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Effects of Catfish (*Pangasius hypophthalmus*) or Coconut (*Cocos nucifera*) Oil, and Water Spinach (*Ipomoea aquatica*) in Diets on Growth/Cost Performances and Carcass Traits of Finishing Pigs

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Abstract

Twenty-four crossbred (Landrace × Yorkshire) finishing pigs with an average live weight of 56.8 ± 1.8 kg (mean ± S.E.) comprising equal numbers of barrows and gilts were used for 48 days. Couples of both a barrow and gilt were randomly allocated to a total of 12 pens. The trial was designed as a 2 × 2 factorial experiment with dietary treatments which consisted of diets containing 5.0% catfish (*Pangasius hypophthalmus*) or coconut (*Cocos nucifera*) oil (F5 or C5, respectively), with or without 5.8% water spinach (*Ipomoea aquatica*) (W0 or W6, respectively). No significant effects or interaction by the treatments were found on the daily weight gain, feed conversion ratio (FCR) and cost conversion ratio expressed as feed cost multiplied by FCR ($p > 0.1$). An interaction on backfat thickness was found ($p < 0.05$); it tended to be lower ($p < 0.1$) for diets supplemented with catfish oil than for diets with coconut oil, when water spinach was not added; and it was reduced ($p < 0.001$) by the water spinach supplementation, when coconut oil was also supplemented. As for the carcass traits, the types of oils had an effect on the iodine value of backfat; the value was significantly higher in F5 diets than that in C5 diets ($p < 0.001$). Significant differences were found in the pH values, the DM (dry matter) content of fresh loin muscle and the iodine value of backfat between W0 and W6 diets ($p < 0.01$). Overall, a diet with 5.8% water spinach and that with 5.0% catfish oil with no water spinach would be recommended to improve the farmers' common pig diet in the region.

Discipline: Animal industry
Additional key words: farming systems, green plant, Mekong Delta, natural oil, underutilized feed resources

Introduction

The pig is the most dominant livestock in Vietnam, as pork production contributes over 70% of total meat production of the country[3]. Pork production is an important component of many forms of rice-based integrated farming systems that have taken root in the Mekong Delta, an area of 39,653.2 km^2, one of the two granaries of Vietnam. Most production in the region is operated by small-scale farmers in order to generate income. However, due to the high percentage of rice bran used in pig's diet, the deficiencies of protein, especially of essential amino acids, excess of energy and lack of minerals have become apparent[15]. To compensate for this imbalance, the farmers also use commercial protein-concentrate feed (concen-

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trate feed for short) as a protein supplement, but the additional costs of concentrate feed often become a financial burden for the producers. In addition, the market has a tendency to equate a higher proportion of fat with lower quality, and lean pork with higher quality. The increasing consumer demand for high quality pork, led by increasing incomes, especially in urban areas, has resulted in a price difference between lean and fat pork[4].

On the other hand, there are many types of agricultural and agro-industrial by- or mid-products such as catfish and coconut oils and aquatic plants such as water spinach, in the region. Catfish cultivation on the large fresh water surface of the Mekong River branches has been increasing since the first half of the 1990's. Frozen white cobbler fillet is mostly exported from some large-scale factories, and the abundant residues of the belly are pressed to extract the raw oil[6]. Coconut is one of the most prevalent fruits in the region, while its oil is the main mid-industrial product mostly used as a component of vegetable cooking oils. Water spinach is an aquatic plant that is easily grown year-round by farmers for both human and animal consumption. The effects of supplementation with each feed resource on the growth performances of pigs had been examined. The results showed that each resource was able to supply up to 5–6% of the feed and replace concentrate feed without significant reduction of growth performances, such as daily weight gain (DG) and feed conversion ratio (FCR)[8,9,13].

