphorus and nitrogen free extract. In contrast, the lowest value of crude protein and ether extract were in waste water and waste matter. Moreover, the highest concentration of ash, calcium and phosphorus were found in head and bone. Furthermore, among catfish by-product meals, waste water and waste matter contained the highest concentrations of crude fibre and nitrogen free extract (Table 4).

Essential amino acids are named essential because they cannot be synthesized by the animal at all or not in sufficient amounts, and therefore, must be supplied in the diet. The composition of amino acids contained in protein and their digestibility determine the nutritive value of that protein. An imbalanced protein that does not contain the correct proportion of amino acids would have a lower nutritive value. The animal has a specific requirement of amino acids rather than of protein (Table 5).

Table 4: Dry matter (%) and chemical composition (% in DM) of catfish by-product meals.

	Head and bone meal	Broken meat and skin meal	Waste water and waste matter meal
Dry matter	86.9	93.5	85.4
Ash	25.4	8.75	19.6
Crude protein	40.0	52.4	22.2
Ether extract	14.6	28.6	8.73
Crude fibre	1.06	1.55	6.50
Calcium	9.76	5.85	6.83
Phosphorus	2.64	1.00	1.60
Nitrogen-free extract	18.9	8.70	42.9

Source: Nguyen Thi Thuy et al (2007)

According to Miles *et al* (2006), the oil content in fish can be separated into liquid fish oil and solid fats during the processing of fish meal. The remaining lipids range from 4 to 20 % in fish meal and are highly digestible by all species of animals. Moreover, fish lipid is an excellent source of essential polyunsaturated fatty acids. In general, the oil content in catfish by-products meals is high, which is a specific catfish characteristic (Nguyen Thi Thuy *et al*, 2007) (Table 6).

Table 5: Amino acid composition (g/kg DM) of fish meal (FM) catfish by-product meal (CBM), ensiled catfish by-product (CBE) and processing waste water (WWB)

	FM	CBM	CBE	WWB
Essential amino acids (EAA)				
Arginine	28.8	32.8	16.5	14
Isoleucine	20.1	11.1	11	11.6
Leucine	30.1	23.2	23.5	21.4
Lysine	51.1	49	33.5	36.3
Histidine	13.5	13.5	5.9	6.2
Methionine	18.9	16.8	11.5	10.6
Phenylalnine	17.8	13.1	11.6	12.9
Threonine	18.9	12.9	10.7	12.1
Tyrosine	26.6	24	14.7	11.2
Valine	27.7	20.1	16.9	19
Total EAA	253	216	156	155
Non essential amino acids				
Alanine	40.6	36.1	21.5	30.9
Aspartic acid	1.5	1.6	3.2	4.5
Glutamic acid	61	53	34.7	24.5
Glycine	46.7	32.8	29.2	31.9
Proline	49.8	36	30.9	29.5
Serine	34	31.6	17.6	14.5

Source: Nguyen Thi Thuy et al (2010)

Table 6: Fatty acid composition (% in DM) of catfish by-product meals

	Head and bone meal	Broken meat and skin meal	Waste water and waste matter meal
Lauric C12:0	0.24	0.53	0.10
Myristic C14:0	3.96	4.52	3.53
Palmitic C16:0	33.4	32.4	36.3
Palmitoleic C16:1	1.78	0.90	1.70
Stearic C18:0	9.74	8.23	11.5
Oleic C18:1	36.1	38.8	34.2
Linoleic C18:2	6.47	8.15	3.77
Linolenic C18:3	0.53	0.73	0.23
Arachidic C20:0	0.34	0.20	0.37
Eicosenoic C20:1	1.29	1.20	1.67
Behenic C22:0	0.24	0.25	0.20
Cetoleic C 22:1	0.20	0.18	0.33

Source: Nguyen Thi Thuy et al (2007)

2.3 Nutrient requirements of pigs

According to NRC (1998), the dietary requirements of growing pigs are as shown in Table 7, in diets which are based on maize and soybean meal and fed *ad libitum*.

Table 7: Dietary requirements of pigs allowed feed based on maize and soybean meal and fed *ad libitum* (90% dry matter)

	Body weight (kg)		
	20-50	50-80	80-120
Average weight (kg)	35	65	100
ME content of diets (J/kg)	13.6	13.6	13.6
Crude protein (%)	18	15.5	13
Estimate feed intake (g/day)	1855	2575	3075
Amino acid requirement (%)			
Arginine	0.37	0.27	0.19
Histidine	0.30	0.24	0.19
Isoleucine	0.51	0.42	0.33
Leucine	0.90	0.71	0.54
Lysine	0.95	0.75	0.60
Methionine	0.25	0.20	0.16
Methionine+cystine	0.54	0.44	0.35
Phenylalanine	0.55	0.44	0.34
Phenylalanine + tyrosine	0.87	0.70	0.55
Threonine	0.61	0.51	0.41
Tryptophan	0.17	0.14	0.11
Valine	0.64	0.52	0.40

In the tropical regions, the nutritional requirements for pigs are different from those in the temperate countries. High ambient temperatures can be beneficial in that little energy is needed to maintain body temperature. In addition, there is a negative effect of high ambient temperature, which reduces voluntary feed intake (Preston, 1995).

