Use of Duckweed as a Protein Supplement for Growing Ducks

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ABSTRACT : An experiment was conducted at the experimental duck farm of Cantho University to determine the effects of feeding duckweed *(Lemna minor)* that completely replaced commercial protein supplements in diets for crossbred meat ducks. The experiment included five treatments, with four replicates and ten crossbred ducks per replicate (pen). The five diets were based on broken rice offered *ad libitum*, supplemented with either 27 (control, SB100), 19 (SB70), 15 (SB55), 12 (SB40) or zero (SB0) g/day of ground, roasted soya beans, with fresh duckweed supplied *ad libitum*, except for the control (SB0) treatment. A vitamin / mineral premix and salt were included in the control (SB100) diet, but not in the diets with duckweed. These diets were fed to growing crossbred meat ducks (Czechoslovak Cherry Valley hybrids) from 28 to 63 days of age, when two birds (one male and one female) per pen were slaughtered for carcass evaluation. Total daily intakes were 95, 108, 108, 105 and 107 g of dry matter (DM) ($p<0.001$) and daily live weight gains 26.1, 29.1, 28.3, 27.1 and 27.6 g ($p<0.001$) for the SB100, SB70, SB55, SB40 and SB0 diets, respectively. Corresponding feed conversion ratios (FCR, dry matter basis) were 3.63, 3.71, 3.82, 3.89 and 3.88 kg feed/kg gain, respectively. There were no significant differences in carcass yields, chest and thigh muscle weights, and internal organ weights between the ducks fed the control diet and those fed duckweed diets. Fresh duckweed can completely replace roasted soya beans and a vitamin-mineral premix in broken rice based diets for growing crossbred ducks without reduction in growth performance or carcass traits. If the duckweed is grown on farm, and managed and harvested by household labour, the saving over purchased protein supplements is up to 48%. ***(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 12 : 1741-1746)***

Key Words : Crossbred Meat Ducks, Duckweed, Intake, Feed Conversion Ratio, Daily Gains, Carcass Quality

INTRODUCTION

The duck industry in Vietnam has developed over a long period of time, and today plays an important role in providing meat and eggs in the diets of the people (Men and Su, 1991). Table ducks are raised throughout the country, but are concentrated in the Mekong and Red River Deltas, and also in suburban areas of the large cities. There are several breeds, including local and exotic ducks and their crosses, raised and finished off from 2 to 3 months of age. Local farmers have considerable experience of traditional integrated duck systems, of which the rice-duck system is very common. However, the system has recently been experiencing problems due to the spread of fast-maturing, high yielding rice varieties, which limits the time available for duck flocks to scavenge. The ducks are fed various local feeds such as water plants, kitchen waste and whole rice or rice by-products, and obtain the rest of their feed by scavenging or as commercial feeds in confinement systems (Men, 1996). Recently the price of feeds, particularly protein supplements, has increased considerably, which pushes the cost of inputs higher if the raisers feed their ducks commercial rations.

Duckweed (*Lemna minor*), which is common throughout the country, is a tiny water plant that grows very well on stagnant pond surfaces all the year round. It can tolerate high nutrient stress and is able to survive extremely adverse conditions (Leng et al., 1995), and appears to be more resistant to pests and diseases than other aquatic plants in the tropics. Under ideal conditions Duckweed grows faster than almost any other higher plant and can yield 80 tonnes/ha/year of dry matter (Journey et al., 1991). It has a high content of nutrients, especially protein and carotene, which are necessary for growing animals. Duckweed protein has a better array of essential amino acids than most vegetable proteins and closely resembles animal protein (Hillman and Culley, 1978). Duckweed has been traditionally used in Vietnam to feed fish and poultry, so as part of an overall development strategy promoting integrated farming systems it can be a useful candidate to be developed as a feed resource for ducks so as improve production all the year round (Men, 1996).

The objectives of the experiment were to determine the optimum level of duckweed as replacement of a protein supplement in diets for growing crossbred ducks, and to evaluate the effects of duckweed on growth and economic performance.