However, the comparison of the effects of the two types of oils in diets has not yet been done. In addition, combination effects of each oil and water spinach in diets weren't known. Thus, the present study aims to determine the effects of supplementations of catfish or coconut oil, with or without water spinach, on growth/cost performances and carcass traits of finishing pigs to contribute to the establishment of feeding management systems in the region.

Materials and methods

1. Varieties of the resources

The *Tra* catfish (*Pangasius hypophthalmus*) and *Ta Xanh* coconut (*Cocos nucifera*) oils, and *Nuoc* water spinach (*Ipomoea aquatica*) were chosen for the trial. *Tra* and *Basa* (*Pangasius bocourti*) have been the two major catfish varieties in recent years, and the production of these *Pangasius* catfish has increased from 30,000 tons in 1994 to 150,000 tons in 2002 (Cantho Univ. and the CIRAD, unpubl. leaflet) as a result of the national open market economy and exportation to international markets. The *Tra* is more prevalent than the *Basa* because the *Tra* matures earlier than the *Basa*[6]. Several varieties of coconuts are cultivated in the delta. *Ta Xanh* is the most popular coconut for oil extraction. It has 6–7 fruits per bunch, green and slightly round fruit, 2 cm thick copra, and the copra contains a high percentage of oil, as high as 72%[14]. There are two different varieties of water spinach (*Ipomoea aquatica*), *Hat* and *Nuoc*, that grow in Cantho Province, an area of 2,986 km^2, the socio-economic and geographic center of the Mekong Delta. The *Hat*, mainly for human consumption, is seeded in fields, and the *Nuoc* grows along the river and canal banks and is used for both human and animal consumption.

2. Experimental design, feeds and pigs

The experiment was conducted for 48 days during April and June of 2003 at Song Hau State Farm in the Omon District of Cantho Province. Twenty-four cross-bred (Landrace × Yorkshire) finishing pigs comprising an equal number of barrows and gilts with an average live weight of 56.8 ± 1.8 kg (mean ± S.E.) were used. Barrow-gilt couples were sorted according to their initial live weight; then they were randomly allocated to a total of 12 pens. The trial was designed as a 2 × 2 factorial experiment with dietary treatments which consisted of diets containing two different oil sources, the 5.0% catfish or coconut oil (F5 or C5, respectively), with or without the 5.8% raw water spinach (W0 or W6, respectively). Three samples of each feedstuff were taken, and their DM, CP (crude protein), crude fiber (CF), and ether extract (EE) contents were analyzed according to AOAC (2000)[1]. The values of amino acids and metabolic energy (ME) of feedstuff were referred from the composition and nutritive value of animal feeds in Vietnam by the National Institute of Animal Husbandry (1995). Then, the chemical compositions of each diet such as CP, lysine on a DM basis and energy were set at exactly the same levels (13.5%, 0.70% and 3,100 kcal/kg, respectively; Table 1). The feed costs, expressed in Vietnamese Dong (VND: One US dollar was converted to approximately 15,500 VND in 2003) per kg, of the diets with water spinach were 3–4% lower than the diets without the plant. The amount of daily feed was equal to 3.5% of the mean live weight of the couple of pigs in the pen, which was estimated weekly. The pigs were fed twice daily and were allowed free access to water using nipple-type drinkers situated in pens throughout the trial.

3. Parameters and data collection

All of the pigs were weighed at the beginning and end of the trial, when the mean live weight of the pigs reached approximately 85 kg, then the DG of the pigs was calculated. Feed refusals were collected every morning to measure the daily feed intake (FI), and the intake of nutri-

Table 1. Ingredients, chemical composition and current market costs of the experimental diets for finishing pigs