The demand for the highly digestible protein sources used in modern pig production has increased. To stimulate higher feed intake in swine, several animal protein sources have been used. These protein sources comprise spray-dried animal plasma, blood cell meal, fish meal, meat and bone meal, and poultry by-product meal (Bergstrom *et al* 1997; Shelton *et al* 2001; Derouchey *et al* 2002). However, these protein sources are expensive, and therefore, finding alternatives to replace these, without decreasing pig performance is necessary. Catfish by-product meals are derived from the filleting process and consist of viscera, head and bone, and scrap meat that are rich in protein, fat and macro- and micro-minerals (Nguyen Thi Thuy *et al* 2007). Moreover, digestible CP, EE and amino acids and ileal and total tract apparent digestibility were not different among these by-products (Nguyen Thi Thuy *et al* 2010).

Table 8. Mean values for average daily gain (Experiment 1) and the coefficients of apparent digestibility (Experiment 2)

	Average daily gain, g/day	CP apparent digestibility, %	EE apparent digestibility, %
BH	182	75.9	79.5
FM	365	80.8	81.9
OE	372	81.2	82.4
BM	629	87.9	87.5

BH: bone and head diet, FM: fish meal diet, OE: oil extracted diet, BM: broken meat diet

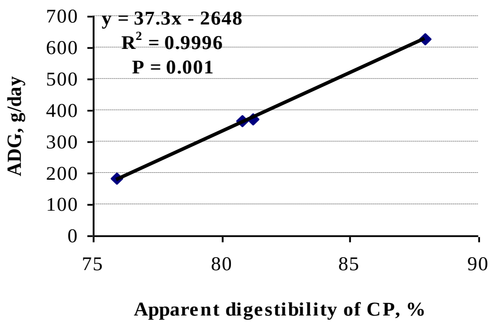

Figure 2: Relationship between ADG and coefficient of CP apparent digestibility

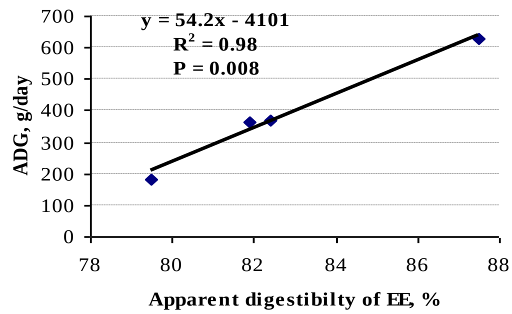

Figure 3: Relationship between ADG and coefficient of EE apparent digestibility

There were significant positive relationships between the coefficient of total tract apparent digestibility (CTTAD) of CP and EE and average daily gain, with $R^2 = 0.9996$, P = 0.001 and $R^2 = 0.98$, P = 0.008, respectively. The CTTAD for CP and EE tended to be in the same order as the growth performance (Table 8) (Figure 2 and 3). According to Holness (2005) pigs depend on both the amount and quality of the protein and energy in their diet for good growth performance.

Conclusions

There were differences in the total tract apparent digestibility of dry matter, crude protein and ether extract among the protein sources that was a factor contributing to the different pig growth rates.

Average daily gain, feed conversion ratio and economic benefit of the broken meat (BM) diet were best, followed by oil extracted (OE) meal and marine fish meal (FM). The poorest performance was on the bone and head meal diet (BH). Furthermore, iodine number in back-fat in decreasing order was BM, OE, FM and BH.

Acknowledgements

The studies presented in this thesis were conducted in the Angiang University Experiment Station in Chau Phu district, Angiang Province, Vietnam, supported by the Swedish International Development Agency/Department for Research Cooperation with Developing Countries (Sida/SAREC).

I would like to express my gratitude to the Swedish International Development Co-operation Agency, Department for Research Cooperation (Sida-SAREC) for the financial support of this thesis research.

I would like to express my gratitude to Professor Brian Ogle, Director of the 'Regional-SAREC MEKARN Sustainable Livestock Production Systems' Project, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, my supervisor, for valuable advice and useful guidance during the study period.

I would like to express my gratitude to Dr. Thomas Reg Preston, who helped me during the period of the study.

I would like to express my gratitude to Dr. Ngo Van Man, Regional Coordinator and Mr. Nguyen Van Cong for their valuable support.

I would also like to express my appreciation to all of the professors, associate professors, doctors and instructors who provided me with useful knowledge during the courses.

I would like to thank colleagues in Department of Animal Husbandry and Veterinary Science, Faculty of Agriculture and Natural Resources, Angiang University, who shared my work in the office during my research.

I would like to give my best wishes to my parents, my older sisters and younger brothers for their sentiment; to my wife for her love and her sharing in all happiness and sadness; to my children daughter and son for her warmness given to me.

