EFFECT OF TARO (*Colocasia esculenta*) FOLIAGE ON THE PERFORMANCE OF GROWING COMMON DUCKS

by

Nguyen Tuyet Giang

Institutionen för husdjurens utfodring och vård
SLU
Swedish University of Agricultural Sciences
Department of Animal Nutrition and Management

Msc. Thesis
Uppsala 2010
ISBN 978-91-86197-92-6

EFFECT OF TARO (*Colocasia esculenta*) FOLIAGE ON THE PERFORMANCE OF GROWING COMMON DUCKS

by

Nguyen Tuyet Giang



Institutionen för husdjurens utfodring och vård	**Msc. Thesis**
SLU	
Swedish University of Agricultural Sciences	**Uppsala 2010**
Department of Animal Nutrition and Management	**ISBN 978-91-86197-92-6**

Delication

To my father (Nguyen Thanh Liem), my mother (Nguyen Thi Bach Tuyet), my father-in-law (Le Van Hau), my mother-in-law (Huynh A Muoi), my husband (Le Hai Nam) and my son (Le Thien Ha)

Effect on the performance of common ducks of supplementing rice bran with taro (*Colocasia esculenta*) foliage

Nguyen Tuyet Giang

Department of Animal Husbandry and Veterinary Medicine,
Angiang University, Vietnam
ntgiang@agu.edu.vn

Abstract

Two on-farm experiments were carried out in An Giang Province, Vietnam, to investigate the effect of diets of rice bran with taro (*Colocasia esculenta*) foliage on the growth performance of common ducks.

The first experiment was on chopped fresh taro leaves supplemented to a basal diet, which included rice bran, broken rice and soybean meal, to determine the intake level, the growth performance and carcass traits of crossbred common ducks. In total 168 ducks (crosses of an exotic and indigenous breed) were used in a completely randomized design (CRD) with 7 dietary treatments and 3 replicates. The ducks were offered chopped fresh taro leaves *ad libitum*, supplemented with five levels (3, 4, 5, 6 and 7% of live weight [LW] as dry matter [DM]) of a basal diet with a premix added. There were two other treatments, the basal diet without premix fed at 3% of LW, with free-access to taro leaves, and the basal diet with premix, fed at the equivalent of 7% of LW, with no taro leaves provided. Each experimental unit included 8 ducks, balanced for sex. The total DM intake was highest on the treatment in which the ducks were fed 7% of LW of the basal diet supplemented by fresh taro leaves *ad libitum* (110g/day), and lowest in the treatment with 3% of LW of the basal diet and taro leaves *ad libitum* (84.4g/day). The average daily gain (ADG) among treatments was significantly different ($P<0.05$), and was poorest in the treatment 3% of basal diet-taro leaves *ad libitum*. There was no effect on ADG and feed conversion ratio (FCR) of including a mineral-vitamin premix when Taro leaves were also fed.

The second experiment was conducted to evaluate the effect of taro silage (made from leaves and stem of *Colocasia esculenta*) and rice bran on the growth performance of common ducks. In total 80 common ducks were used, with ten treatments, two replicates and four ducks (balanced for sex) per replicate. The dietary treatments were arranged as a 5*2 completely random factorial design, with ingredient ratio (5) and feeding system (2) as factors. The basal diet was high protein rice bran supplemented by five levels of taro silage (20, 30, 40, 50, and 60%), fed to the ducks in mixed or separate form. The calcium oxalate content was reduced 2.45 times in the silage product compared to the concentration in fresh taro leaf (0.31 vs 0.76% DM basis, respectively). Ducks gained better when they were fed rice bran and taro silage in the “mixed system”, and the ADG was significantly different from that in the “separate system” ($P<0.05$). The ADG was the same over a range of ratios of rice bran and taro silage, from 80:20 to 40:60, and was 8% higher when the feeds were given as a mixture rather than separately. Calcium oxalate in taro leaf-stem silage was lower than in fresh taro leaves. There was a positive effect on carcass quality (lower abdominal fat) from supplementing rice bran with taro silage.

For smallholder farmers in the Mekong delta there can be significant economic benefits from fattening common ducks using resources (rice bran and taro foliage) that are widely available in the region and of lower cost than commercial feeds.

Key words*: Mekong delta, fresh taro leaves, silage, intake, average daily gain, abdominal fat, economic benefit*

Table of contents

Abbreviations

DM	Dry matter
CP	Crude protein
EE	Ether extract
ADF	Acid detergent fiber
NDF	Neutral detergent fiber
ADG	Average daily gain
FCR	Feed conversion ratio
DMI	Daily feed intake
LW	Live weight
TL	Taro leaves
RB	Rice bran
TS	Taro silage
VND	Vietnamese Dong

1. Introduction

Poultry production is a common activity in Southeast Asia, and is a major source of livelihood for over a million people in the rural areas. In the last two decades, Asian duck production has become more important, making up 87% of the world's duck population, and duck meat and egg production has increased more than four times (Chein Tai and Jui-Jane Liu Tai, 2001). This expansion has mainly come from the preservation of local breeds and strains, such as the local Muscovy duck and several Vietnamese breeds such as the Co and Tau duck (Duong Thanh Liem 2001), and imports of exotic and improved breeds. Improved ducks have become widely accepted and have increased in number, and are generally called "common ducks".

Duck production is one component of several integrated farming systems which are regarded as being part of a sustainable development in agriculture. Ducks *(Anas platyrhynchos)* can be integrated with rice, orchards, cash crops, livestock, and fish. Thus, the stakeholders not only can develop their livelihoods without accumulating debts, but also can get extra income through off-farm and non-farm activities (Le Thanh Phong et al 2007). The Mekong Delta, located in the South of Vietnam, is considered as the country's granary, accounting for 48% of the national rice production (followed by the Red River Delta). Besides, the Mekong Delta has a warm ambient temperature and high annual rainfall that is suitable for duck production. Natural resources, including paddy rice fields, canal networks, and plants and grasses, for instance, are advantageous for ducks to increase in number. Ducks can effectively utilize low quality feed (agricultural residues, by-products and insects) and can produce highly nutritious foods for humans (Bui Xuan Men et al 1998). Duck production is diversified into several rearing systems according to economic criteria: for example, industrial integrated, medium to large commercial, medium to small commercial and mixed farming systems (integration of rice-ducks, ducks-fish or rice-fish-ducks) or spatial criteria, such as scavenging, semi-confined and confined systems (Edan et al 2006). The large scale system has developed only recently in some areas of the delta. It is generally agreed that better breeds, together with improvements in management of stock health and using local feed resources, as well as other appropriate technologies should enhance sustainable small-scale duck production.

However, the free-raising of ducks in the rice fields or canals (scavenging system) without strict management of outbreaks of diseases is a risk for community health and also duck production. In order to deal with this important issue and create a sustainable duck production, semi-confined and confined systems are being introduced and widely extended, with the aim of limiting the spread of infectious diseases such as Duck Plague and Avian Influenza.

An Giang Province, situated in the Mekong Delta, is a well- known area for rice production, with 3,519,343 tonnes produced in 2008 (An Giang Statistical Yearbook 2009). The most common duck production system in this area is free grazing in the rice fields, utilizing the leftover rice grains, weeds, insects and snails as part of an integrated pest management system (Teo 2001). According to the An Giang Statistical Yearbook (2009), in 2008, there were 4,296,840 poultry, of which 3,437,129 were ducks, raised in An Giang Province.

