Effect of Replacing Soybean Meal with Soya Waste and Fish Meal with Ensiled Shrimp Waste on the Performance of Growing Crossbred Ducks

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ABSTRACT : Two experiments were conducted with growing crossbred Super-Meat ducks at the experimental duck farm of Cantho University to evaluate the effects of reducing the proportion of soybean meal (SBM) in a broken rice (BR)-SBM mixture and providing soya waste (SW) *ad libitum* (Expt. 1), and reducing the proportion of fish meal (FM) in a BR-FM mixture and supplying ensiled shrimp waste (ESW) *ad libitum* (Expt.2). Both experiments included five treatments, with three replicates and ten growing ducks per replicate. In Expt.1, the five diets were based on BR and five levels of SBM, with SW offered *ad libitum.* The control diet (SBM25) consisted of 75% BR and 25% SBM, and the other four treatments included SBM levels of 20% (SBM20), 14% (SBM14), 8% (SBM8) and 0% (SBM0) mixed with BR to 100%, and with SW *ad libitum.* In Expt. 2, the control diet consisted of 86% BR and 14% FM, and the other dietary treatments had FM levels of 11% (FM11), 8% (FM8), 4% (FM4) and 0% (FM0) mixed with BR, and with ESW *ad libitum*. In Expt. 1, total intakes of dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF) and metabolizable energy (ME) were higher for birds given SW ($p<0.001$). Total CP intake was highest on the SBM20 diet, and lowest on the SBM0 diet ($p<0.001$). Lower daily gain (DG) was found for the SBM0 diet ($p<0.01$). Carcass weights were higher on the control treatment, with the lowest values on the SBM0 diet ($p<0.001$). Gizzard weights were higher on diets with high intakes of SW ($p<0.05$). In Expt. 2, birds with high intakes of ESW (FM4 and FM0) had lower ($p<0.01$) daily intakes of DM. The total CP intakes declined ($p<0.001$) with higher intakes of ESW. The highest DG were for the control and FM11 diets, while the lowest value was for diet FM0 ($p<0.001$). The poorest feed conversion ratio (FCR) was for the FM0 treatment ($p<0.01$). Lower weights of carcass and breast muscle were found on the FM0 diet ($p<0.001$). Feed costs per kg gain were only slightly different between diets. However, the lowest feed cost was for ducks on the SBM0 and FM11 diets in Expt.1 and Expt. 2, respectively. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 6 : 825-834)***

Key Words : Soya Waste, Ensiled Shrimp Waste, Crossbred Super-meat Ducks, Feed Intake, Daily Gain

INTRODUCTION

Duck production in Vietnam has developed over a long period of time. Ducks are raised throughout the country, but are concentrated in the Red River and Mekong Deltas. Several breeds are reared, including local and exotic ducks and their crosses, of which so-called Crossbred Super-Meat ducks have become popular in both rural and urban areas in the Mekong Delta because of their good performance and high resistance to diseases**.** However, giving diets based on concentrate or conventional feedstuffs, such as fish meal and soy bean meal, is often unprofitable for producers because the price of these, especially protein supplements, has increased considerably. In recent years, the inclusion of agro-industrial by-products in diets for ducks has increased, especially soya waste and shrimp waste, which are protein-rich feed resources that are widely available and inexpensive in the Mekong Delta. Large amounts of these by-products are produced locally almost all the year round from both large factories in the cities and small artisanal enterprises in the rural areas. Shrimp waste is considered to be a valuable protein source for animals. The product consists of the head and shell, and is characterized not only by a high content of crude protein (CP) and minerals, but also by a high concentration of chitin (Evers and Carroll, 1996; Göhl, 1998). Chitin is considered to have low digestibility when fed to animals (Austin et al., 1981), but Hirano et al. (1990) reported that some species of bird produce chitinase in the proventriculus, and chitin and chitosan fed to hens and broilers were 88% and 98% digestible, respectively. The high CP content, and reasonably good balance of essential amino acids (Ngoan et al., 2000a), make shrimp waste a useful potential alternative to fish meal in diets for monogastric animals. In the Mekong Delta an earlier study by Cuc et al. (2002) showed that shrimp waste could be preserved for at least 8 weeks by ensiling with molasses, the ensiled product having high concentrations of crude protein (31.6%), Ca (4.2%) and P (1.6%). Studies on the effect of inclusion of shrimp by-product meal on the carcass characteristics of pigs (Göhl, 1998) indicated that fish meal could be replaced by ensiled shrimp by-product without affecting carcass quality.

The present study was aimed at evaluating the effects of including soya waste and ensiled shrimp waste in diets for growing crossbred ducks in terms of performance and carcass traits as well as profitability.