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Evaluation of the apparent digestibility of diets containing fish meal and Tra catfish (*Pangasius hypophthalmus*) by-product residue meals in growing pigs

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Abstract

The coefficients of total tract apparent digestibility (CTTAD) of diets with four different protein sources were determined in growing pigs. The four diets were based on cassava root meal as energy source. Control diet (FM) included marine fish meal as the main protein source, diet BM included broken meat catfish by-product meal, diet OE included oil extracted catfish by-product meal and diet BH included bone and head catfish by-product meal. The four diets were fed to four growing pigs in a 4x4 Latin Square design. There were differences among the diets in the CTTAD of dry matter (DM), crude protein (CP), ether extract (EE) and ash, with the highest CTTAD of DM and CP in BM (87.8 % and 87.9 %, respectively) and the lowest in BH (77.5 % and 75.9 %, respectively) ($P<0.05$). Apparent digestibility of organic matter was highest in diet BH (91.3 %) ($P<0.05$), and lowest in diet FM (86.6 %) and diet OE (86.7 %). There was a significant negative relationship between apparent digestibility of CP and ash content in the diet ($R^2=0.95$; $P<0.05$). It can be concluded that the total tract apparent digestibility of dry matter, crude protein and ether extract was highest in the diet with broken meat by-product meal and lowest in the diet with bone and head by-product meal.

***Key words**: Catfish by-product meals, growing pig, total tract apparent digestibility.*

Introduction

In the Mekong Delta, the total number of livestock and fish farms in 2008 was 2,530 and 25,311, respectively (Vietnam Statistical Yearbook, 2008), and Angiang Province accounted for 69 and 1,455 of these, respectively (Angiang Statistical Yearbook, 2008). Utilization of sources of nutrients that are by-products from crop production, such as broken rice, rice bran and cassava root meal, together with fish meal and vegetables for pig production in smallholder farms in the Mekong Delta is common, and pigs sales account for a substantial percentage of cash income (Kamakawa *et al* 2003).

There are two common methods to process catfish by-products, boiling and drying. According to Bui Xuan Men (2005), the crude protein content in the residue meal is not influenced by the processing method of the catfish by-product. However, the protein content is very different between the sources of the by-product (head and bone by-product, broken meat meal and skin). Nguyen Thi Thuy *et al* (2007) for example reported that the crude protein content in catfish by-products ranges from 37.1 to 61.0 % in DM.

Catfish by-product meal contains a high level of fat; it ranges from 6.3 to 33.8 % in DM depending on the source of catfish by-product and processing method, and is higher than in conventional fish meals, especially the content of unsaturated fatty acids (Nguyen Thi Thuy *et al* 2007). This means that it is difficult to store because of auto-oxidation and breakdown of the fatty acids. Especially when fed to pigs it causes soft fat in the carcass (Maw *et al* 2002).

The present experiment was carried out to determine the apparent digestibility of nutrients in diets based on cassava root meal and containing fish meal and different catfish processing by-products as protein sources.

Materials and methods

Location and climate of the study area

The experiment was conducted in the Angiang University Experiment Station in Chau Phu District, Angiang Province, from September 9th to November 18th 2009.

The average annual temperature is 27^{0}C, with the highest temperatures of 35 to 36^{0}C from April to May and the lowest, of 20 to 21^{0}C from December to January. The mean annual rainfall is 1400 to 1500 millimeters. The climate has two seasons, the rainy season from May to November and the dry season from December to April (Angiang Portal 2008).

Animals and management

The animals in the experiment were bought from a private farm in Angiang Province. Four crossbred (Landrace x Yorkshire x Duroc) castrated male pigs with a mean body weight at 60 days of age of 18.5 ± 0.5 kg were used. All pigs were vaccinated against hog cholera and foot and mouth disease and were treated against round worms by Levamysole before starting the experiment.

The pigs were kept in metabolism cages (0.8 m x 0.8 m) made of wood and bamboo and designed to allow recording of feed intake and separate collection of feces and urine.

Experimental feeds

All diet ingredients were bought at the same time. Cassava root meal and fish meal were bought from a local animal feed shop, and head and bone catfish by-product meal, broken meat catfish by-product meal and oil extracted catfish by-product meal were bought from local catfish processing factories in Angiang Province. Before making the dietary formula, samples of ingredients were taken and analyzed for crude protein, and then were mixed together following the formula every week.

Treatments

The four protein sources and diets were:

- Control diet (**FM**): Cassava root meal plus marine fish meal and one percent of a premix of minerals and vitamins.
- Diet **BM**: Cassava root meal plus broken meat catfish by-product meal and one percent of a premix of minerals and vitamins.
- Diet **OE**: Cassava root meal plus oil extracted catfish by-product meal and one percent of a premix of minerals and vitamins.
- Diet **BH**: Cassava root meal plus catfish bone and head by-product meal and one percent of a premix of minerals and vitamins.

Experimental design

The digestibility experiment was designed as a 4 x 4 Latin Square (Table 1) with 14 days for each period. The first seven days were for adaptation to the experimental diets, which were fed *ad libitum*. For the last seven days the amount of feed offered was reduced to 90 % of the previous *ad libitum* intake, and the last five days were for feces collection.

Table 1. Experimental layout

Pigs	1	2	3	4
Period 1	FM	BH	BM	OE
Period 2	BH	BM	OE	FM
Period 3	BM	OE	FM	BH
Period 4	OE	FM	BH	BM

Measurements and data collection

During the last five days of each period, the amount of offered and refused feed was recorded to calculate feed intake. Samples of feed offered and feces of individual pigs were collected in the morning and stored at -4^{o}C. At the end of the experiment total samples were pooled and sub-samples taken for analysis.