Annually, rice mills produce large quantities of grain for export, as well as the by-products (rice husk, rice bran and broken rice). The broken rice is not as valuable as rice grain but it can be exported or used locally for human consumption. Rice bran is the outer layer of the brown rice kernel (after separating the husk) which is removed while milling brown rice to white. Rice bran is a rich source of nutrients and a pharmacologically active compound and is currently used as livestock feed and for oil production (Tahira et al 2007). According to Houston (1972), rice bran accounts for 5-8 percent of paddy rice (whole grain). Commonly, in Vietnam, the rice mills have produced three kinds of rice bran: the initial bran (mixed with rice husk fragments) and two types of bran produced in the polishing process which are very fine and have higher nutritive value than the initial bran. In the Mekong Delta, rice bran is cheaper than rice grain and broken kernel, so it is the most widely available feed resource for duck production.

Taro can be commonly found growing wild in the Mekong Delta, particularly on the banks of ponds and along rivers and canals. Traditionally, some taro species (*Colocasia antiquorum* and *Colocasia gigantea*), which have a large corm or palatable stem, can be used for home consumption, while *Xanthosoma sp.*, *Alocasia sp.*, *Alocasia cucullata* and *Alocasia macrorrhiza* (giant taro/giant elephant ear) can be used both as human food and animal feed. Wild taro (*Colocasia esculenta*) originates from India and Southeastern Asia. It is a perennial herb 1.5 m tall, with thick stems, very small corms, and with leaf blades around 60 in length and 50 cm in width. Wild taro is very easy to grow, develops fastest in wet land and is highly resistant to pests and diseases. The wild taro leaf has a high nutritional value, with 22.5-26.3% crude protein in the dry matter (DM) (Malavanh Chittavong et al 2008a and Chhay Ty et al 2007). However, in common with other species of the Aracae family, an anti-nutritional substance, calcium oxalate, is found in all parts of the plant, causing irritation in the throat and mouth epithelium and indirectly affecting the feed intake. The influence of calcium oxalate can be reduced by ensiling with molasses (Malavanh Chittavong et al 2008b), or by the addition of the stems without any further additive (Du Thanh Hang and Preston 2010; Nguyen Tuyet Giang 2008).

2. Objective

To investigate the opportunities to use taro leaves as an alternative to soybean meal as a protein source for growing ducks fed a basal diet of rice bran

3. General discussion

3.1 Duck production in Vietnam

Vietnam is a country situated in Southeast Asia with a population of 85.79 millions and an area of 331,114 km^2. Vietnam has a paddy rice culture and approximately 70% of the population lives in the countryside, and 90% of households raise poultry. According to Doan Xuan Truc (2001), Vietnam ranks 5th in ASEAN and 47th in the world in poultry meat and egg production. Traditionally, poultry are kept in small scale systems in the back yard and close to farmers' houses. Hall et al (2006) showed that small-scale farmers in Vietnam keep poultry for cash income and food, and raising poultry provides only a small proportion of total household economic activities (5-10%) compared to more intensive enterprises (20-85%). According to an FAO (2004) classification, poultry production (including ducks) diversifies into sectors depending on the management and marketing system: industrial integrated system (integrated farms with various components are managed under high biosecure procedures); the industrial sector (commercial poultry production system with moderate to high biosecurity and birds/products usually marketed commercially; birds are kept indoors, completely inhibited from contact with other animals); semi-commercial sector (low to minimal biosecure level in which birds are housed in cages; open sheds allowing some time outside the shed) and the sector of village or backyard production, which is under or without biosecurity, and birds and products are sold or consumed locally.

In Vietnam, there is also another standard using herd size to classify the poultry sector, which can be found in both rural and industrial sectors. There are around 400,000 small and medium scale farms with 50 to 5,000 head of poultry and at least 8 million households use small-scale systems with less than 50 poultry. Vietnam has many advantages with regard to duck production. Firstly, the natural resources with appropriate climate conditions, a large number of rivers, as well as canal networks, are suitable for developing duck production. The duck is a water fowl that can easily adapt to different environments, with or without water. Vietnamese farmers have a long experience of raising ducks; they utilize local feed sources that are cheap and available through out the year. Vietnam is ranked 4th in the world, after China, France and Thailand (Doan Xuan Truc 2001) in duck production. Products from duck production are meat, eggs and feathers. In addition, salted duck eggs have become a product that is exported to some Asian markets in recent years. Ducks are raised mostly for meat and egg purposes. Farmers like to keep ducks because of the low investment, utilizing local materials for housing; ducks are well resistant to common diseases and grow well on locally available feed resources. Ducks are easily raised with low nutritional feed inputs but they rapidly bring benefits, with a short life cycle, and high growth development and productivity. In addition, ducks can be seen widely in the rural and remote areas where farmers are stakeholders, although they are facing handicaps in accessing appropriate technologies, information, market and help services (Shan-Nan Lee 2009).

Among the Vietnamese agro-ecosystems, the Red River Delta, Mekong River Delta and North East regions have the highest proportion of poultry (Desvaux Stephanie et al. 2008). According to Bosma et al. (2005), since livestock require less and lower land quality than cultivated plants, farmers invest more in livestock activities, raising ducks or chickens, fish or pigs, buffaloes or cattle, for example. In fact though, raising ducks for eggs is a risky investment for the smallholder in the Mekong Delta. In contrast to chickens, ducks may lay eggs everywhere, and they also need to be fenced and restricted by nets in order to keep the birds safe at night. Also bedding of straw or rice husks should be prepared to protect the eggs from breaking. In intensive systems, the flock size varies from about 500 to 5,000 ducks. Landless farmers generally start with smaller flocks and expand slowly in order to minimize the investment and labour.

3.2 Rearing systems

3.2.1 Scavenging free range system

Vietnamese farmers have a long experience of keeping scavenging ducks in the backyard or garden. Complete scavenging systems or semi-scavenging are suitable for most local duck breeds (Nguyen Thi Kim Dong 2005). Most stakeholders apply this system because they can start with a small size flocks (5-50 ducks) in the backyard or garden. Although this system is distinguished by low feed offer, with or without housing, farmers can profit from the products they get (meat and eggs). If predators are a problem at night, the open areas or pens can be covered by inexpensive net or wire mesh (Dean and Sandhu 2006). Ducks can effectively be fed home wastes or cheap by-products (such as rice bran or broken rice) 2-3 times per day; they also have free access to other feed sources in rivers, pond or areas of the rice fields (Bui Xuan Men 1996).