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MATERIALS AND METHODS

Experimental design and birds

Experiment 1 was carried out from February to May, in the dry season, and Experiment 2 from June to September, in the rainy season, at the experimental duck farm and laboratories of the Agriculture Faculty, Cantho University in the Mekong Delta in Southern Vietnam. In each trial a total of 150 crossbred Super-Meat ducks (male Super-Meat crossed with female crosses between Cherry Valley and Pekin ducks) at three weeks of age was used. One-day-old ducklings were bought from a traditional hatchery and fed a commercial diet *ad libitum* from 1 to 21 days of age. The birds were identified by cutting their feet membranes and then were individually weighed (average initial live weights were 725±2.35 g, and 850±0.05 g, for Expt. 1 and Expt. 2, respectively) each week and at slaughter. All ducks were vaccinated with Duck Plague vaccine and FC3 (pasteurellosis vaccine) at two and three weeks of age and given antibiotics (Coliterravet and Oxomid) to prevent common diseases.

The trials were complete randomised designs with five dietary treatments and three replicates of ten birds, balanced for sex, in each group. In Expt. 1, the five diets were based on broken rice (BR) mixed with 5 different levels of soybean meal (SBM), and with soya waste (SW) offered *ad libitum*. A control diet (SBM25) consisted of BR (75%) and SBM (25%) only, and the other diets consisted of BR mixed with SBM at levels of 20% (SBM20), 14% (SBM14), 8% (SBM8) and 0% (SBM0), and with SW supplied *ad libitum*. In Expt. 2, the five dietary treatments were based on broken rice (BR) and five levels of FM, with ensiled shrimp waste (ESW) offered *ad libitum*. A control diet consisted of broken rice (86%) and FM (14%) (FM14) only, and the other dietary treatments consisted of FM at levels of 11% (FM11), 8% (FM8), 4% (FM4) and 0% (FM0) mixed with BR, and with ESW provided *ad libitum* (Table 7). In both trials, fresh duckweed (100 g/bird/day), bone meal (1%) and salt (0.3%) were also supplied to all birds to provide vitamins and minerals. The experimental period was seven weeks.

Housing and management

In both experiments, the birds were housed in a shed divided into pens constructed from nylon nets, with thatched roofs and concrete floors covered with rice straw for bedding, with an average density of four birds per m^2. The ducks also had access to outside concrete yards, with an average area of one m^2 per duck. The temperature in the house averaged 23-25°C in the morning, 32-37°C at noon and 21-25°C at night. Natural light was used in the day and electric bulbs at night to allow eating. The yards were cleaned daily in the morning and manure was removed once every week. Both drinkers and feeders were cleaned daily each morning.

Diets and feeding

In the brooding stage (from day 1 to day 21 after hatching) all ducklings were fed a commercial starter diet *ad libitum*, which contained 12.2 MJ ME/kg DM and 19.5% CP (DM basis). The birds were housed and fed in groups of 10 from 21 to 70 days old, and given the experimental diets. Total protein offered was based on the recommendations of Yeong (1992) for growing and finishing ducks.

Broken rice : The broken rice used for each experiment was bought on one occasion from a local feed mill and kept for use throughout the trials.

Soybean meal : The soybean meal used was purchased from a local feed mill on one occasion and was roasted before grinding to eliminate anti-nutritional factors and then stored for later use. In Expt. 1, soybean meal was mixed with broken rice, and then offered *ad libitum*.

Soya waste : Soya waste (SW) is a by-product of soybean processing for tofu, soya milk and soya sauce production. The soybean seeds are soaked in water for around 3 h, then dehulled, ground and boiled. Finally, the soya juice is removed by filtering and is used in various soybean products, with the residue called soya waste. SW can be stored for up to 2-3 days before feeding. In our experiment, it was bought every two days at a local tofu processing factory, stored anaerobically in plastic containers, and offered *ad libitum* in separate feeders.

Fish meal : FM in Expt. 2 was from a single batch purchased at the same time from a local feed company. It was mixed with broken rice (BR), then offered *ad libitum*.

Ensiled shrimp waste : For Expt. 2, shrimp waste was supplied by a local processing factory in Cantho City. The by-product originated from three common shrimp species (*Penaeus monodon, Penaeus semisulcatus* and *Metapenaeus affinis*), and was immediately finely chopped and mixed with molasses at a ratio of 3:1 (wet weight). This ratio was indicated to be optimum with respect to silage quality in an earlier study (Cuc et al., 2002). The mixture was preserved in plastic bags and sealed to prevent air contamination. The bags were placed in containers at room temperature (25-32°C) and the ensiled shrimp waste was first used at least two weeks after ensiling. It was offered in separate feeders to the FM-BR mixture.

Duckweed (*Lemna* spp.) : The duckweed (DW) was collected daily in the morning, and washed, then drained before feeding.

The ducks were offered feed twice a day, at 08:00 h and 15:00 h. The refusals remaining in the basins, and spillage, were collected and weighed daily in the morning, and were analysed for DM to calculate intakes.