Chemical analysis

Samples of feed and feces were analyzed for dry matter (DM) ether extract (EE) and ash according to the standard methods of AOAC (1990), and crude protein (CP) was determined by the Kjeldahl procedure.

Statistical analysis

The data for apparent digestibility of dry matter, crude protein, ether extract and ash were analyzed as a Latin Square Design by using the General Linear Model (GLM) of the Analysis of Variance (ANOVA) procedure of the Minitab statistical software release 14 (Minitab, 2003). The Tukey Test for pair-wise comparisons was used to separate means when the differences were significant at the five percent level. Sources of variation were: animals, treatments, periods and error.

Results

Ingredient and chemical composition of the diets

The diets were based on cassava root meal, fish meal, broken meat meal, oil extracted meal, and bone and head catfish by-products and were formulated to contain 17 to 18 % of crude protein, to meet requirements according to NRC (1998). The chemical composition of the ingredients is shown in Table 2 and the ingredient composition of the diets is shown in Table 3.

Table 2: Dry matter content (%) and chemical composition of ingredients (%, dry matter basis)

	DM	CP	EE	Ash
Cassava root meal	88.5	3.31	6.72	3.15
Fish meal	88.6	43.5	7.82	26.5
Broken meat meal	90.4	71.5	21.0	4.66
Oil extracted meal	89.6	45.5	8.81	24.6
Bone and head meal	89.0	33.0	5.29	45.6

Coefficients of total tract apparent digestibility (CTTAD)

There were differences among the diets in the coefficients of apparent total tract digestibility (CTTAD) of dry matter, crude protein, ether extract and ash, that were highest in diet BM and lowest in diet BH (P<0.05). The CTTAD of organic matter was highest in diet BH (P<0.05) and lowest in diets FM and OE (Table 4).

Table 3: Ingredient and chemical composition (%) of the experimental diets

	FM	BM	OE	BH
Cassava root meal	63	78	64	52
Fish meal	35.5	0	0	0
Broken meat meal	0	20.5	0	0
Oil extracted meal	0	0	34.5	0
Bone and head meal	0	0	0	46.5
Premix of minerals and vitamins	1	1	1	1
Salt	0.5	0.5	0.5	0.5
Total	100	100	100	100
Chemical composition of diets (%, dry matter basis)				
Dry matter	87.1	87.4	87.6	88.1
Crude protein	17.1	17.9	18.2	18.3
Ether extract	6.71	11.8	7.18	5.29
Crude fibre	3.17	2.92	3.11	2.48
Ash	11.4	3.04	9.37	20.3

FM: fish meal diet; BM: broken meat meal diet; OE: oil extracted meal diet; BH: bone and head meal diet

Table 4: Coefficients of total tract apparent digestibility (%) of the experimental diets in pigs

	FM	BM	OE	BH	SEM	P
Dry matter	79.9^b	87.8^a	81.4^b	77.5^b	1.64	0.001
Organic matter	86.6^b	89.9^{ab}	86.7^b	91.3^a	1.22	0.016
Crude protein	80.8^b	87.9^a	81.2^b	75.9^b	1.65	0.001
Ether extract	81.9^{ab}	87.5^a	82.4^{ab}	79.5^b	1.59	0.006
Ash	56.5^{ab}	62.8^a	53.7^{ab}	48.1^b	3.77	0.050

FM: fish meal diet; BM: broken meat meal diet; OE: oil extracted meal diet; BH: bone and head meal diet; $^{a-b}$ *Means within row with different letters differ significantly (P<0.05)*

There was a significant negative relationship between the CTTAD of CP and ash content in the diet (R^2=0.95; P<0.05) (Figure 1), and a close numerical relationship between the CTTAD of OM and the crude fibre content of the diet (R^2 = 0.87; P= 0.07) (Figure 3). There was a positive relationship between the CTTAD of EE and the EE content of the diet (R^2 = 0.99; P<0.01) (Figure 2).

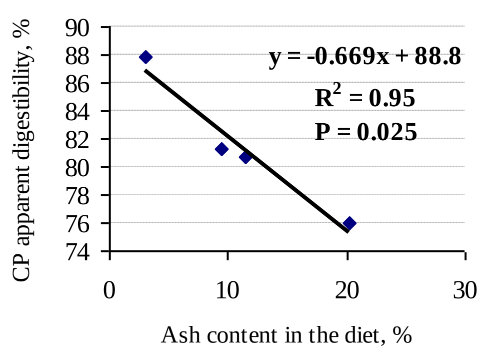

Figure 1: Relationship between ash content in the diets and apparent digestibility of CP, %

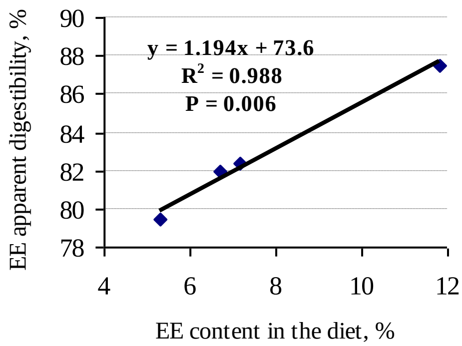

Figure 2: Relationship between EE content in the diet and apparent digestibility of EE, %