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MATERIALS AND METHODS

Experimental design and birds

The experiment was carried out at the experimental duck farm of Cantho University in the Mekong Delta between March and May, in the late dry and early rainy season. A total of two hundred four-week old crossbred ducklings (female Pekins imported in the 1970s × male Cherry Valley, imported from Czechoslovakia) with initial average live weights of between 830 and 860 g were used. The one-day old ducklings were selected from scavenging breeding flocks hatched at a traditional duck hatchery in Cantho province, then brooded and fed a conventional diet *ad libitum* from 1 to 28 days of age at the experimental farm. The birds were identified and then individually weighed initially, weekly and at slaughter. They were allocated at random to five treatments with four replicates of ten birds, balanced for sex within replicate.

Housing and management

The ducks were housed in a shed divided into pens. The pens were made from bamboo, with thatched roofs and concrete floors coverd with rice straw for bedding, with an average density of three ducks per m^2. The ducks also had access to outside concrete yards, with an area of 1 m^2 per duck. The temperature in the house averaged 25°C in the morning, 32°C (maximum 37°C) at noon and 21-27°C at night. The yards were scaffolded by palm leaves to provide shade in the middle of the day, and were cleaned daily in the morning by a stream of fresh water. Dry rice straw was used as litter, and new litter added when the old litter become wet and dirty. Natural light was used in the day time and artificial light from electric bulbs at night, with an intensity of 5 W/m^2.

Feeders used for the experiment were round plastic basins 40 cm in diameter and 10 cm deep. Drinkers were 15 cm deep rectangular 30×60 cm pottery basins. They were filled intermittently with water to meet both the drinking and bathing requirements of the ducks. Both drinkers and feeders were cleaned daily in the morning.

Diets and feeding

The ducks in the experiment were fed a commercial starter diet *ad libitum* in the brooding stage from 1-28 days that contained 12.2 MJ ME/kg and 19.5% crude protein. They were housed and fed in groups of 10 from 28 to 63 days old and given diets based on broken rice *ad libitum* as the major energy source. Total protein offered was based on the recommendations of Yeong (1992) and Shen (1988) for growing and finishing ducks, and on intake levels in pilot trials to determine actual protein requirements of the experimental ducks on the control diet. Based on the protein intakes from broken rice, the ducks were supplemented with roasted soya beans in amounts calculated to balance the protein in the diets. A premix containing trace minerals and vitamins was mixed with the roasted soya beans in the control diet only. Daily allowances of roasted soya beans in the experimental treatments were reduced from 30 g (SB100) to 21 (SB70), 16 (SB55), 12 (SB40) and 0 g (SB0). The ingredient and chemical composition of the diets are shown in tables 1 and 2, respectively. The roasted soya beans were mixed with a vitamin-mineral premix and salt for the control diet and offered twice a day, between 8:00 and 8:30 h in the morning and between 14:00 and 16:30 h in the afternoon. The ducks in all treatments were offered broken rice *ad libitum*, and refusals remaining in the basins were collected daily in the morning and weighed to calculate intake levels.

The broken rice used for the experiment was from single batch stored for use throughout the experiment and was offered two times per day based on estimated intakes of the ducks to keep constant levels of broken rice in the feeders. The soya beans used in the trial were whole grains that were roasted for around 10 minutes over a hot metal stove, stored and ground once weekly for use throughout the experiment.

Duckweed

The duckweed offered to the ducks was grown on ponds enriched with nutrients from waste waters of the experimental pig farm of Cantho University, and was collected twice daily in the morning and afternoon. After collecting it was cleaned by strong water jets and put in a large bamboo basket for one hour to drain the excess water. Fresh duckweed was offered *ad libitum* three times per day in the morning, afternoon and evening. The amounts given on each occasion depended on the intakes on the previous two occasions, to minimize spillage. The residues were gathered and weighed the following morning to calculate the actual intakes. The composition of the duckweed offered and refusals was the same, indicating that there was no selection of parts of the plant.

Table 1. Ingredient composition of the experimental diets

Treatment	Feed ingredient			
	Broken rice	Roasted soya beans		Duckweed
		g/day	%	
SB100 (control)	*Ad libitum*	30*	100	
SB70	*Ad libitum*	21	70**	*Ad libitum*
SB55	*Ad libitum*	16	55**	*Ad libitum*
SB40	*Ad libitum*	12	40**	*Ad libitum*
SB0	*Ad libitum*	0	0	*Ad libitum*

* Including 0.25% of a vitamin/mineral premix that contained: Vitamin A, 400,000 IU per 100 g; Vitamin D_3, 80,000 IU per 100 g; Vitamin E, 1.0%; Vitamin K, 0.1%; Vitamin B_1, 0.03%; Vitamin B_2, 0.2%; Vitamin B_{12}, 0.0006%; Calcium pantothenate, 0.5%; Folic acid, 0.04%; Nicotinic acid, 1.0%; Choline chloride, 10.0%; Fe, 1.28%; Zn, 1.6%; Mn, 2.56%; Cu, 0.32%; I, 0.032%; Co, 0.016%; Se, 0.0064%; methionine, 2.0%.