Table 1. Chemical composition of the feed ingredients (% in DM), Expt. 1

Item*	Broken rice	Soybean meal	Soya waste	Duckweed
DM	84.4	88.6	8.38	4.46
OM	96.9	92.6	95.7	81.4
CP	9.11	33.5	23.8	30.3
EE	1.77	14.8	4.85	4.30
NFE	83.4	39.5	47.0	36.0
NDF	6.90	25.3	32.2	27.3
ADF	1.78	12.5	27.1	17.0
Ash	3.06	7.40	4.29	18.6
Ca	0.22	0.44	1.16	2.98
P	0.34	0.94	0.86	0.61
ME, (MJ/kg)	14.1	12.2	11.2	9.2

* DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber and ME = Metabolizable energy (calculated).

Chemical analyses

Samples of broken rice, soybean meal, fish meal, soya waste, ensiled shrimp waste and duckweed were analyzed for dry matter (DM), crude protein (CP) (N×6.25), crude fiber (CF), ether extract (EE), nitrogen free extract (NFE), ash, calcium and phosphorus by standard AOAC methods (AOAC, 1990). Analyses of neutral detergent fibre (NDF) and acid detergent fiber (ADF) were done following the procedures of Goering and Van Soest (1991). The feeds were also analyzed for GE, and ME contents were calculated from these (ME = GE, MJ/kg analyzed× coefficient ME/GE) according to the Standard Tables of Feed Composition in Japan (1995). Representative samples of feed ingredients were analyzed for essential amino acids (Spackman et al., 1958). The chitin content of ensiled shrimp waste was measured by an enzymatic method based on the use of purified chitinases (Jeuniaux and Voss-Foucart, 1997).

Measurements

All birds were weighed individually, at the beginning, weekly and at the end of each trial. Daily feed intakes were calculated according to the total feed consumption of the group in each pen. At the end of the experiment 30 representative ducks in terms of live weight, including one male and one female from each pen, were slaughtered for carcass evaluation, and carcass traits and internal organ weights were recorded.

Statistical analysis

The data from both experiments were analyzed by analysis of variance using the ANOVA General Linear Model (GLM) of Minitab Reference Manual Release 13 (2000). Linear regression analyses of the effects of ADF and CP intakes on the gizzard weight and DG were performed. The model used was as follows:

$$Y_{ij} = \mu+T_i+\varepsilon_{ij}$$

where, Y_{ij} is the individual observation, μ the overall mean, T_i treatment effect and ε_{ij} is the residual error. When the F-test was significant at $p<0.05$, paired comparisons were performed using Tukey's procedure (Minitab, 2000).

Economic analysis

Economic analyses were done using current prices in Vietnamese Dong (VND) to compare the feeding costs on the different treatments and to calculate feed costs per kg gain.

RESULTS AND DISCUSSION

Experiment 1

Chemical composition of feedstuffs : The chemical composition of the broken rice, soybean meal, soya waste and duckweed is shown in Table 1. The contents of CP and ME in the control diet are consistent with the recommendations of Dean (1985) for growing Pekin ducks (16% CP). The amino acid analysis indicated that except for methionine, the contents of the most important essential amino acid contents in SBM and SW are considerably higher than those of the ideal protein for ducks reported by Rose (1997) (Table 2).

The concentrations of DM and CP in the soya waste used in the experiment are in agreement with the value reported by Phuong (2001), and similar to those in an earlier study done at the same station (Dung, 2001).

Table 2. Essential amino acid composition of feed ingredients and ideal protein, Expt. 1

Item	Feed ingredient				
	Broken rice*	Soybean meal*	Soya waste*	Duckweed*	Ideal protein**
Lysine	100	100	100	100	100
Isoleucine	162	109	121	81	77
Leucine	297	154	190	136	130
Methionine	106	28	25	42	75 (Met+cys)
Threonine	179	99	85	129	66
Valine	176	86	110	109	89

* Analyzed values (lysine as 100).

** Ideal protein for growing ducks, Rose (1997). Absolute values of lysine were 0.25, 2.10, 1.67 and 0.95% in DM for broken rice, soybean meal, soya waste and duckweed, respectively.

Table 3. Feed and nutrient intakes (g DM/day) of growing ducks fed diets with different levels of soybean meal (SBM) and with soya waste supplied *ad libitum*, Expt. 1

Item	Diet					SEM/P
	SBM25 (Control)	SBM 20	SBM 14	SBM 8	SBM 0	
Total DM	118^{a}	131^{b}	129^{b}	127^{b}	121^{a}	1.316/0.001
Broken rice	84.2^{a}	84.6^{ab}	85.2^{bc}	84.9^{b}	85.5^{c}	0.134/0.001
Soybean meal	29.5^{a}	22.2^{b}	14.6^{c}	7.80^{d}	0.0	0.044/0.001
Soya waste	0.0	19.6^{a}	25.3^{ab}	30.0^{b}	31.2^{b}	1.30/0.001
Duckweed	4.46	4.46	4.46	4.46	4.46	ns
Total CP	18.9^{a}	20.8^{b}	19.6^{ab}	18.4^{a}	16.6^{c}	0.558/0.001
CP from SBM	9.87^{a}	7.43^{b}	4.87^{c}	2.60^{d}	0.0	0.014/0.001
% CP from SBM	52.3^{a}	35.2^{b}	24.4^{c}	13.8^{d}	0.0	0.40/0.001
CP from SW	0.0	4.65^{a}	6.01^{ab}	7.13^{b}	7.43^{b}	0.307/0.001
% CP from SW	0.0	21.9^{a}	30.0^{b}	37.9^{c}	44.8^{d}	1.08/0.001
NDF	25.1^{a}	30.3^{b}	30.4^{b}	30.1^{b}	29.6^{b}	0.479/0.001
ADF	8.47^{a}	12.9^{b}	13.5^{b}	13.9^{b}	13.8^{b}	0.349/0.001
ME, MJ	1.59^{a}	1.73^{b}	1.70^{b}	1.67^{b}	1.60^{a}	0.015/0.001
CP/ME, (g/MJ)	11.9^{a}	12.3^{b}	11.7^{a}	11.3^{c}	10.4^{d}	0.077/0.001