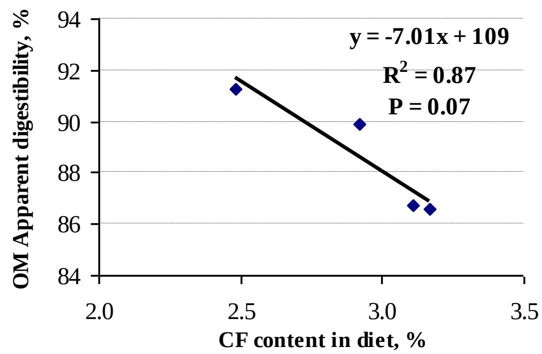

Figure 3: Relationship between CF content in the diet and apparent digestibility of OM, %

Discussion

The catfish by-product meals contained different CP, EE and ash contents because they had different proportions of scrap meat, skin, head and bone and were bought from different processing factories, and with differences in oil extraction processes between factories (Nguyen Thi Thuy *et al*, 2007). The fish meal used in the experiment was produced from very small, whole marine fish, and therefore had a higher proportion of bone and more ash and lower CP content than is usual in commercial fish meals.

The total tract digestibility of DM, CP and ash was different among the diets. There was a negative effect on apparently digestible components of the diets related to ash content. This was shown by the fact that as the ash content increased in the diets, DM and CP apparent digestibility was reduced (Figure 1 and 2). These results are agreement with previous studies by Jørgensen *et al* (1984) and Knabe *et al* (1989) on diets containing fish meal and meat and bone meal, and Noblet and Perez (1993) also reported that diets which had higher ash content, had lower fecal apparent digestibility of DM and CP. The CP apparent digestibility of BM, FM and OE was higher than in the study of Nguyen Thi Thuy *et al* (2010) on catfish by-products in diets based on broken rice, maize meal and rice bran as energy sources. This can be explained by the fact that the cassava root meal, that was the main source of energy in the present experiment, had a lower CF content, and a higher digestibility than the more fibrous energy sources in the study of Nguyen Thi Thuy *et al* (2010). According to Sauer and Ozimek (1986), diets that contained higher amounts of CF had higher nitrogen losses from the hindgut and increased fermentation in the large intestine and enhanced microbial population growth, and subsequently higher protein excretion. Le Goff and Noblet (2001) also showed that total tract digestible CP was reduced when more ash and fiber were present in the diet.

There was a difference in digestible OM between FM, OE, and BH, mainly because of differences in ash content, as the CF concentrations in all diets were low and had little influence on digestibility values. However, OM digestibility was lower than in the study by Le Van An *et al* (2004) in diets based on cassava root meal and casein, but in contrast, was higher than in the study of Nguyen Thi Thuy *et al* (2010) in diets based on rice bran, broken rice and maize meal and including catfish by-products, probably because the fibre contents in the diets were different.

The EE apparent digestibility among the diets was different. This can be explained by the fact that the EE contents in the diets were different (Figure 3). According to Noblet and Perez (1993) and Le Goff and Noblet (2001) there is a positive relationship between EE content in the diet and apparent digestibility of EE. However, the EE digestibility was higher than in the study of Nguyen Thi Thuy *et al* (2010), probably because of the lower CF content in the diets in the present study. There was a negative relationship between CF content in the diet and digestible EE and a positive relationship between EE in the diet and EE digestibility. This is because microbes use lipids to synthesize membranes and release high amounts of fecal endogenous material, and therefore digestibility is reduced (Noblet and Perez, 1993). Also, unsaturated fatty acids are more digestible than saturated fatty acids, and the BM diet contained higher levels of unsaturated fatty acids than the BH diet.

Acknowledgements

The authors would like to express most sincere thanks to Sida-SAREC (Swedish International Development Cooperation Agency - Department for Research Cooperation), through the regional MEKARN program, for financial support of this study.

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Effects on performance of replacing fish meal by Tra catfish (*Pangasius hypophthalmus*) by products in the diets of growing pigs

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Abstract

The effects of diets with four different protein sources were determined with respect to average daily gain (ADG), feed conversion ratio (FCR), back-fat thickness and economic benefits in growing pigs. The four treatment diets were based on cassava root meal as energy source: A control diet (FM) was cassava root meal plus marine fish meal; Diet BM was cassava root meal plus catfish broken meat by-product meal; Diet OE was cassava root meal plus oil extracted catfish by-product meal and Diet BH was cassava root meal plus bone and head catfish by-product meal. The four diets were fed to twenty four growing pigs in a Complete Randomized Block design with four treatments and six replications, and the experimental unit was one pig. There were differences among the diets in ADG, dry matter intake (DMI), FCR and back fat thickness, with a descending trend from BM, OE, FM and BH ($P<0.05$). The DMI, ADG, back fat thickness and iodine number were highest in BM (1955 g, 629 g, 13.7 mm and 52.8, respectively) ($P<0.05$) and lowest in BH (182 g, 925 g, 7.81 mm and 40.1, respectively) ($P<0.05$). The FCR in BM was the lowest (3.13 kg/kg gain) and highest in BH (5.31 kg/kg gain) ($P<0.05$). The feed cost per kg weight gain of pigs in BM was lowest ($P<0.05$). The gross income and net benefit per pig of BM were higher than the other diets ($P<0.05$). It can be concluded that the growth performance and economic benefit of the treatment with catfish broken meat by-product meal (BM) were highest, followed by OE, FM and BH.