3.2.2 Integrated systems

In the Mekong Delta, farmers use many traditional ways to raise ducks, of which the various integrated systems are the most common. Bui Xuan Men (1996) mentioned that scavenging is a very traditional system, which is not so profitable today. Ducks can be raised along with growing rice but do not harm the plants in the early stage of growth, before flowering. After the brooding stage (at more than 1 week of age), ducklings are let into the rice fields (20 days after transplanting until flowering). Ducklings can find and consume snails and insects in the rice field. While scavenging, ducklings can consume weeds, swim and stir the mud around the plant roots without harming the rice plants. Ducks' excreta also fertilize and stimulate rice growth. In this way, farmers can save money for pesticides, herbicides as well as chemical fertilizer. The second model is raising ducks in the post-harvest rice fields. Commonly, both laying and meat type ducks are reared. Above 3 weeks of age, ducklings can consume whole rice grains. After harvesting, ducks can scavenge in the rice field leftover or fallen rice grains, insects, shellfish, frogs, weeds, fish and water plants. Today, varieties of high yielding rice are preferred, and after the harvest it only takes a few days to start a new crop. In such circumstances, this system becomes less flexible. Ducks can also integrate with fish (Le Hong Man 2002) to get higher fish yields (an increase of 30–40% in comparison with fish without duck integration) due to the duck manure and waste feed. Duck houses are often built above or near the fish pond, where herbivorous and omnivorous fish can be reared, such as carp, roach and tilapia. Duck are kept in a house at night and allowed to range freely during daylight. They scavenge snails, crab, algae, plankton, fingerings and other available feeds in the pond. Generally, the number of ducks can ranges from 200–300/ha. After 2–3 years, both duck and fish yields start to decrease, since the ponds are full of sludge and become toxic to the fish. The sludge collected from the pond is a good source of organic fertilizer for the gardens and rice field. The third integrated model is also applied, and is referred to research carried out by Islam et al. (2004). They reported that thirty ducks and four fish species were introduced along with rice. Ducks were allowed to graze during the day and then were confined in houses built on the corner of the land. No supplement was supplied for the fish. The rice yield was lower than the culture with fish only. However, farmers could also benefit from the increase in the yield of fish and eggs from ducks.

3.2.3 Intensive duck production systems

According to Dean and Sandhu (2006), commercial duck production can be categorized into two types: absolute confinement and semi-confinement. The modern intensive total-confinement system is clearly differentiated by high duck density, high capital investment for housing, commercial feed and labour (Nguyen Thi Kim Dong 2005). Feed is supplied as well balanced rations; floors are designed to eliminate wetness, and water troughs are installed such that ducks can not spread water. The intensive system is mainly found in agro-industrial zones or in peri-urban areas. Exotic and improved duck breeds are commonly reared in this system, mostly for meat. Ducks grow fast and are killed at early stage with high productivity. In the semi-confinement system, housing is similar to the confinement system, except that ducklings after 2-3 weeks can be allowed outdoors during the day.

However keeping ducks is risky; diseases may kill all the birds in a flock within a few days. Due to disease outbreaks, it was a negative experience for some farmers that took out loans with high interest rates or sold land to refund and restart with ducks. It is also recognized that duck production in small flocks creates many challenges for outbreak control. Farmers keeping these small flocks and even some intensive farmers are unaware of biosecurity and only seek veterinary service if their poultry have severe health problems. The transportation of birds should be under the government control. It is a concern that the free-ranging system plays an important role in AI spread in Vietnam, especially in remote areas where there are interactions between ducks of different villages (Edan et al 2006).

3.3 Common ducks

According to Nguyen Thi Kim Dong (2005), common ducks are crossbreds of male Cherry Valley (imported to Vietnam since 1975) and female Pekin ducks. Other common ducks are crosses between male Super-Meat ducks (meat type ducks imported from the United Kingdom in 1989) and female crossbred ducks (between Cherry Valley and Pekin ducks). According to various studies carried out recently, common ducks reach normal slaughter weight at around 9-10 weeks of age. Common ducks can grow at a similar rate to the Muscovy although they consumed double the amount of duckweed than Muscovy ducks (Men et al 1996). Common ducks are preferred by farmers in the peri-urban and rural areas due to their ability to utilize low quality feed (by-products and natural forages), but the feed conversion ratio is poor (Nguyen Thi Kim Dong 2005; Bui Xuan Men et al 1995).

However, the pure breeds are facing a problem in that they are being lost. A sign of this is that people can not recognize the difference between breeds in the field. In the Mekong Delta, for example, ducks that are called “Tau” now look very close to the Khaki Campbell, since the indigenous pure breeds have become less common and have been crossed with other breeds (Desvaux Stephanie et al 2008).

3.4 Nutrient requirements of ducks

Ducks can grow well, whether by scavenging or consuming a complete ration. However, the feed offered should contain enough nutrients and the ration should be balanced with regards to the requirements for growth, maintenance and reproduction. Their needs can differ, depending on the stage (age) and the production purpose (Table 1).

3.5 Feeds for ducks

Ducks are easy to raise under various management conditions. They can grow faster and reach higher performance earlier in a commercial system (semi- or full-confinement), if supplied commercial feeds with a balanced formula for each development stage. These feeding systems are now widely applied, but rarely found in rural and remote areas where there is a lack of appropriate technologies and financial and advisory support. However, ducks are preferable to other poultry species because of their better adaptation to local feed resources, such as household waste, agro-industrial by-products and forages.

The Mekong Delta region is the “rice basket” of the country. Annually, rice mills produce large quantities of grain for export, as well as the by-products (rice husk, rice bran and broken rice). The broken rice is not as valuable as rice grain but it can be exported or used locally for human consumption. Rice bran is the outer layer of the brown rice kernel (after separating the husk) which is removed while milling brown rice to white. Rice bran, a rich source of nutrients and pharmacologically active compounds, is currently used as livestock feed, and is also used for oil production (Tahira et al 2007). According to Houston (1972), rice bran accounts for 5-8 percent of paddy rice (whole grain). Commonly, in Vietnam, the rice mills produce three kinds of rice bran: the initial bran (mixed with rice husk fragments) and two types of bran produced in the polishing process which are very fine and have higher nutritional value than the initial bran. In the Mekong Delta, rice bran is cheaper than rice grain and broken kernels, so it is the most widely available feed resource for duck production.

Table 1. Nutrient requirements of White Pekin Ducks, percentage or unit per kilogram of diet (90% DM basis)

Nutrient	Unit	0 to 2 Weeks	2 to 7 Weeks	Breeding
ME	kcal/kg diet	2,900	3,000	2,900
Protein and amino acids				
Protein	%	22	16	15
Arginine	%	1.1	1.0	
Isoleucine	%	0.63	0.46	0.38
Leucine	%	1.26	0.91	0.76
Lysine	%	0.90	0.65	0.60
Methionine	%	0.40	0.30	0.27
Methionine+Cystine	%	0.70	0.55	0.50
Trytophan	%	0.23	0.17	0.14
Valine	%	0.78	0.56	0.47
Marcro minerals				
Calcium	%	0.65	0.60	2.75
Chloride	%	0.12	0.12	0.12
Magnesium	Mg	500	500	500
Nonphytate phosphorus	%	0.40	0.30	
Sodium	%	0.15	0.15	0.15
Trace minerals				
Manganese	mg	50		
Selanium	mg	0.20		
Zinc	mg	60		
Fat soluble vitamins				
A	IU	2,500	2,500	4,000
D_3	IU	400	400	900
E	IU	10	10	10
K	mg	0.5	0.5	0.5
Water soluble vitamins				
Niacin	mg	55	55	55
Pantothenic acid	mg	11.0	11.0	11.0
Pyridoxine	mg	2.5	2.5	3.0
Riboflavin	mg	4.0	4.0	4.0

Source: National Academy of Sciences (1994)

The Mekong Delta is also well-known for fish and shrimp production (Le Viet Ly 1994), thus their by-products are available in large amount. Commonly, fish meal and soybean meal are widely used to supply protein. A good dietary balance amino acids is necessary for all monogastric livestock species. However, due to the increasing oil price and the competition with human demands, local feed resources are a good alternative in terms of convenience and maximum net profit. Recent studies have shown that expensive feedstuffs can be replaced by alternative cheap ingredients without reducing the feeding value. Nguyen Thi Kim Dong (2005) for example found that soybean meal can be replaced by soya waste at up to 60% and ensiled shrimp waste could replace fish meal (up to around 20%) without any effects on the growth performance of growing crossbred ducks, thus resulting in higher incomes for farmers. A study carried out on meat-type ducks under Vietnamese farming conditions also showed that meat and bone meal, as well as poultry by-product meal, can fully replace fish meal (Nguyen Quang Dat and Yu Y 2003).