[a, b, c, d] Means with different superscripts within rows are significantly different (p<0.001).

Table 4. Daily intakes (g/day) of macro minerals and amino acids of growing ducks fed diets with different levels of soybean meal (SBM) and with soya waste supplied *ad libitum*, Expt. 1

Item	Diet					SEM/P
	SBM25 (Control)	SBM 20	SBM 14	SBM 8	SBM 0	
Calcium	0.71^{a}	0.93^{b}	0.96^{b}	0.98^{b}	0.95^{b}	0.016/0.001
Phosphorus	0.71^{a}	0.83^{b}	0.80^{b}	0.78^{b}	0.71^{a}	0.012/0.001
Leucine	1.64^{a}	2.03^{b}	1.97^{b}	1.89^{b}	1.68^{a}	0.041/0.001
Lysine	0.87^{ad}	1.05^{b}	0.98^{bc}	0.92^{ac}	0.78^{d}	0.021/0.001
Methionine	0.42^{ad}	0.47^{b}	0.45^{bc}	0.44^{ac}	0.40^{d}	0.006/0.001
Threonine	1.41^{a}	1.59^{b}	1.50^{ab}	1.41^{a}	1.23^{c}	0.024/0.001
Valine	0.95^{a}	1.18^{b}	1.15^{b}	1.12^{b}	1.00^{a}	0.023/0.001

[a, b, c, d] Means with different superscripts within rows are significantly different (p<0.001).

However, the SW in the present study had a higher CP content than that reported by Hong et al. (2003). The DM content of SW was very low, but CP and ME contents on a DM basis were reasonably high. The fibre content of SW however was much higher than in SBM, and the Ca and P contents of SW higher than those of SBM and BR.

Feed and nutrient intakes : Daily intakes of dietary ingredients and nutrients are shown in Table 3. The SW offered was consumed readily on all treatments, and total DM and BR intakes of birds fed SW were higher (p<0.001) than for those fed the control diet. Intakes of SW increased (p<0.001) as the SBM supplied was progressively restricted, reaching a maximum level on the SBM0 diet. The increased SW intakes may reflect the palatability of SW, and were slightly higher than those recorded in a similar study in the Mekong Delta in which growing common ducks were supplied with SW as the main dietary protein source (Dong and Ogle, 2003b). Total intakes of CP were different between diets, with the highest intake on the SBM20 treatment and the lowest on the SBM0 diet (p<0.001). The percentage of CP from SW of the total CP intake increased gradually with decreasing supply of SBM and correspondingly increasing amounts of SW consumed. Total intakes of NDF and ADF increased with increasing SW intakes (p<0.001), due the high fibre content in SW. This is consistent with studies that reported that ducks are able to consume and digest high fibre diets efficiently (Jamroz et al., 1996). Total ME intakes were lower on the SBM25 and SBM0 diets (p<0.001), but there was no significant difference among the other diets. The higher intakes of BR and SW on the SW diets demonstrated that the birds were attempting to adjust their feed intake in order to meet their energy requirements. This is in agreement with the report of Siregar et al. (1982a), who indicated that ducks have a remarkable ability to adjust their feed intake so that their ME consumption is relatively constant, and is independent of both the concentration of dietary ME and protein (Zakaria, 1992). The values in our study are slightly lower than ME intakes for adult Muscovy ducks recommended by Sauveur and Steven (1985). The ratio of CP to ME was highest for birds fed SBM20 and lowest for those given the diet without SBM (SBM0) (p<0.001). Except for the SBM0 diet, these ratios are close to those recommended by Dean (1985), who indicated optimum ratios within a range of 11.5

Table 5. Daily gains and feed utilization of growing ducks fed diets with different levels of soybean meal (SBM) and with soya waste supplied *ad libitum*, Expt. 1