Key words: *Average daily gain, backfat thickness, catfish by-product meals, feed conversion ratio, growing pigs, iodine number.*

Introduction

Pig production in the Mekong delta increased strongly by 25.5 % between 2000 and 2006. However, during the same period production in Cantho Province decreased by 45 %, and continued to decline, by 4.3 % annually, between 2006 and 2008 (Vietnam Statistical Yearbook, 2008).

The nutritive value of any protein is directly related to the amino acid composition of that protein. A protein that does not contain the proper amounts of amino acids will be imbalanced. Tra catfish by-product meal (broken meat and skin) contains an excellent balance of essential amino acids, especially with respect to lysine and methionine (Nguyen Thi Thuy *et al* 2007).

According to Nguyen Thi Thuy *et al* (2007) catfish residue meals contain high levels of minerals and concentrations also were shown to vary considerably among by-products and factories. For example, ash contents ranged from 3.5 to 33.8 % depending on catfish by-product, and calcium and phosphorus concentrations ranged from 7 to 13 %, and 2 to 3 %, respectively, which means that catfish by-products are a good source of macro-minerals for growing pigs and sows.

According to Le Thi Men *et al* (2005), Tra catfish residue meal can completely replace fish meal in fattening pig diets based on broken rice as the main ingredient and without effects on back fat thickness.

The present study was conducted in order to determine average daily gain, feed conversion ratio, back fat thickness and economic benefits among diets based on cassava root meal, with marine fish meal and different by-product meals from processing catfish as protein sources.

Materials and methods

Location and climate of the study area

The experiment was carried out in the experimental station of Angiang University, in Chau Phu district, Angiang Province, from August 25 to December 26, 2009.

The average annual daily temperature is 27^0C, with the highest temperatures of 35 to 36^0C from April to May and the lowest of 20 to 21^0C from December to January. The mean rainfall is 1400 to 1500 millimeters. The climate has two seasons, the rainy season from May to November and the dry season from December to April (Angiang Portal 2008).

Animals and management

The animals in the experiment were bought from a pig farm in Angiang Province. Twenty four crossbred (Landrace x Yorkshire x Duroc) castrated male pigs with a mean body weight of 22.7 kg ± 0.5 at 70 days of age were used in the experiment. All pigs were vaccinated against hog cholera and foot and mouth disease and were treated against round worms with Levamysole before starting the experiment.

The pigs were housed in individual pens (0.6 m x 1.2 m) made of bamboo with feeding troughs to allow recording of offered feed and to collect refused feed. Animals were given feed ad-libitum four times per day at 07:00, 11:00, 14:00 and 17:00 h and feed refusals were collected and weighed before the morning and afternoon feeding.

During the trial, one pig in treatment FM died due to lung problems.

Experimental diets

The diets were based on cassava root meal, marine fish meal, broken meat by-product, oil extracted by-product and head and bone by-product, and were formulated to contain from 17 to 18 % crude protein (CP) in DM to meet requirements according to NRC (1998).

All ingredients were bought at one time at the beginning of the experiment. The bone and head, broken meat and oil extracted catfish by-product meals were bought in local processing factories, and the cassava root meal and fish meal were bought from an animal feed shop in Angiang province. Before making the dietary formula, samples of ingredients were taken and analyzed for crude protein, and then were mixed together following the formula every week.

Treatments

- Control treatment (FM): cassava root meal plus marine fish meal and one percent of a premix of minerals and vitamins.
- Treatment BM: cassava root meal plus broken meat catfish by-product meal and one percent of a premix of minerals and vitamins.
- Treatment OE: cassava root meal plus oil extracted catfish by-product meal and one percent of a premix of minerals and vitamins.
- Treatment BH: cassava root meal plus bone and head catfish by-product meal and one percent of a premix of minerals and vitamins.

Experimental design

The experiment was designed as a Complete Randomized Block with four treatments and six replications, and the experimental unit was one pig. The pigs were allocated to blocks based on initial live weight and at random within blocks according to treatment. The experiment was conducted over four months (finishing when the pigs reached slaughter weight, at 90 to 100 kg). The chemical composition of the ingredients is shown in Table 1 and the ingredient composition of the diets is shown in Table 2.