Duckweed (*Lemna spp*.) is easily grown in lakes, ponds and lagoons and has a high content of organic matter and crude protein (86.0 and 40.2%, respectively). However, in an experiment carried out on growing ducks, Khanum et al (2005) found that because of the low dry matter content and low crude protein digestibility ducks had poor growth performance, and duckweed could only be included at around 50% in duck diets without negative influences on carcass quality. Farmers can produce duckweed in lagoons near their homesteads and/or may collect it from natural sources as feed to their ducks. This will help to reduce feed costs by about 50%. Nguyen Duc Anh and Preston (1997) asserted that duckweed can be fed as a non-conventional protein source to support duckling (5-20 days of age) growth performance. Duckweed can be used to totally replace soybean meal but the protein is utilized is less efficiently than the protein in soybean because of the lower digestibility. Nguyen Thi Hong Nhan et al (1997) reported that *Trichantera* leaf meal can be used in diets for laying ducks, hens and quails. In the case of fattening ducks, they were given free access to fresh leaves of *Trichantera* or water spinach (the basal diet included broken rice, soybean and fish meal). The intake was around 70-80 g DM/duck/day. The authors asserted that soybean or fish meal can be reduced by 10% if the ducks had free access to either *Trichantera* leaves or water spinach, with no negative influence on growth performance or carcass quality.

3.6 Taro (Colocasia esculenta) in the Mekong Delta

3.6.1 Nutrient composition

Taro, which belongs to the Aracea family, can be cultivated or collected from the wild in the Mekong Delta, particularly on the banks of ponds and along rivers or canals. Some taro species (*Colocasia antiquorum* and *Colocasia gigantea*), which have a large corm or palatable stem, can be used for human consumption, while *Xanthosoma sp., Alocasia sp. Alocasia cucullata* and *Alocasia macrorrhiza* (giant taro/giant elephant ear) can be used both as food and animal feed. Wild taro (*Colocasia esculenta*) originates from India and Southeastern Asia. It is a perennial herb 1.5 m tall, with thick stems, very small corms, and with leaf blades of around 60 in length and 50 cm in width. Wild taro is abundant, particularly in wet lands and is highly resistant to pest and diseases. The wild taro leaf has a high nutritive value, with 22.5-26.3% crude protein (Malavanh Chittavong et al 2008b; Chhay Ty et al 2007). However, in common with other species of the Aracae family, calcium oxalate (an anti-nutritional factor), is found in all parts of the plant, causing irritation in the throat and mouth epithelium and indirectly affecting the digestibility. Another constraint of taro is the high content of fibre (in taro leaves, crude fibre is around 17.1-18.3% of DM, Chhay Ty et al 2007 and Malavanh Chittavong et al 2008b).

3.6.2 Uses of taro as animal feed

Taro is used for feeding livestock not only in Vietnam but also in other tropical countries. A survey in Cambodia on taro varieties and their use reported that taro is a common plant grown or developing naturally near the houses, in the forests, ponds, streams and canals but farmers rarely fed taro to their pigs because of the itchiness (Pheng Buntha et al 2008b). Others researchers also evaluated the use of wild taro (*Colocasia esculenta*) in growing crossbred pigs (Chhay Ty et al 2007, Nguyen Tuyet Giang 2008 and Pheng Buntha et al 2008a) and Mong Cai gilts (Malavanh Chittavong et al 2008a).

3.6.3 Processing methods and their influence on the nutritional value of taro

A major constraint to livestock production is the lack of animal feed resources (Kayouli and Stephen 1999). Many by-products and forages are not available throughout the year and therefore need to be stored with appropriate processing methods.

Taro contains an anti-nutritional factor, namely calcium oxalate, which causes irritation on contact. This substance is present in all parts of the taro plant. Leslie and Patrick (1979) stated that the density of calcium oxalate crystals in corms increases rapidly in the early stage, then decreases in older and larger corms. Ravindran et al (1996) showed that calcium oxalate was a main factor contributing to anti-palatability and anti-nutritive effects. Corms can be cooked for human consumption, but Cambodian farmers rarely use taro petioles and leaves for animal feeding. In order to reduce the itchiness of taro caused by the calcium oxalate, most farmers boil taro before feeding it to their pigs or add sugar palm syrup after boiling, while others apply salt, frying or sun drying (Pheng Buntha et al 2008b).

Table 2. Nutritional composition of taro after various processing methods

Taro forms	DM, %	As % in DM				Sources
		OM	CP	CF	Calcium oxalate	
		85.3	26.3	17.1		Chhay Ty et al. 2007
Dried taro leaves	92.2	87.6	26.7	15.2		
Ensiled taro leaves	18.3	91.7	25.9		0.11	
Sun dried taro leaves					1.10	Pheng Buntha et al. 2008a
Fresh taro leaves					3.08	
Ensiled taro leaves	20.2	88.4	19.0	13.2	0.30	Malavanh Chittavong et al. 2008a
Fresh taro leaves	16.0	88.3	22.5	18.3		Malavanh Chittavong et al. 2008b
Taro silage (stems and leaves)	29.4	78.3	18.7			Nguyen Tuyet Giang 2008
Fresh leaves	13.7	89.5	25.3	11.4	760	
Sun dried leaves	88.4	86.7	25.6	11.3	600	
Soaked leaves	17.2	89.5	25.6	11.5	570	Du Thanh Hang and Preston 2010(*)
Cooked leaves	9.60	89.6	25.6	11.3	360	
Ensiled leaves	17.0	89.5	25.3	11.0	350	

(*) *Calcium oxalate was analyzed on samples dried at 65^0C for 24h, unit: mg/100g*

There are various ways to process taro in order to store it and reduce the density of calcium oxalate crystal content, such as cooking, sun-drying, soaking and ensiling (Table 2).

Ensiling is a process that has been applied to preserve carbohydrate rich materials, with or without additives (Machin 1999). The particular feature of ensiling is the fermentation of feed with organic acids produced by bacteria. Ensiled forages are a good feed source for animals, as monogastrics can digest all enzymically digestible components in the small intestine and fibrous materials are fermented quickly in the large intestine then easily absorbed as nutrients. This method is suitable and easy to apply for smallholders under tropical conditions because it is safe, takes less investment and results in significant incomes.