Item	Diet*					SEM/P
	SBM25 (Control)	SBM 20	SBM 14	SBM 8	SBM 0	
Initial weight (g)	726	723	719	725	727	2.35/0.227
Final weight (kg)	2.55[a]	2.53[a]	2.53[a]	2.45[ab]	2.38[b]	0.02/0.005
Daily gain (g)	32.6[a]	32.3[a]	32.4[a]	30.7[ab]	29.5[b]	0.51/0.006
FCR (kg feed/kg gain)	3.63[a]	4.06[b]	4.00[b]	4.13[b]	4.11[b]	0.07/0.005
ME/gain (MJ/kg)	48.8[a]	53.5[b]	52.6[ab]	54.3[b]	54.1[b]	0.96/0.012
CP/gain (g/kg)	580[a]	656[b]	617[ab]	612[ab]	562[a]	13.9/0.050
Feed cost/kg gain VND*	9,610	10,080	9,550	9,540	9,050	-

[a, b] Means with different superscripts within rows are significantly different (p<0.05).
* 1USD = 15,000 VND.

Table 6. Carcass parameters of growing ducks fed diets with different levels of soybean meal (SBM) and with soya waste (SW) supplied *ad libitum*, Expt. 1

Item	Diet					SEM/P
	SBM25 (Control)	SBM 20	SBM 14	SBM 8	SBM 0	
Final weight (kg)	2.63[a]	2.46[ab]	2.58[ab]	2.50[ab]	2.37[b]	0.04/0.023
Carcass weight (CW) (kg)	1.83[a]	1.71[ab]	1.69[b]	1.64[bc]	1.55[c]	0.03/0.001
Carcass (%)	69.7[a]	69.4[ab]	65.7[bc]	65.9[bc]	65.3[c]	0.83/0.006
Breast muscle (g)	298[a]	284[ab]	304[a]	284[ab]	255[b]	7.79/0.011
Breast muscle (% of CW)	16.3	16.6	18.0	17.3	16.5	0.58/0.293
Thigh muscle (g)	99.5	106	105	104	103	2.48/0.45
Thigh muscle (% of CW)	5.45[a]	6.20[ab]	6.23[ab]	6.33[ab]	6.70[b]	0.22/0.03
Fat (g)	22.5	21.0	19.3	18.5	16.7	5.34/0.94
Gizzard (g)	68.5[a]	72.7[a]	85.8[b]	90.7[b]	91.5[b]	2.08/0.001
Gizzard (% of CW)	3.75[a]	4.25[a]	5.08[b]	5.52[bc]	5.93[c]	0.14/001
Liver (g)	58.3	61.7	66.3	57.5	57.8	3.03/0.26
Small intestine (cm)	201	194	201	207	218	7.77/0.31
Large intestine (cm)	18.4	18.5	17.6	18.5	18.8	0.67/0.74
Cecum (cm)	17.6	18.8	20.8	19.7	20.6	1.01/0.23

[a, b, c] Means with different superscripts within rows are significantly different (p<0.05).

to 13.9 g CP/ MJ ME for meat ducks after 3 weeks of age.

Intake of essential amino acids was significantly lower on the diet without SBM (SBM0) and the control (SBM25) diet (p<0.001) (Table 4). The mean dietary concentration of lysine (0.73%) was slightly lower than the reported recommendation of 0.77%, while that of methionine (0.35%) was close to the recommendation of 0.32% of growing Pekin ducks (Scott and Dean, 1991). However, the mean intakes of other essential amino acids such as leucine, threonine and valine were higher than the recommendations (Scott and Dean, 1991). The daily intakes of Ca and P (Table 4) were significantly lower (p<0.001) for birds given the SBM25 (control) treatment, due to the low Ca concentration in BR and SBM. In spite of the low Ca content in BR and SBM, the Ca intakes on all treatments were adequate, due to the Ca supplied from bone meal. Thus the results from the present study are in good agreement with Scott and Dean (1991) who recommended dietary levels for growing Pekin ducks of 0.6% Ca and 0.6% total P.

Daily gain and feed conversion ratio : The results in Table 5 show that the rates of gain were not significantly different among the diets containing SBM. However, gains on the SBM0 diet were lower (p<0.01) than on the SBM25, SBM20 and SBM14 diets, probably due to the lower CP intake and the lower ratio of CP/ME. The explanation for the finding that daily gains were approximately similar among the treatments with SW is that birds increased their intakes of CP and ME from SW in order to compensate for the reduced intakes from SBM. The daily gains and the final weights in the present study were slightly higher than in a study with ducks fed diets based on broken rice and molasses and with SW supplied *ad libitum* as the protein source (Dong and Ogle, 2003b). In another study carried out in Vietnam, Minh (2000) evaluated the effect of including tofu waste, which is similar in composition to SW, in diets for laying ducks, and found that a level of 18% of fresh tofu waste in the diet gave normal performance, and was the optimum economical level of replacement. In the present study, optimum growth rates were found when SW accounted for 19.6% of the total DM intake, and 31.9% of the dietary protein.