Table 1: Dry matter content (%) and chemical composition of ingredients (%, dry matter basis)

	DM	CP	EE	Ash
Cassava root meal	88.5	3.31	6.72	3.15
Fish meal	88.6	43.5	7.82	26.5
Broken meat meal	90.4	71.5	21.0	4.66
Oil extracted meal	89.6	45.5	8.81	24.6
Bone and head meal	89.0	33.0	5.29	45.6

Table 2: Ingredient and chemical composition of the experimental diets

	FM	BM	OE	BH
Cassava root meal	63	78	64	52
Fish meal	35.5	0	0	0
Broken meat meal	0	20.5	0	0
Oil extracted meal	0	0	34.5	0
Bone and head meal	0	0	0	46.5
Premix of minerals and vitamins	1	1	1	1
Salt	0.5	0.5	0.5	0.5
Total	100	100	100	100
Chemical composition of diets (%, dry matter basis)				
Dry matter	87.1	87.4	87.6	88.1
Crude protein	17.1	17.9	18.2	18.3
Ether extract	6.71	11.8	7.18	5.29
Ash	11.4	3.04	9.37	20.3
ME of diets, MJ/kg	12.0	13.4	12.3	10.8

FM: fish meal diet; BM: broken meat meal diet; OE: oil extracted meal diet; BH: bone and head meal diet
*According to McDonald et al (2002): ME (MJ/kg, DM) contents of diets were estimated as: ME = %EE*25.4 + %(CP+CHO)*12.7;%(CP+CHO) = 100 - %EE - %ash -%CF*% digestibility*

Measurements and data collection

All pigs were weighed at the beginning and end of the experiment to determine daily live weight gain.

Amounts of offered and refused feed in every pen were recorded every day to calculate feed intake, and then feed conversion ratio was calculated and an economic analysis performed.

Back fat thickness at the last rib of all pigs was measured by an ultrasonic technique (RENCO Co., Ltd, Minneapolis, USA) at the end of the experiment.

The formulae to calculate average daily weight gain (ADG), and feed conversion ratio (FCR) were:

ADG = (W2 –W1)/T

FCR = Total dry matter intake/weight gain

Where: W1 is live weight at start of experiment; W2 is live weight at the end of the experiment, and T is the number of days on experiment.

Chemical analysis

All ingredients were analyzed for dry matter (DM) ether extract (EE) and ash according to the standard methods of AOAC (1990), and crude protein (CP) was determined by the Kjeldahl procedure before making the diets.

Offered and refused feed samples were analyzed for dry matter by using microwave radiation (Undersander et al 1993).

One representative pig in each treatment was slaughtered, and back-fat samples taken for analysis of iodine number according to the standard method of AOAC (1984).

Statistical analysis

The data for feed intake, growth rate and feed conversion ratio were analyzed as a Randomized Complete Block Design by using the General Linear Model (GLM) of the Analysis of Variance (ANOVA) procedure of the Minitab statistical software release 14 (Minitab, 2003). Sources of variation were: animals, treatments, blocks and error. The Tukey Test for pair-wise comparisons was used to separate means when the differences were significant at the five percent level.

Results

Average daily gain, feed conversion ratio, back-fat thickness and iodine number

There were differences in the average daily gain (ADG), feed conversion ratio (FCR), back fat thickness and iodine number among diets ($P<0.05$), with a descending trend from BM, OE, FM and BH. Dry matter intake (DMI) was highest in BM (1955 g/day), followed by FM (1573 g/day), OE (1264 g/day) and BH (925 g/day) ($P<0.001$). The differences between BM and FM, and BH and OE were non-significant ($P>0.05$). Average daily gain was highest in BM (629 g) followed by OE (372 g), FM (365 g) and BH (182 g) ($P<0.001$). The difference between OE and FM was non-significant ($P>0.05$). The FCR in BM was lower than in FM ($P<0.05$), but not different from OE, and the FCR in BH was higher than in FM ($P<0.05$) (Table 3). Back-fat thickness on the FM and OE diets did not differ, while BM had the highest value, and BH lowest ($P<0.05$). Iodine number of BM was higher than FM and OE (P<0.05), and was lowest in BH (P<0.05) (Table 3).

Economic benefit

The feed cost per kg weight gain of pigs fed diet BM was the lowest, and differed from the other diets (P<0.05), while differences among diets FM, OE and BH were non-significant (P>0.05) (Table 4). There were no differences among treatments FM, OE and BH in gross income and net benefit per pig. However, they were lower than in diet BM (P<0.05) (Table 4).

Table 3: Effect of protein source on daily feed and nutrient intake, daily live weight gain, feed conversion ratio and back-fat thickness

	Diet					
	FM	**BM**	**OE**	**BH**	**SEM**	**P**
Initial weight, kg	22.5	23	22.8	22.8	1.24	0.99
Final weight, kg	67.8[b]	101[a]	69[b]	45.3[c]	6.26	0.001
Dry matter intake (g/d)	1573[ab]	1955[a]	1264[b]	925[c]	81.9	0.001
Average daily gain (g/d)	365[b]	629[a]	372[b]	182[c]	24.7	0.001
Feed conversion ratio, kg/kg	4.38[b]	3.13[a]	3.32[a]	5.31[c]	0.18	0.001
Back-fat thickness (mm)	10.7[b]	13.7[a]	9.71[b]	7.81[c]	0.44	0.001
Back-fat thickness (mm) adjusted for live weight as covariate	10.9	10.6	9.87	10.5	0.5	0.36
Iodine number of back fat	44.5[b]	52.8[a]	45.3[b]	40.1[c]	0.39	0.001
ME of diets, MJ/kg	12.0	13.4	12.3	10.8		
CP intake, g/day	269	350	230	169		
ME intake, MJ	18.9	26.2	15.6	9.99		
ME:CP ratio, MJ ME/g CP	0.07	0.08	0.07	0.06		