	F5-W0[1)]	C5-W0	F5-W6	C5-W6
Ingredients, %				
Broken rice	30.0	33.2	30.0	33.9
Rice bran	46.5	43.0	44.4	40.0
Catfish oil	5.0	0.0	5.0	0.0
Coconut oil	0.0	5.0	0.0	5.0
Water spinach	0.0	0.0	5.8	5.8
Soybean meal	11.8	12.1	8.1	8.6
Lysine	0.14	0.14	0.15	0.15
Threonine	0.06	0.06	0.05	0.05
Salt	1.0	1.0	1.0	1.0
Calcium phosphate	5.0	5.0	5.0	5.0
Premix[2)]	0.50	0.50	0.50	0.50
Total	100.0	100.0	100.0	100.0
Analyzed dry matter (DM), and chemical composition on a DM basis, %[3)]				
DM	89.9	89.8	89.9	89.8
Crude protein	13.5	13.5	13.5	13.5
Crude fiber	3.8	3.5	4.3	4.1
Ether extract	9.1	8.5	9.2	8.8
Calculated amino acid and fatty acid composition, % DM[4)]				
Lysine	0.70	0.70	0.70	0.70
Methionine + cystine	0.47	0.47	0.44	0.44
Threonine	0.51	0.51	0.51	0.51
Tryptophan	0.15	0.15	0.13	0.13
C12:0	0.03	2.55	0.03	2.56
C16:0	2.66	1.56	2.70	1.61
C18:1	3.83	2.26	3.78	2.22
C18:2	2.48	2.06	2.48	2.08
C18:3	0.09	0.07	0.22	0.22
Costs, VND/kg[5,6)]	2,529	2,547	2,442	2,459

1): F5: diet with 5.0% catfish oil, C5: diet with 5.0% coconut oil, W0: diet without water spinach, W6: diet with 5.8% water spinach.
2): Unupco Pig Grower, produced by Anglian Nutrition Products Co., England. The manufacturer supplied the nutritional values of the feed as follows: 10,000,000 IU vitamin A, 2,000,000 IU vitamin D3, 10,000 IU vitamin E, 180,000 mg Cu, 150,000 mg Fe, 110,000 mg Zn, 30,000 mg Mn, and 1,000 mg I in 2.5 kg.
3): Three samples of each diet were used for the analysis.
4): The data of Men et al. (2006) and the National Institute of Animal Husbandry (1995) were used for the calculations.
5): The market prices of each feedstuff per kg in Omon District of Cantho Province in 2003, broken rice: 2,100 VND, rice bran: 1,900 VND, soybean extracted: 4,100 VND, catfish oil: 6,000 VND, coconut oil: 6,000 VND, lysine: 25,130 VND, threonine: 60,000 VND, premix: 14,165 VND, and water spinach: 1,600 VND (on a DM basis).
6): Vietnamese Dong: One US dollar was converted to approximately 15,500 VND in 2003.

ents was calculated from the FI. The feed conversion ratio (FCR) was calculated from the DG and the FI. The backfat thickness at two opposite points, 6 cm apart from the mid-line, at the 10th–12th ribs of all live barrows was estimated using ultrasonic equipment (RENCO Co., Ltd., Minneapolis, USA) at the time of the measurement of final live weight. Cost performance was represented by a cost conversion ratio (CCR), expressed as feed cost multiplied by FCR, and the CCR was calculated for each treatment.

Half of the experimental pigs, one barrow and two gilts in every dietary treatment, were chosen from every pen and slaughtered after 12 hours of starvation. Each empty body was weighed, and the carcass yield was calculated. The iodine value of 8 lipid samples extracted from the backfat at the 10th rib was determined by the

Wijs method using iodine monochloride[14]. The loin eye area was measured at the 10th rib of the hot carcasses. Eight fresh loin muscle samples were taken for chemical analysis of the DM, CP and pH.

4. Statistical analyses

The data was analyzed in a factorial design by ANOVA using General Linear Model of Minitab Statistical Software Version 13 to find out the effects of each of the oils with or without water spinach and their interaction (Ryan et al. 2000)[12]. Sources of variation were dietary treatments in factors. Where interactions were significant, the differences between the means were compared by the Tukey test at the 5% level.