Table 7. Chemical composition of the feed ingredients (% in DM), Expt. 2

Item*	Broken rice	Fish meal	Ensiled shrimp waste	Duckweed
DM	87.9	85.5	22.1	5.93
OM	98.8	69.9	77.8	75.3
CP	8.70	48.5	35.3	32.8
EE	1.40	10.9	8.15	5.80
NFE	81.3	0.52	28.4	23.0
NDF	6.90	7.97	6.86	25.7
ADF	1.78	1.77	5.90	16.6
Ash	1.16	31.0	22.2	19.6
Ca	0.18	5.20	5.89	3.10
P	0.31	2.30	1.39	0.52
ME (MJ/kg)	14.4	12.5	10.3	8.60

* DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber and ME = Metabolizable energy (calculated).

Feed conversion ratios were poorer on the diets containing SW ($p<0.01$). The birds given the SW diets consumed high amounts of fibre, and it was reported by Janssen and Carre (1985) that plant cell walls may act as a barrier to the attack of intracellular compounds by enzymes of the gastro-intestinal tract of chickens. These results are consistent with those of Siregar et al. (1982b), who showed that feed conversion ratios decreased with an increase in dietary energy concentration. In our experiment, the ME content of the control diet (SBM25) was 13.9 MJ ME/kg DM, which was higher than in all treatments with SW, and as expected the FCR on a DM basis of birds on the control diet was better than for those given SW.

Carcass evaluation : The highest carcass weights and carcass percentages (Table 6) were found for the control diet (SBM25), and the lowest values on the diet in which SBM was completely replaced by SW ($p<0.001$ and $p<0.01$, respectively). The declining carcass percentages with increased consumption of SW would have been a result of the bulkiness and high moisture content of the SW, which would have increased the weight of gut contents and the gizzard. Thigh weight expressed as a proportion of CW was slightly higher on the diets containing SW compared to the Control, the difference being significant for the SBM0 treatment ($p<0.05$). Gizzard weights increased with SW intake ($p<0.001$), as a result of the large amounts of fibre consumed. This result is in agreement with the studies of Siregar et al. (1982c), Jamroz et al. (1996) and Jorgensen et al. (1996), who showed that dietary fibre influences the development of the gastrointestinal tract and organs. In two earlier experiments carried out in the Mekong Delta fibrous brewery waste was fed to growing common ducks and had similar effects on gizzard weights (Dong and Ogle, 2003a). The effect of ADF intake on gizzard weight in the present study is shown by following equation:

$$Y = 3.69X+35.6, \qquad r^2 = 0.62$$

Where Y = gizzard weight (g), X = ADF intake (g/day).

The weights of abdominal fat and the lengths of small and large intestine and cecum were not significantly different between treatments.

Health status : Mortality was zero, and throughout experiment the growing ducks fed SW appeared healthy, and had good appetites. Moreover, anti-nutritional factors would have been destroyed by heat after boiling the SW.

Economic analysis : The results in Table 5 show that the feed costs per kg gain were fairly similar for all diets and lowest for the group not given SBM (SBM0), which implies that it is possible to completely replace SBM by SW offered *ad libitum*. However, as the SW contains over 90% moisture, transport costs will restrict its use to producers situated close to tofu, soya milk or soya sauce factories.

Experiment 2

Chemical composition of feeds : The chemical composition of the feed ingredients is shown in Table 7. The ensiled shrimp waste (ESW) used had a high content of CP (35.3% of DM), calcium and chitin (11.3-13.9%). These values are comparable to those of Evers and Carroll (1996), who reported that the chemical composition of shrimp by-products varies widely, with CP from 30-55%, ether extract from 5-7%, chitin from 14-20%, ash from 20-40% and calcium from 10-15%. Ngoan et al. (2000b) reported that the CP content of ESW in Vietnam was 26.9%, while the CP content of the ESW in the current study was much higher (35.3% of DM), due to differences in shrimp species and processing method. However, the concentrations of Ca, P and chitin found are close to other reports. Analysis of amino acids showed that the most important essential amino acid concentrations in ESW are similar to those of the ideal protein for ducks reported by Rose (1997) (Table 8).

Feed and nutrient intakes : To date, little research has been done or data published concerning the intake of shrimp by-product by growing ducks and effects on performance. Intakes of DM and BR decreased linearly as the level of ESW increased and were significantly lower on the FM0 diet compared to the other ESW treatment groups

Table 8. Essential amino acid composition of the feed ingredients and ideal protein, Expt. 2

Item	Feed ingredient				
	Broken rice*	Fish meal*	Ensiled shrimp waste*	Duckweed*	Ideal protein**
Lysine	100	100	100	100	100
Isoleucine	163	67	105	87	77
Leucine	314	77	127	152	130
Methionine	101	43	51	37	75 (Met+cys)
Threonine	181	69	76	116	66
Valine	179	59	93	118	89

* Analyzed values (lysine as 100). ** Ideal protein for growing ducks, Rose (1997). Absolute values of lysine were 0.23, 4.37, 1.72 and 0.99% in DM for broken rice, fish meal, ensiled shrimp waste and duckweed, respectively.