** Daily supply of roasted soya beans relative to the control diet.

Table 2. Chemical composition of the dietary ingredients used in experiment, % of DM

	Duckweed	Broken rice	Roasted soya beans
DM, %	4.7	86.8	87.0
CP (N*6.25)	38.6	9.5	44.0
Ether extract	9.8	1.4	21.1
NFE	23.9	85.9	19.5
Crude fibre	8.7	2.0	9.8
Ash	19.0	1.2	5.6
Ca	0.71	0.01	0.18
P, total	0.62	0.20	0.92
K	4.92	-	-
Na	0.14	-	-
Fe	0.27	-	-
Mg, mg/kg	1,723	-	-
Zn, mg/kg	75	-	-
Cu, mg/kg	20	-	-
Carotene, mg/kg	1,025	-	-
ME, MJ/kg (caculated)	9.8	14.9	16.1
Lysine	2.4	-	2.4*
Leucine	3.0	-	3.1*
Threonine	1.5	-	1.7*
Methionine	1.2	-	1.4**

* Perez, 1997; ** Methionine + cystine.

Measurements

All ducks were weighed individually, at the beginning, weekly and at the end of the experiment. Daily feed intakes were calculated according to the feed consumption of the group in each pen. At the end of the experiment eight representative ducks per treatment were slaughtered for carcass evaluation, and carcass traits and internal organ weights were recorded.

Chemical analyses

The samples of broken rice, roasted soya beans, and duckweed were analysed for dry matter (DM), crude protein (N × 6.25), crude fibre, ether extract, nitrogen free extract, ash, calcium, phosphorus and carotene by standard AOAC methods (AOAC, 1990) at the laboratories of Cantho University.

Statistical analyses

The data were analysed by analysis of variance using the ANOVA General Linear Model procedure of MINITAB version 12 program statistical software (1998).

Economic analyses

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

RESULTS AND DISCUSSION

Chemical composition of feedstuffs and diets

The fresh duckweed used in the experiment had an average DM content of only 4.7%. The nutrient concentrations (DM basis) are shown in table 2. The crude protein (CP) content (38.6% of DM) was higher than that found in an earlier study carried out at our station (26.3%) (Becerra, 1994), due to the fact that the duckweed in our trial was grown on ponds enriched with digester effluent. Concentrations of lysine, methionine and threonine were similar to those reported by Perez (1997) for roasted whole soya beans. The fibre content of the duckweed used was lower than that reported by Becerra (8.7 vs. 11.0%, respectively), and its metabolizable energy (ME) concentration was much lower than broken rice and soybean meal (9.8, 14.9 and 16.1 MJ ME/kg of DM, respectively). Macro and micro mineral concentrations in the duckweed were higher than those of the broken rice and soybean meal used in the experiment and comparable to values reported by NIAH (1995). The carotene concentration in the fresh cultivated duckweed used was very high (1,025 mg / kg DM).

Feed intakes

The duckweed offered was consumed readily on all treatments from SB70 to SB0 (table 3), and total DM intakes of the ducks on the duckweed diets were significantly higher than for the control diet ($p<0.001$), which demonstrates the high palatability of duckweed. Intake of broken rice was depressed slightly on the diet which contained 70% of the control level of soya beans (SB70) and increased when no soya beans were given (SB0). The intake of duckweed increased as the soya beans were progressively restricted, reaching a maximum of 566 g/day, fresh weight on the SB0 treatment. These levels of intake are higher than those (434 to 450 g/day) recorded at our station by Becerra (1994) for ducks in a similar trial, but fed with reconstituted sugar cane juice instead of broken rice. This may be a reflection of the use in our experiment of duckweed with a lower fibre contents. Total protein intake was highest on the 70% soya bean level (SB70) and least on the control and SBM0 diets. There were no significant differences in total ME intake ($p>0.05$), which was consistent with the reports of Siregar et al. (1982a) and Dean (1986), who showed 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). In spite of the high levels of fibre (near double that