Taro leaves, or the mixture of petioles and leaves, are harvested and chopped into small pieces. The size of the fragments depends on what type of animal is reared. Then, the taro pieces are partially sun-dried to reduce the moisture content and packed tightly into plastic bags or containers. The bags should be sealed tightly to prevent contamination by air. Chhay Ty et al (2007) mixed taro with rice bran and salt (10 kg rice bran, 0.5 kg salt and 89.5 kg taro leaves), and the silage was stored in normal temperatures for 30 days before being used. The purpose of this procedure was to reduce the content of calcium oxalate. Other additives can be used to stimulate the fermentation of bacteria and improve the palatability, such as molasses (Du Thanh Hang and Preston 2010 and Malavanh Chittavong et al 2008a), and sugar palm syrup (Pheng Buntha et al 2008a).

Du Thanh Hang and Preston (2010) showed that neither ensiling nor different processing methods (sun-drying, soaking and cooking), affected the crude fibre content of taro leaves.

However, Malavanh Chittavong et al (2008a, b) reported that the fibre content in taro leaves was reduced by ensiling.

3.7 Effect of taro foliage on the growth performance of common ducks

3.7.1 Fresh taro leaves

The DM and CP intakes in the present study were significantly different among treatments in which ducks were offered by basal diet with five feeding levels (3, 4, 5, 6 and 7% of BW) and fresh taro leaves fed *ad libitum*. The increasing fresh taro leaves intake was to compensate for the reduced amount of basal diet. The result is consistent with the study carried out by Nguyen Thi Kim Dong (2005). The mineral as well as vitamin content of the fresh taro leaves can meet the demand of ducks, confirmed by the similar growth performance of confined common ducks (FCR and ADG) between diets, with and without a premix of vitamins and minerals.

In spite of ducks being able to consume high amounts of bulky and fibre-rich feeds, the growth rate is poorer than if they are given a low fibre and high-energy diet. The growth performance of ducks in the present study was lower than of ducks fed "A" molasses substituted for broken rice and rice bran at 15 or 30% in the diets (Bui Xuan Men and Vuong Van Su 1990). There was a relationship between the percentage of taro leaves intake in dry matter intake and the length of caecum as well as the weight of abdominal fat. The more taro leaves consumed, the less fat stored and the longer the caecum. The fibrous bulk in the digestive tract could be the reason for the increase in ceacum length.

3.7.2 Silage of taro foliage (leaves and stem)

The ensiling process applied in forages should lead to an increase in the concentration of metabolizable energy in the diets, and therefore to improved performance in terms of growth rate and feed conversion. In fact, there were no differences in growth performance in the present study, but there were major effects on the carcass, with linear decreases in carcass percentage and in abdominal fat as the level of taro silage in the diet was increased. These responses can be considered as positive in terms of carcass quality of the product and the opportunity to use a local available forage which grows wild in the Mekong delta.

It is apparent that the ensiled taro foliage (leaves plus stems) has a relatively high nutritive value. The observations in this experiment do not permit conclusions to be made as to the relative nutritional values of the leaf and stem in the ensiled product. Rodríguez and Preston (2009) concluded that ensiling the combined leaf and stem of New Cocoyam (*Xanthosoma sagittifolium*) was a simpler process than ensiling only the leaf. When leaves were ensiled alone a source of fermentable carbohydrate (sugar cane juice) had to be added. However, it was found that the stem contained appreciable amounts of soluble sugars, and thus there was no need for an additive when the leaves and stems were ensiled together. Dao Thi My Tien et al (2010, unpublished data) also observed that the stems of taro (*Colocasia esculenta*) contained high levels of soluble sugars (up to 40% in the DM) and that this facilitated the ensiling process of the combined taro leaves and stems.

4. Conclusions

- Vietnam is an agricultural country with huge annual rice production, so the by-product (rice bran) from mills is abundant. This is a cheap and available feed resource for duck production.

- Taro foliage can be supplemented to local feed resources for common ducks to bring economic benefits for smallholders in the Mekong Delta.

- Live weight gain was reduced from 30 to 20 g/day, and FCR was poorer when the basal diet of rice bran, broken rice and soybean meal was restricted to 3% of LW (as DM) with fresh Taro leaves *ad libitum*
- There was no effect on ADG and FCR of including a mineral-vitamin premix when Taro leaves were also fed

- Growth rates of ducks were:
    - The same over a range of ratios of rice bran and taro silage from 80:20 to 40:60
    - 8% higher when the feeds were given as a mixture rather than separately

- Calcium oxalate in taro leaf-stem silage was lower than in fresh taro leaves
- There was a positive effect on carcass quality (lower abdominal fat) from supplementing rice bran with taro silage.
- Smallholders farmers in the Mekong Delta can get significant economic benefits from fattening common ducks using the local feed resources (rice bran and taro foliage) that are very cheap compared with commercial feeds and widely available in the region and are safe for ducks.

5. Acknowledgements

The experiments presented in this thesis were carried out in a private farm in Long Xuyen City, An Giang Province, Vietnam, and were funded by the Swedish International Development Agency/Department of Research Cooperation with Developing Countries (Sida/SAREC).

I would like to express my gratitude to:

The Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management

Prof. Dr. Brian Ogle, International Co-ordinator of the SAREC “Sustainable Livestock Production Systems" project, my supervisor, for all your support, advice and explanations throughout the research, also for your reading and correcting my thesis papers.

Dr. Thomas Reg Preston, my teacher and adviser, for all your valuable guidance and support during the study.

I would also like to extend sincere thanks to Dr. Ngo Van Man, Co-ordinator of the SAREC-MEKARN project and the staff of Sida-SAREC regional office in NLU, especially Mr. Nguyen Van Cong, for needed help, best preparation for accommodation, transportation and study facilities. Associate professor Dr. Bui Xuan Men, staff of the Animal Husbandry Department, Cantho University, Cantho city, Vietnam, Professors, lecturers and assistant lecturers in MEKARN courses, for giving me care and useful knowledge.

Warm thanks are extended to my father, Mr. Nguyen Thanh Liem for his great help and support. My mother, Ms. Nguyen Thi Bach Tuyet, for her assistance and encouragement, my parents in law, my husband, Mr. Le Hai Nam and my son Le Thien Ha for their love.

I would like to warmly thank Pham Duc Tho, Nguyen Thi Ngoc Giang, my analysis assistants and my colleagues in the Department of Animal Husbandry and Veterinary, Faculty of Agriculture and Natural Resources, Angiang University. All of my friends in the MSc course 2008-2010 from the three countries: Vietnam, Laos and Cambodia, for sharing the culture, friendship and creating a warm atmosphere throughout the time of the course.

I would like to thank all the people who contributed to this study.

7.References

Bosman Roel H, Cao Quoc Nam, Udo Henk M J, Verreth Johan A J and Visser Leontine E 2005: Agriculture Diversification in the Mekong Delta: Farmers' Motives and Contributions to Livelihoods,

Bui Duc Lung and Le Hong Man 1999: *Feeds and feeding poultry*. Agricultural Publishing House, Hanoi, Vietnam. Pp. 211.