Table 9. Feed and nutrient intakes (g, DM/day) of growing ducks fed diets with different levels of fish meal (FM) and with ensiled shrimp waste supplied *ad libitum*, Expt. 2

Item	Diet					SEM/P
	FM14 (Control)	FM11	FM8	FM4	FM0	
Intakes (g DM/d)						
Total DM	128^{a}	124^{a}	122^{ab}	116^{b}	108^{c}	1.49/0.001
Broken rice	105^{a}	102^{ab}	101^{ab}	98.7^{ab}	95.2^{b}	1.45/0.007
Fish meal	16.6^{a}	12.0^{b}	8.1^{c}	4.3^{d}	0.0	0.12/0.001
ESW	0.0	5.07^{a}	6.74^{b}	6.65^{b}	7.43^{b}	0.21/0.001
Duckweed	5.93	5.93	5.93	5.93	5.93	ns
Total CP	19.1^{a}	18.4^{a}	17.1^{b}	14.9^{c}	12.8^{d}	0.13/0.001
Total EE	3.62^{a}	3.48^{b}	3.19^{c}	2.74^{d}	2.27^{e}	0.02/0.001
Total NDF	10.1^{a}	9.8^{ab}	9.6^{b}	9.1^{c}	8.5^{d}	0.10/0.001
Total ADF	3.15^{a}	3.30^{b}	3.33^{b}	3.21^{ab}	3.10^{a}	0.02/0.001
ME (MJ)	1.77^{a}	1.72^{a}	1.68^{ab}	1.59^{b}	1.49^{c}	0.02/0.001
CP/ME (g/MJ)	10.8^{a}	10.7^{a}	10.1^{b}	9.4^{c}	8.6^{d}	0.04/0.001

a, b, c, d, e Means with different superscripts within rows are significantly different (p<0.01).

(p<0.001 and p<0.01, for DM and BR, respectively). The intakes of CP, EE and NDF were also lower (p<0.001) on the ESW treatments compared to the control group (FM14). Adverse effects on DM and nutrient intakes in growing pigs by admixing dried shrimp waste meal (Mohan and Sivaraman, 1993) and shrimp head and animal blood ensiled with molasses (Lien et al., 1994) have been reported previously, supporting our findings. Total ME intakes decreased significantly with increasing intakes of the ESW, with the lowest value found for the FM0 diet (p<0.001), as a result of reduction of total DM intake and the low ME content of ESW. The ratios of CP to ME were highest for the control and FM11 diets, and then decreased with increasing ESW intakes (p<0.001). These values are slightly lower than those recommended by Dean (1985). Intake of essential amino acids decreased (p<0.001) with increasing ESW intakes (Table 9), being least for birds fed the diet without SBM (SBM0), due to the low content of essential amino acids in ESW. The mean dietary concentration of lysine (0.61%) was lower than the recommendation of 0.77% (Scott and Dean, 1991), except in the control diet, while the content of methionine (0.37%) was slightly higher than the recommendation of 0.32% for growing Pekin ducks. However, the intakes of other essential amino acids such as leucine, threonine, and valine were quite close to recommendations (Scott and Dean, 1991). The daily intakes of Ca and P decreased with the reduction in intake of FM (p<0.001), due to the high content of macro-minerals in FM (Table 10). The lowest dietary concentration of Ca (0.95%) on the FM0 treatment was higher than the reported recommendation of 0.60%, but the concentration of P (0.50%) was slightly lower than the recommendation for growing Pekin ducks (0.6% total phosphorus) reported by Scott and Dean (1991).

Daily gain and feed conversion ratio : Daily gains were similar for the FM14 and FM11 diets but then decreased (p<0.001) with each reduction in FM content (Table 12). This was probably due to the declining intakes of CP and ME. Moreover, ESW contains a high level of chitin, which would have affected nutrient and energy digestibility. Ngoan et al. (2000b) also reported that replacement of 50% and 100% of FM protein by ESW in diets for pigs reduced the daily gain by around 10% and 20%, respectively, while in the present experiment completely replacing the FM reduced daily gain by 27.6%. Optimum growth rates were found when ESW accounted for only 4.1% of the total DM intake, and 9.7% of the dietary protein. The DG of all dietary treatment groups was related to the CP intake, and is expressed by the regression equation:

$$Y = 1.53X+5.63, \qquad r^2 = 0.94,$$

where Y = DG (g), X = CP intake (g/d)

Table 10. Daily intakes (g/day) of macro minerals and amino acids of growing ducks fed diets with different levels of fish meal (FM) and ensiled shrimp waste supplied *ad libitum*, Expt. 2.

Item	Diet					SEM/P
	FM14 (Control)	FM11	FM8	FM4	FM0	
Calcium	1.52[a]	1.57[b]	1.46[c]	1.24[d]	1.02[e]	0.007/0.001
Phosphorus	0.87[a]	0.82[b]	0.74[c]	0.65[d]	0.54[e]	0.006/0.001
Leucine	1.41[a]	1.34[b]	1.25[c]	1.10[d]	0.94[e]	0.011/0.001
Lysine	1.02[a]	0.90[b]	0.79[c]	0.59[d]	0.40[e]	0.006/0.001
Methionine	0.57[a]	0.52[b]	0.47[c]	0.39[d]	0.30[e]	0.005/0.001
Threonine	1.01[a]	0.92[b]	0.83[c]	0.70[d]	0.56[e]	0.008/0.001
Valine	0.93[a]	0.87[b]	0.80[c]	0.69[d]	0.57[e]	0.008/0.001

[a, b, c, d, e] Means with different superscripts within rows are significantly different ($p<0.001$).