Table 3. Daily intakes of dietary ingredients by crossbred common ducks

Item	Treatment						
	SB100	SB70	SB55	SB40	SB0	SE	P value
Feed intake, g/day/duck							
Broken rice	82	78	83	82	92	1.3	0.001
Roasted soya beans	27	19	15	12	0	-	-
Fresh duckweed	0	496	499	505	566	7.60	0.001
Duckweed DM/kg BW*, g	-	17.1	17.3	17.8	20.1	-	-
Premix and salt	0.25	0	0	0	0	-	-
Total DM	95	108	108	105	107	1.35	0.001
Total CP	17.1	22.7	21.6	20.6	17.9	0.25	0.001
CP from duckweed	0	9.0	9.0	9.2	10.3	0.14	0.001
Lysine	0.62	0.97	0.93	0.89	0.80	0.01	0.001
Methionine	0.27	0.36	0.37	0.36	0.37	0.004	0.001
Crude fibre	3.7	7.3	7.1	6.9	6.6	0.09	0.001
ME, MJ	1.43	1.49	1.49	1.44	1.43	0.02	0.050
% CP from duckweed	0	40	42	45	58	-	-
CP, % of DM	18.1	21.0	20.0	19.6	16.7	-	-
CP/ME, g/MJ	12.0	15.3	14.4	14.3	12.5	-	-

* Mean bodyweight (BW) during experiment ((final BW + initial BW)/2).

of the control diet) and low energy content of the duckweed diets, the ducks were able to increase their consumption of duckweed to meet their energy requirements.

Daily live weight gains

The rates of live weight gain were significantly higher on the SB70 and SB55 diets than on the control diet ($p<0.001$) (table 4). Calculated intakes of lysine and methionine of the ducks on the control diet were significantly lower than for the duckweed diets ($p<0.001$), so even the diet with complete replacement of the soya beans (SB0) supported slightly better growth than the control diet. The ratios of crude protein (g)/ME (MJ) in the control and SB70 to SB0 diets were within a range of 12.0 to 15.2, which are equal or higher than those of investigations that have indicated optimum ratios within a range of 11.5 to 13.9 g protein/MJ ME for meat ducks after 3 weeks of age (Dean, 1986). However, the total crude protein intakes of the ducks on the SB100 (control) and SB0 diets were significantly lower than those of the SB70 and SB55 diets ($p<0.001$), while the ME intakes were constant, and thus the proportions of CP in the dietary intakes of the SB100 (18.1% of DM) and SB0 treatments (16.7% of DM) were below requirements for growing meat ducks (19-20%, Scott and Dean, 1991). This, and the low intakes of lysine and methionine, are the probable explanations for the significantly lower daily gains on these treatments compared to the SB70 and SB55 diets.

The ducks on the SB0 diet,showed a remarkable ability to consume enough of the bulky fresh duckweed to meet their nutrient requirements for growth without any other protein supplement. These results are contrary to the findings of Becerra (1994), who concluded that duckweed can only replace up to 20% of the conventional protein in diets of fattening ducks. The important difference in our experiment was the improved duckweed quality (higher CP and lower fibre compared to Becerra's trials), as a result of the ponds being enriched by fertilizing with biodigester effluent and home wastewater.

Feed conversion ratios were slightly higher on the diets containing duckweed ($p=0.05$). The ducks given the duckweed diets consumed high amounts of fibre and ash,

Table 4. Daily weight gains and feed conversion ratios of crossbred common ducks fed duckweed as replacement for roasted soya beans in basal diets of broken rice

Item	SB100	SB70	SB55	SB40	SB0	SE	P value
Live weight, g							
Initial	859	851	830	859	842	11.90	0.37
Final	1,771	1,869	1,882	1,807	1,806	22.60	0.05
Daily weight gain, g	26.1	29.1	28.3	27.1	27.6	0.57	0.003
Feed conversion, kg DM/kg gain	3.63	3.71	3.82	3.89	3.88	0.07	0.05
ME/gain, MJ/kg	55.0	51.1	52.6	53.3	52.1	0.91	0.087
CP/gain, g/kg	654.7	779.0	761.8	760.7	650.0	12.15	0.001

Table 5. Mean values for carcass traits of crossbred ducks given duckweed as replacement for roasted soya beans in diets based on broken rice