Results

The results analyzed in a factorial design are shown in Tables 2 and 3. The means which showed significant interactions were compared between each type of oil with or without water spinach, respectively (Table 4). Neither an interaction nor an effect of each of the oils or water spinach on the DG was found ($p > 0.1$) (Table 2). All of the pigs examined were in good health during the experiment, as seen in the average DG of 566 g/d (F5) and 601 g/d (C5), and in the FI of each dietary treatment which was over 3% of average live weight of pigs examined. An interaction on feed intake was also found ($p < 0.01$; Table 2), and the combination of coconut oil and water spinach somewhat reduced the FI compared with the other combinations ($p < 0.01$; Table 4). However, the difference in the

Table 2. Effects of catfish (*Pangasius hypophthalmus*) or coconut (*Cocos nucifera*) oil (Oils), and water spinach (*Ipomoea aquatica*) (WS) in the diet on mean daily weight gain (DG), backfat thickness, daily feed/nutrient intake, feed conversion ratio (FCR), and cost performance (CCR) of finishing pigs (on a DM basis)[1,2)]

	Oils		WS		SEM	Significance		
	F5[1)]	C5	W0	W6		Oils	WS	Oils×WS
No. of pens[3)]	3	3	3	3				
DG, g/d	566	601	596	571	29.9	NS	NS	NS
Feed intake, g/d	2,051	2,072	2,100	2,023	20.3	NS	*	**
FCR[4)]	3.64	3.51	3.59	3.56	0.17	NS	NS	NS
CCR[4)]	9,228	8,594	8,919	8,903	407	NS	NS	NS
Backfat thickness, mm	14.0	15.3	15.6	13.7	0.5	†	*	*

1): Oils × WS: interaction between Oils and WS, SEM: standard error mean. For the other abbreviations, see Table 1.
2): NS: not significant, †: $p < 0.10$, *: $p < 0.05$, **: $p < 0.01$.
3): Each pen contains a barrow and a gilt finishing pig.
4): FCR: feed conversion ratio, CCR: a cost conversion ratio expressed as feed cost multiplied by FCR.

Table 3. Effects of catfish (*Pangasius hypophthalmus*) or coconut (*Cocos nucifera*) oil, and water spinach (*Ipomoea aquatica*; WS) in the diet on traits of the pork[1,2)]

	Oils		WS		SEM	Significance		
	F5[1)]	C5	W0	W6		Oils	WS	Oils×WS
No. of pens[3)]	3	3	3	3				
Carcass parameters								
Carcass yield, %	76.5	76.8	77.4	75.9	0.37	NS	*	NS
Loin eye area, cm^2	37.4	37.9	36.6	38.8	0.42	NS	**	NS
Iodine value of backfat	61.1	53.8	58.5	56.5	0.48	***	**	NS
Chemical parameters of the fresh loin meat								
pH	5.5	5.5	5.5	5.6	0.02	NS	**	NS
Dry Matter, % fresh matter	27.1	27.2	26.3	28	0.31	NS	**	*
Crude protein, % DM	21.5	20.8	21	21.3	0.25	†	NS	NS

1): For abbreviations, see Tables 1 & 2.
2): NS: not significant, †: $p < 0.10$, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.
3): Each pen contains a barrow and a gilt finishing pig.

Table 4. Treatment means which have a significant interaction by the results of factorial analysis compared between each type of oil with or without water spinach[1,2)]

		Oils		Significance
		F5	C5	
Backfat thickness, mm				
WS	W0	14.1	17.2	†
	W6	13.8	13.5	NS
Significance		NS	†	
Feed Intake, g/d				
WS	W0	2,032	2,169	†
	W6	2,070	1,975	**
Significance		NS	***	
Dry matter proportion in the fresh loin muscle, % DM				
WS	W0	25.7	26.8	†
	W6	28.7	27.4	NS
Significance		**	NS	

1): For abbreviations, see Table 1.
2): NS: not significant, †: $p < 0.10$, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.