Table 11. Daily gains and feed utilization of growing ducks fed diets with different levels of fish meal (FM) and with ensiled shrimp waste supplied *ad libitum*, Expt. 2

Item	Diet					SEM/P
	FM14 (Control)	FM11	FM8	FM4	FM0	
Final weight (kg)	2.53 [a]	2.53 [a]	2.40 [b]	2.26 [c]	2.08 [d]	0.02/0.001
Daily gain (g)	34.4[a]	34.5[a]	31.8[b]	28.9[c]	24.9[d]	0.41/0.001
FCR (kg feed/kg gain)	3.70[a]	3.63[a]	3.83[a]	4.00[ab]	4.33[b]	0.08/0.002
CP/gain (g/kg)	556	533	536	518	513	10.2/0.08
ME/gain, MJ/kg	51.7 [a]	49.8 [a]	52.8 [a]	55.2[ab]	60.0 [b]	1.22/0.001
Feed cost/kg gain VND*	10,751	10,171	10,456	10,528	10,938	-

[a, b, c, d] Means with different superscripts within rows are significantly different ($p<0.01$).

* 1 USD = 15,000 VND.

Table 12. Carcass parameters of growing ducks fed diets with different levels of fish meal (FM) and with ensiled shrimp waste supplied *ad libitum*, Expt. 2

Item	Diet					SEM/P
	FM14 (Control)	FM11	FM8	FM4	FM0	
Final weight (kg)	2.53[a]	2.56[a]	2.52[a]	2.32[b]	2.04[c]	0.02/0.001
Carcass weight (CW) (kg)	1.77[a]	1.75[a]	1.69[a]	1.59[a]	1.38[b]	0.04/0.001
Carcass %	70.0	68.3	67.2	68.6	67.0	1.32/0.54
Breast muscle (g)	306[a]	309[a]	295[ab]	234[bc]	193[c]	14.4/0.001
Breast muscle (% of CW)	17.3	17.6	17.5	14.8	14.1	0.99/0.08
Thigh muscle (g)	221	227	204	212	183	10.1/0.07
Thigh muscle (% of CW)	12.4	13.0	12.1	13.3	13.3	0.67/0.60
Abdominal fat (g)	21.7	22.0	19.8	20.8	11.8	3.85/0.37
Gizzard (g)	61.3[a]	71.7[ab]	74.5[ab]	76.8[ab]	79.7[b]	3.77/0.049
Gizzard (% of CW)	3.46[a]	4.10[ab]	4.39[b]	4.84[b]	5.82[c]	0.17/0.001
Liver (g)	60.5	58.7	59.1	56.3	58.0	3.40/0.93
Small intestine (cm)	196	199	194	202	194	6.02/0.84
Large intestine (cm)	12.3	12.6	13.7	13.6	14.0	0.82/0.56
Cecum (cm)	17.2	17.0	17.5	17.6	17.6	1.13/0.99

[a, b, c] Means with different superscripts within rows are significantly different ($p<0.001$).

Feed conversion ratio (FCR) was poorer for the FM0 diet ($p<0.01$), which is in disagreement with Ngoan et al. (2000b), who indicated there was no significant difference in FCR when 50 or 100% of FM protein was replaced by ESW in diets for pigs. Although there were differences in CP consumption per kg gain among the treatments, they were not significant ($p>0.05$).

Carcass evaluation : Carcass weight was significantly lower on the FM0 diet ($p<0.001$) (Table 11). Breast muscle weight was higher for the control, FM11 and FM8 diets compared to the FM4 and FM0 diets ($p<0.001$), although the differences were mainly a result of differences in carcass weight. No significant differences were found for the weight of thigh muscle, liver and abdominal fat, and length of large and small intestines and cecum. However, gizzard weight increased with increasing intakes of ESW, probably as a result of higher intakes of chitin.

Health status and economic analysis : Overall mortality was very low, at only 1.3% (2/150). Feed cost per kg weight gain was least on the FM11 diet and highest for the FM0 and control diets (Table 10).

CONCLUSIONS

It can be concluded from the results of the present study, that soya waste can replace around 60% of the soybean meal in diets for growing ducks without reducing performance. However, complete replacement of soybean meal by soya waste gave the lowest feed cost.

Replacing around 20% of the fish meal in the diet by ensiled shrimp waste did not affect growth performance and resulted in the lowest feed costs. As artisan producers of soya waste and shrimp waste in the Mekong Delta often rear ducks, using these by-products in their diets increases the sustainability and profitability of the system.

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