FM: fish meal diet, BM: broken meat meal diet, OE: oil extracted meal diet, and BH: bone and head meal diet [a-c] *Means within row with different letters differ significantly (P<0.05)*

Table 4: Effect of diet on economic benefits

	Diet					
	FM	**BM**	**OE**	**BH**	**SEM**	**P**
Gross income/pig, USD	126[b]	188[a]	129[b]	84.5[b]	11.8	0.001
Pig cost/pig, USD	43.5	44.4	44.1	44.1		
Feed cost/kg, USD	0.26	0.21	0.28	0.23		
Feed cost/kg weight gain, USD	1.09[b]	0.65[a]	0.99[b]	1.20[b]	0.05	0.001
Total feed cost/pig , USD	49.3[a]	50.9[a]	44.3[ab]	26.7[b]	4.97	0.009
Net benefit/pig, USD	33.7[b]	92.6[a]	40.3[b]	13.8[b]	3.64	0.001

FM: fish meal diet, BM: broken meat meal diet, OE: oil extracted meal diet, and BH: bone and head meal diet, [a-c] *Means within row with different letters differ significantly (P<0.05)*

Discussion

The metabolisable energy (ME) content in diet BH was very low (10.8 MJ/kg) because of the very high ash content and low content of EE. In contrast diet BM had a high content of EE and low content of ash, and therefore a high ME content (13.4 MJ/kg). Crude fibre content in all diets was very low, around 3% of DM.

The DM intake differed among diets. The low ME content of diet BH would have been expected to have increased DMI, as pigs try to adjust their feed intake to give a constant ME intake. However, that this was not the case could have been due to the lower palatability of diet BH, probably due to the very high ash content, and also due to possible rancidity. This could also explain the positive relationship between DMI and ratio of ME:CP in the diets, as diets FM and OE also had a high ash content, and DMI that were much lower than that of pigs on BM, which had an ash content of only 3 %. Furthermore, there were positive relationships between apparent digestibility of DM and CP (Tuan et al 2010) and the DMI. Pomar et al (2003) and Speedy (1997) confirmed that voluntary feed intake is limited when the feed is unbalanced in terms of the ratio between energy and protein. According to Holness (2005) the optimum ratio of ME and CP, and ME requirement of pigs in the tropics are 0.08 and 12 MJ/kg, respectively.

Average daily gains on the tested diets in descending order were BM, OE, FM and BH (Table 3), and generally reflected daily dry matter intakes. Growth rates were highest on diet BM, which also had the highest DMI. Average daily gain and DMI were very low in diet BH, but although DMI was higher in the fish meal (FM) diet than in the diet containing the oil extracted meal (OE), ADG in these two diets were similar, probably because the ME content in the diets and ratio of ME:CP between the treatments were different, and calculated ME content in diet BH was lower than the requirement of tropical pigs, as the ideal mean ME in diets for pigs in the tropics from 20 to 120 kg is 12.0 (Holness, 2005), which is much higher than the ME content in diet BH, of 10.8 MJ/kg. There is a positive relationship between ME intake, and protein deposition in pigs (Renaudeau et al, 2006). Several authors confirmed that subsequent growth performance was reduced when pig had low energy intake in the early growing period (Chadd and Cole, 1999; Smith *et al*, 1999; De la Llata *et al*, 2001). In addition, ash content in the diet could also have negatively affected growth rate for a different reason, because animals must excrete minerals through urine and use energy to do this when intakes are higher than body demand. Consequently, all the above factors probably affected ADG.

The FCR among the diets were different. This can be explained by the fact that the diets had different ME and CP ratios, and thus the diet (BM) that resulted in higher protein deposition in pigs, also had higher efficiency of feed utilization. These results are in agreement with Lopez *et al* (1997) who found that when the ME concentration in the diet was higher, the FCR was lower, and when the ratio of ME : CP was high, the FCR was reduced (Le Bellago *et al*, 2002).

The back-fat thickness was different among treatments, and there was a positive relationship between ME content in the diet and back-fat deposition. According to Renaudeau *et al* (2006) the higher the ME intake, the thicker the back-fat.

There were differences among the treatments in iodine number of back-fat, with the BM diet having the highest value. Generally, when the catfish oil level was increased, the iodine number was higher. This can be explained by the fact that the proportion of EE in diets BM and OE was higher than in diets FM and BH and the unsaturated fatty acid content in catfish by-product meal is very high. According to Nguyen Thi Thuy *et al* (2007) the unsaturated fatty acid content in catfish by-product meal is higher than in other fish meals. However, our values for iodine number were lower than those reported by Le Thi Men *et al* (2003) in a study on the effects of catfish oil in diets for fattening pigs.

The BM diet was the best in terms of economic benefit. Although the other diets were not different from each other, broken head meal should not be used in pig diets because of the very poor performance.

It can therefore be concluded that the average daily gain, feed conversion and economic benefit of the broken meat meal diet was the best, followed by diets OE, FM and BH.

Acknowledgements

The authors would like to express most sincere thanks to SIDA-SAREC (Swedish International Development Cooperation Agency - Department for Research Cooperation), through the regional MEKARN program for financial support of this study.

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Angiang Portal 2008 article March 13, 2008

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