Bui Xuan Men 1996: The Role of Scavenging Ducks, Duckweed and Fish in Integrated Farming Systems in Vietnam, from http://www.fao.org/ag/AGAinfo//////resources/documents/frg/conf96pdf/men.pdf

Bui Xuan Men and Vuong Van Su 1990: A molasses in diets for growing ducks. http://www.lrrd.org/lrrd2/3/vietnam2.htm

Bui Xuan Men, B Ogle and T R Preston 1996: Duckweed (*Lemna spp*) as replacement for roasted soya beans in diets of broken rice for fattening ducks on a small scale farm in the mekong delta, from http://www.lrrd.org/lrrd8/3/men831.htm

Bui Xuan Men, B Ogle and T R Preston 1995: Use of duckweed (*Lemna spp*) as replacement for soya bean meal in a basal diet of broken rice for fattening ducks, from http://www.lrrd.org/lrrd7/3/2.htm

Chhay Ty, Khieu Borin, T R Preston and Sokveasna Mea 2007: Intake, digestibility and N retention by growing pigs fed ensiled or dried Taro (*Colocasia esculenta*) leaf as the protein supplement in basal diets of rice bran/broken rice or rice bran/cassava root meal. Livestock Research for Rural Development. Volume 19, Article #137, from http://www.cipav.org.co/lrrd/lrrd19/9/chha19137.htm

Dao Thi My Tien, Nguyen Tuyet Giang and Preston T R 2010: A note on ensiling banana pseudo-stem with Taro (*Colocasia esculenta*) leaves and petioles

Dean W and Sandhu T 2006: Duck housing and management, from http://www.duckhealth.com/housmngt.html

Desvaux Stephanie, Vu Dinh Ton, Phan Dang Thang and Pham Thi Thanh Hoa 2008: A general review and a description of the poultry production. Agricultural Publishing House, from http://www.aitoolkit.org/site/DefaultSite/filesystem/documents/Review%20of%20Poultry%20Production%20in%20Vietnam.pdf

Doan Xuan Truc 2001: Poultry production in Vietnam has a bright future. WORLD POULTRY-Elsevier Volume 17,No 2. '01, from http://www.worldpoultry.net/backgrounde/the-future-of-central-american-poultry-is-tough-6188.html

Du Thanh Hang and T R Preston 2010: Effect of processing Taro leaves on oxalate concentrations and using the ensiled leaves as a protein source in pig diets in central Vietnam, from http://www.lrrd.org/lrrd22/4/hang22068.htm

Edan M, Bourgeois Luthi N, Gautier P and Guerne-Bleich E 2006: Free ranging ducks and risks in Avian Flu disease in Vietnam, from http://www.sciquest.org.nz/crusher_download.asp?article=10003445

FAO 2004: Recommendations on the Prevention, Control and Eradication of Highly Pathogenic Avian Influenza (HPAI) in Asia

Hall David C, Benigno C and Wantanee Kalpravidh 2006: The impact of avian influenza on small and medium scale poultry producers in South East Asia (preliminary findings), from http://ageconsearch.umn.edu/bitstream/21348/1/sp06ha07.pdf

Islam S S, Azam M G, Adhikary S K and Wickramarachchi K S 2004: Efficiency of integrated rice, fish and duck polyculture as compared to rice and fish culture in a selective area of Khulna district, Bangladesh, from http://198.170.104.138/pjbs/2004/468-471.pdf

Kayouli Chedly and Stepen Lee 1999: Silage from by-products for smallholders, from http://www.fao.org/docrep/005/X8486E/x8486e0l.htm

Khanum J, Chwalibog A and Huque K S 2005: Study on digestibility and feeding systems of duckweed in growing ducks, from http://www.lrrd.org/lrrd17/5/khan17050.htm

Le Hong Man 2002: Duck-fish integration in Vietnam, from http://www.fao.org/docrep/004/ac155E/AC155E15.htm

Machin D H 1999: The potential use of tropical silage for livestock production, with special reference to smallholders, from http://www.fao.org/ag/AGP/AGPC/gp/SILAGE/HTML/Paper5.htm

Malavanh Chittavong, T R Preston and B Ogle 2008b: Ensiling leaf of Taro (*Colocasia esculenta* (L.) Shott) with sugar cane molasses. Livestock Research for Rural Development. Volume 20, supplement, from http://www.cipav.org.co/lrrd/lrrd20/supplement/mala1.htm

Malavanh Chittavong, T R Preston and B Ogle 2008a: Effect of replacing soybean meal with a mixture of Taro (Colocasia esculenta (L.)Schott) leaf silage and water spinach on apparent digestibility in Mong Cai gilts at two stages of gestation. Livestock Research for Rural Development. Volume 20, supplement, from http://www.cipav.org.co/lrrd/lrrd20/supplement/mala3.htm

National Academy of Sciences 1994: Nutrient Requirements of Poultry. Ninth Revised Edition, 1994, page 42-43, from http://www.nap.edu/openbook.php?record_id=2114&page=42

Nguyen Duc Anh and T R Preston 1997: Evaluation of protein quality in duckweed (Lemna spp.) using a duckling growth assay, from http://www.lrrd.org/lrrd9/2/anh92.htm

Nguyen Quang Dat and Yu Y 2003: Total replacement of fish meal by meat and bone meal and poultry byproduct meal in meat duck diet, from http://nationalrenderers.org/assets/duck_feeding_trial.pdf

Nguyen Thi Hong Nhan, T R Preston and Dolberg F 1997: Use of *Trichantera gigantea* leaf meal and fresh leaves as livestock feed, from http://www.lrrd.org/lrrd9/1/nhan91.htm

Nguyen Thi Kim Dong 2005 An evaluation of brewery waste as a replacement for concentrates in diets for growing crossbred common ducks. Tropical Animal Health and Production. 36 (7): 715-729.

Nguyen Tuyet Giang 2008 Taro (*Colocasia esculenta*) silage and water spinach as supplements to rice bran for growing pigs. http://www.mekarn.org/msc2008-10/miniprojects/minpro/giang.htm

Pheng Buntha, Khieu Borin, T R Preston and B Ogle 2008a: Digestibility and nitrogen balance studies in pigs fed diets with ensiled taro (*Colocasia esculenta*) leaf as replacement for fish meal. Livestock Research for Rural Development. Volume 20, supplement, from http://www.cipav.org.co/lrrd/lrrd20/supplement/bunt2.htm

Pheng Buntha, Khieu Borin, T R Preston and B Ogle 2008b: Survey of taro varieties and their use in selected areas of Cambodia. Livestock Research for Rural Development. Volume 20, supplement, from http://www.cipav.org.co/lrrd/lrrd20/supplement/bunt1.htm

Ravindran V, Sivakanesan R and Cyril H W 1996: Nutritive value of raw and processed colocasia (*Colocasia esculenta*) corm meal for poultry, from http://cat.inist.fr/?aModele=afficheN&cpsidt=3009224

Samli H E, Senkoylu N, Akyurek H, Agma A 2006: Using rice bran in laying hen diets, form http://www.agr.hr/jcea/issues/jcea7-1/pdf/jcea71-18.pdf

Shan-Nan Lee 2009: Improved Duck Production of Small-Scale Farmers in Asia. http://www.agnet.org/library/ac/2007g/