FCR and CCR by oil type or by the water spinach substitution was not significant, nor was the interaction ($p > 0.1$).

On the other hand, an interaction in the difference of the oils and water spinach supplementation on backfat thickness was found ($p < 0.05$; Table 2). The backfat thickness differed by diet; it tended to be thinner ($p < 0.1$) by the supplementation of catfish oil than with coconut oil when water spinach was not added and it was also thinner ($p < 0.05$) by the supplementation of water spinach when coconut oil was also supplemented (Table 4).

In the carcass traits, no significant interactions were found ($p > 0.1$), except that of DM ($p < 0.05$) (Table 3). The DM differed by diet; it tended to be lower ($p < 0.1$) by the supplementation of catfish oil than coconut oil when water spinach was not added and it was significantly ($p < 0.01$) higher by the supplementation of water spinach when catfish oil was supplemented (Table 4). The types of oils had a significant effect only on the iodine value of backfat; the value was significantly higher in F5 diets than in C5 diets ($p < 0.001$). On the other hand, the carcass yield and the loin eye area of the W6 diet was slightly lower ($p < 0.05$) or higher ($p < 0.01$) than the W0 diet, respectively. Significant differences were found in the pH values of the loin meat, the DM content and the iodine value of backfat between W0 and W6 diets ($p < 0.01$), whereas no significant difference was found in the CP content between the dietary treatments.

Discussion

The new consumption trend, led by the increasing income of the urban population, and which had started in the 1980's and accelerated after the *Doi Moi* or liberalization reform brought about a price difference in lean and fat pork[4]. As the DG, FCR and the CCR weren't much different between the treatments in the present study, the leanness of pork would be the important trait to discuss. In addition, the selling prices of pigs per kg live weight are usually determined in local markets of the Mekong Delta, where middlemen base the prices on the external features of the pigs, with leanness favored over fatness. A couple of examples of selling prices of finishing pigs in Cantho Province in 2003 were 12,500 VND/kg for fat pigs and 13,000 VND for lean pigs, 104% relative to the price of the fat pigs. Under these circumstances, the backfat thickness would be the most important trait.

In order to decrease the backfat thickness the water spinach supplementation with any of the types of oil, and the combined catfish oil supplementation with no water spinach were effective. Besides this, the iodine values were higher in the F5 than in the C5 diet and lower in the W6 than in the W0 diet. The results would be explained from the difference of fatty acid compositions in the total lipid contents of the oils and water spinach: 78% of saturated fatty acids (SFA) in coconut oil, 75% of poly-unsaturated fatty acids (PUFA) in catfish oil, and 74% of PUFA in water spinach[7,10]. It was stated that increasing the proportion of dietary energy derived from PUFA decreases

the backfat thickness at P2, or at the 10th rib, and that the increase in PUFA uptake increases the softer fat deposition, or increases the iodine value[11,16]. The results by Tuan and Dan (2000), which determined coconut products in pig diets with a high level of rice bran could reduce the soft fat deposit, is also in the same line[15].

The carcass yield was higher in W0, and the loin eye area and DM of the fresh loin muscle were higher in the W6 than the other, respectively. Not only the decrease of EE but also the increase of CF in W6 from W0 would affect the decrease of fat deposition in W6, as increasing the fiber in the diets would induce slightly lower weight gain, but this would reflect an increase in leanness of the carcass of pigs[2]. Then, the proportion of lean meat exhibited by the loin eye area and DM of pork would be increased. The pH of W6 was significantly higher than that of W0, but both were within the values of normal pork: higher than 5.4 and lower than 6.0[5].

The water spinach contributed to an increase in the leanness of the pork in spite of the differences of the types of the oils. In case water spinach is not available; catfish oil supplementation with no water spinach should be a valuable way to decrease backfat thickness. Thus, in conclusion, a diet with 5.8% water spinach, or a diet with 5.0% catfish oil with no water spinach would be recommended to improve the farmers' common pig diet in the region.

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