Item	SB100	SB70	SB55	SB40	SB0	SE	P value
Live weight, g	1,870	1,865	1,851	1,819	1,821	28.10	0.58
Carcass weight, g	1,253	1,219	1,211	1,175	1,198	25.80	0.31
Carcass yield, %	73.5	72.5	72.6	72.2	72.8	0.79	0.83
Chest muscle, g	203	166	183	164	175	0.79	0.07
Thigh muscle, g	162	156	141	156	153	6.85	0.25
Heart, g	14	12	14	12	14	1.01	0.49
Liver, g	61	61	56	59	61	2.84	0.71
Gizzard, g	55	52	52	57	56	2.26	0.51
Small intestine, cm	188	186	186	190	191	4.49	0.36
Large intestine, cm	12	13	13	12	13	0.58	0.36
Cecum, cm	34	36	34	36	34	1.16	0.46

Table 6. Estimates of feed costs assuming situations of purchase or farm-based production of duckweed (VND: 11,010 VND=1 US$)

Feed cost/kg gain	Treatment				
	SB100	SB70	SB55	SB40	SB0
Duckweed purchased*	11,589	11,760	11,669	11,564	10,101
Duckweed grown by farmer**	11,589	8,351	8,141	7,838	6,000

* Based on prices per kg for roasted soya beans 5,400, broken rice 1,800, fresh duckweed 200, premix 36,000 and salt1,000.

** Assumes no cost of duckweed as the opportunity cost of family household labour (women and children) is usually zero.

and according to Janssen and Carre (1985) the plant cell wall may act as a barrier to the attack of intracellular compounds by enzymes of the gastro-intestinal tract. The higher the fibre content, the stronger the barrier effect. Studies have shown that ducklings have little or no ability to digest fibre (Siregar et al., 1982b), but Schubert et al. (1982) reported that adult ducks were able to digest fibre more efficiently than chickens. The reports of Siregar et al. (1982a), Dean (1986) and Yeong (1986) showed that feed conversion ratios decreased with an increase in dietary energy concentration. In the experiment reported here energy concentration differences between the control diet and the duckweed diets were considerable (13.16 MJ ME/kg or 15.0 MJ ME/kg DM for the control diet, and only 2.18 MJ ME/kg for the SB0 diet as fed, or 13.4 MJ ME/kg DM). So, as expected the FCRs on a DM basis of the ducks on the control diet were lower than those given the duckweed diets.

Carcass evaluation

At a finishing age of 63 days, four female and four male ducks were selected at random from each treatment and slaughtered for carcass analysis. Table 5 shows that there were no significant differences for carcass yields ($p>0.05$). The weights of the chest and thigh muscles tended to be higher on the control diet, but were not significantly different from the other treatments ($p=0.07$ and $p=0.25$, respectively). The weights of the internal organs, such as heart, liver and gizzard, and lengths of the small intestines and ceca were not significantly different between ducks fed the control diet and those fed duckweed diets.

The skin and body fat of the ducks fed duckweed had an orange-yellow colour due to the high carotene content in the cultivated duckweed (1,025 mg/kg of DM). The carotene was digested and stored in the body without any negative effects for the duck, and the carcasses were attractive for consumers and more easily sold in the market.

Economic analysis

The results of the economic analysis are given in table 6, which shows that the lowest feed costs per kg live weight gain were for the SB0 diet, in which the protein supplement was completely replaced by duckweed. There would thus appear to be marked economic benefits to the farmer from using duckweed to replace soya beans in broken rice based diets for fattening ducks, particularly in situations where the duckweed is grown on the farm, and managed and harvested by household labour. This emphasizes the importance of an integrated farming system as a means of reducing costs and improving the economic competitiveness of the small scale farmer.

IMPLICATIONS

From the results of the experiment it can be seen that fresh duckweed can completely replace roasted soya beans and a vitamin-mineral premix in broken rice based diets for growing crossbred ducks without reduction in growth performance or carcass traits. The poorer feed conversion on the diets containing duckweed has no economic significance, since duckweed can be grown easily on the farm, whereas soya beans usually have to be purchased. Complete replacement of the protein supplement by fresh duckweed in the diets of the crossbed growing ducks decreased the feed costs by 13% compared to the control diet, even in a situation where the duckweed was purchased. If the duckweed is grown on farm, and managed and harvested by household labour, the savings over purchased protein supplements would be even greater, up to 48%.

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