Sunell Leslie A and Healey Patrick L 1979: Distribution of Calcium Oxalate Crystal Idioblasts in Corms of Taro (Colocasia esculenta), from http://www.jstor.org/pss/2442567

Effect on the performance of common ducks of supplementing rice bran with taro (*Colocasia esculenta*) foliage

Nguyen Tuyet Giang [1], T R Preston[2] and B Ogle[3]

[1] *Department of Animal Husbandry and Veterinary Medicine, Angiang University, Vietnam*

ntgiang@agu.edu.vn

[2] *University of Tropical Agriculture (Colombia), AA #48, Socorro, Santander, Colombia*

preston@lrrd.org

[3] *Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management.*

Box 7024, 750 07 Uppsala, Sweden

Brian.ogle@huv.slu.se

Abstract

Two on-farm experiments were conducted in a suburb of Long Xuyen City, An Giang province, Vietnam, to investigate the effect of diets of rice bran with taro (*Colocasia esculenta*) foliage on the growth performance of common ducks. In Experiment 1, 168 crossbred common ducks (crosses of an exotic and an indigenous breed) were used in a completely randomized design (CRD) with 7 dietary treatments and 3 replicates. The ducks were offered chopped fresh taro leaves *ad libitum*, supplemented with five levels (3, 4, 5, 6, 7% of live weight [LW] as dry matter [DM]) of a basal diet (soybean meal, rice bran and broken rice) with a premix added There were two other treatments, the basal diet without premix fed at 3% of LW, with free-access to taro leaves, and the basal diet with premix, fed at the equivalent of 7% of LW, with no taro leaves provided. Each experimental unit included 8 ducks, balanced for sex. In Experiment 2, in total 80 common ducks were used, with ten treatments, two replicates and four ducks (balanced for sex) per replicate. The dietary treatments were arranged as a 5*2 completely random factorial design, with ingredient ratio (5) and feeding system (2) as factors. The basal diet was high protein rice bran supplemented by five levels of taro silage (20, 30, 40, 50, and 60%), fed to the ducks in mixed or separate form.

In Experiment 1, the total DM intake was highest on the treatment in which the ducks were fed 7% of LW of the basal diet supplemented by fresh taro leaves *ad libitum* (110g/day), and lowest in the treatment with 3% of LW of the basal diet and taro leaves *ad libitum* (84.4g/day). The average daily gain was significantly different ($P<0.05$) among treatments, and was poorest in the treatment 3% of basal diet-taro leaves *ad libitum*. Live weight gain was reduced from 30 to 20 g/day, and FCR was poorer, when the basal diet of rice bran, broken rice and SBM, was restricted to 3% of LW (as DM) with fresh Taro leaves *ad libitum*. There was no effect on ADG and FCR of including a mineral-vitamin premix when Taro leaves were also fed. In Experiment 2, growth rates of ducks were the same over a range of ratios of rice bran and taro silage from 80:20 to 40:60. The ADG was 8% higher when the feeds were given as a mixture rather than separately. Calcium oxalate in taro leaf-stem silage was lower than in fresh taro leaves. There was a positive effect on carcass quality (lower abdominal fat) from supplementing rice bran with taro silage. For smallholder farmers in the Mekong delta there can be significant economic benefits from fattening common ducks using resources (rice bran and taro foliage) that are widely available in the region and of lower cost than commercial feeds.

Key words: *Mekong delta, taro leaves, silage, intake, average daily gain, abdominal fat, economic benefit*

---

1. Introduction

Poultry production is a common activity in Southeast Asia, and is a major source of livelihood for over a million people in the rural areas. In the last two decades, Asian duck production has become more important, making up 87% of the world's duck population, and duck meat and egg production has increased more than four times (Chein Tai and Jui-Jane Liu Tai, 2001). This expansion has mainly come from the preservation of local breeds and strains, such as the local Muscovy duck, and several Vietnamese breeds such as the Co and Tau duck (Duong Thanh Liem 2001), and imports of exotic and improved breeds. Improved ducks have become widely accepted and have increased in number, and are generally called "common ducks".

Duck production is one component of integrated farming systems which are regarded as being part of a sustainable development in agriculture. Ducks *(Anas platyrhynchos)* can be integrated with rice, orchards, cash crops, livestock, and fish. Thus, the stakeholders not only can develop their livelihoods without accumulating debts, but also can get extra income through off-farm and non-farm activities (Le Thanh Phong et al. 2007). The Mekong Delta, located in the South of Vietnam, is considered as the country's granary, accounting for 48% of the national rice production (followed by the Red River Delta). The Mekong Delta has a warm ambient temperature and high annual rainfall that is suitable for duck production. Natural resources, including paddy rice fields, canal networks, and plant and grasses, for instance, are advantageous for ducks to increase in number. Ducks can effectively utilize low quality feed (agricultural residues, by-products and insects) and can produce highly nutritious foods for humans (Bui Xuan Men et al 1998). Duck production is diversified into several raising systems according to economic criteria, for example: industrial integrated, medium to large commercial, medium to small commercial and mixed farming systems (integration of rice-ducks, ducks-fish or rice-fish-ducks), or spatial criteria, such as scavenging, semi-confined and confinement systems (Edan et al 2006). The large scale system has developed only recently in some areas of the delta. It is generally agreed that better breeds, together with improvements in management of stock health and using local feed resources, as well as other appropriate technologies should enhance sustainable small-scale duck production.

However, the free-raising of ducks in the rice fields or canals (scavenging system) without strict management of outbreaks of diseases is a risk for community health and also duck production. In order to deal with this important issue and create a sustainable duck production, semi-confined and confined systems are being introduced and widely extended, with the aim of limiting the spread of infectious diseases such as Duck Plague and Avian influenza.

An Giang Province, situated in the Mekong Delta, is a well- known area for rice production, with 3,519,343 tonnes produced in 2008 (An Giang Statistical Yearbook 2009). The most common duck production system in this area is free grazing in the rice fields, utilizing the leftover rice grains, weeds, insects and snails as part of an integrated pest management system (Teo 2001). According to the An Giang Statistical Yearbook (2009), in 2008, there were 4,296,840 poultry, of which 3,437,129 were ducks, raised in An Giang Province.

Annually, rice mills produce large quantities of grain for export, as well as the by-products (rice husk, rice bran and broken rice). The broken rice is not as valuable as rice grain but it also can be exported or used locally for human consumption. Rice bran is the outer layer of the brown rice kernel (after separating the husk) which is removed while milling brown rice to white. Rice bran is a rich source of nutrients and a pharmacologically active compound and is currently used as livestock feed and for oil production (Tahira et al 2007). According to Houston (1972), rice bran accounts for 5-8 percent of paddy rice (whole grain). Commonly, in Vietnam, the rice mills have produced three kinds of rice bran: the initial bran (mixed with rice husk fragments) and two types of bran produced in the polishing process, which are very fine and have higher nutritive value than the initial bran. In the Mekong Delta, rice bran is cheaper than rice grain and broken kernels, so it is the most widely available feed resource for duck production.

Taro can be commonly found growing wild in the Mekong Delta, particularly on the banks of ponds and along rivers and canals. Traditionally, some taro species (*Colocasia antiquorum* and *Colocasia gigantea*), which have a large corm or palatable stem, can be used for home consumption, while *Xanthosoma sp.*, *Alocasia sp.*, *Alocasia cucullata* and *Alocasia macrorrhiza* (giant taro/giant elephant ear) can be used both as human food and animal feed. Wild taro (*Colocasia esculenta*) originates from India and Southeastern Asia. It is a perennial herb 1.5 m tall, with thick stems, very small corms, and with leaf blades around 60 in length and 50 cm in width. Wild taro is very easy to grow, develops fastest in wet land and is highly resistant to pests and diseases. The wild taro leaf has a high nutritional value, with 22.5-26.3% crude protein in the dry matter (DM) (Malavanh Chittavong et al 2008a and Chhay Ty et al 2007). However, in common with other species of the Aracae family, an anti-nutritional substance, calcium oxalate, is found in all parts of the plant, causing irritation in the throat and mouth epithelium and indirectly affecting the feed intake. The influence of calcium oxalate can be reduced by ensiling with molasses (Malavanh Chittavong et al 2008b), or by the addition of the stems without any further additive (Du Thanh Hang and Preston 2010; Nguyen Tuyet Giang 2008).

2. Materials and methods

2.1 Location and climate of the study area

Two experiments were conducted on a private farm in Long Xuyen City, An Giang Province, Vietnam. The climate is divided into two seasons: the rainy season (from May to November), and the dry season (from December to April). The annual average temperature is 27ºC. The highest mean daily temperature is 35ºC - 37ºC from April to May and the lowest 20ºC - 21ºC, from December to January. The annual rainfall is 1,400-1,500mm.

2.2 Treatments and design

Experiment 1 was carried out using 168 crossbred common ducks in a completely randomized design (CRD) with 7 dietary treatments and 3 replicates. Each experimental unit involved 8 ducks, balanced in sex. The dietary treatments are presented in Table 1, and composition of the premix used in Table 2.

Table 1. Experimental treatments

Treatment	Feeding level	Taro leaves	Premix
W7PTL	7% of LW	fed ad libitum	supplied
W7P	7% of LW	-	supplied
W6PTL	6% of LW	fed ad libitum	supplied
W5PTL	5% of LW	fed ad libitum	supplied
W4PTL	4% of LW	fed ad libitum	supplied
W3PTL	3% of LW	fed ad libitum	supplied
W3TL	3% of LW	fed ad libitum	-

LW: live weight; P: premix and TL: taro leaves

Table 2. Composition of the vitamin and mineral premix supplied

	Per kg
Premix of vitamins and minerals	
Vitamin A	2,500,000 IU
Vitamin D_3	500,000 IU
Vitamin E	1,500 IU
Niacinamide (Vitamin B_3)	5,000 mg
Calcium Pantothenate	3,000 mg
Vitamin C	3,300 mg
Riboflavin (Vitamin B_2)	1,200 mg
Vitamin K_3	1,000 mg
Thiamine (Vitamin B_1)	1,000 mg
Pyridoxine (Vitamin B_6)	550 mg
Folic acid	440 mg
Biotin (Vitamin B_7)	33,000mcg
Vitamin B_{12}	5,500 mcg
Premix of minerals	
Fe, Cu, Mn, Zn, I_2, Co, organic Se	121,200 mg
Biotin	18 mg
Dicalcium phosphate (DCP)	1,000 mg

Experiment 2 was conducted with common ducks allocated in a 5x2 factorial experiment with a completely randomized design, and with 10 dietary treatments and 2 replicates. There were two factors:

- Five ratios of rice bran to taro silage: 80:20, 70:30, 60:40, 50:50, 40:60 (DM basis).
- Two feeding systems: rice bran - taro silage mixed together, and rice bran - taro silage fed separately.

There were 4 ducks, with 2 males and 2 females, allocated to each experimental unit (replication). The treatments are shown in Table 3.

Table 3: Experimental treatments

Rice bran: taro silage (DM basis)	Feeding system	
	Mixed feeding	Separate feeding
80:20	80-20M	80-20S
70:30	70-30M	70-30S
60:40	60-40M	60-40S
50:50	50-50M	50-50S
40:60	40-60M	40-60S

2.3 Management

One-day-old ducklings were selected in breeding farms with known origin of the eggs. Male and female ducklings were brooded separately in different cages. The ducklings were fed commercial feeds from the second day until 4 days before starting the trial. The temperature was maintained at 32-34^{o}C for the first 7 days and then reduced steadily to normal ambient temperatures. The ducklings were trained to become used to the experimental feeds from the seventh day by mixing increasing amounts with the commercial feed. Vaccinations against two dangerous diseases (Duck Plague and Avian Influenza) were done, following the biosecure procedure (FAO 2008)

The first trial took 50 days (it started when the ducklings reached 21 days of age and finished when they were 70 days of age). The second experiment started when the ducks were 28 days of age and finished when they reached 70 days of age (42 days in duration).

2.4 Animal housing

The experimental ducks were kept in 3m^2 pens in a simple house constructed of bamboo and wire nets. The floor was overlaid with 20 cm of sand for bedding. Feeders and drinkers were put in each cage (Photo 1). Plastic tanks were arranged for bathing.

Photo 1. Experimental house

2.5 Feeds and feeding

In Experiment 1, the confined common ducks were fed a basal diet and chopped fresh taro leaves. The basal diet included three ingredients: rice bran, broken rice and soybean meal. The diets were balanced to approximately 16% crude protein (CP) content.

Wild taro leaves (Photo 2) were harvested and chopped in fresh form before feeding. Rice polishing (rice bran and broken rice) was bought in a local factory and soybean meal was purchased in Afiex *(*Agriculture and Foods Import – Export) Angiang Feed Mill. The basal diet was mixed with water and fed separately from the chopped taro leaves. The premix of vitamins and minerals was weighed and supplied according to the instructions written on the label.

In Experiment 2, the ducks were fed to appetite, which was planned to be about 6% of live weight as DM. In the mixed feeding, the diet components were mixed together. With separate feeding, rice bran was restricted to 80, 70, 60, 50 and 40% of the planned DM intake and the taro silage was supplied *ad libitum* in a different feed bowl. The premix of vitamins and minerals was supplied according to the instructions written on the label.

The basal diet was fine rice bran (very small particles) with a high CP content bought from a local factory in Chau Thanh District. Taro petioles and leaves were harvested from plants growing on roadsides and other unused areas. These materials were chopped into 2-3 cm lengths with a knife, partially sun-dried to reduce the moisture to 75-80%, and packed tightly into plastic bags (50 litre capacity). The bags were covered with plastic sheets and stored at room temperature. After 4 days, the taro silage changed color to dark brown with a palatable smell and was then ready for use (Photo 3).

The ducks were fed three times per day (in the morning, at noon and in the afternoon).

Water was freely available in plastic bowls.

Photo 2. Taro plant (*Colocasia esculenta*)

Photo 3. Taro silage

2.6 Measurements and data collection

2.6.1 Growth parameters

The ducks were weighed in the morning before feeding at the beginning of the experiment, each week, and at the end of the experiment. Growth rate was determined from the linear regression of live weight (Y) on days in experiment (X).

2.6.2 Feed conversion ratio (FCR)

Feed supplied was weighed every morning, and the residues collected and weighed the following morning**.** Representative samples of diets were taken and stored in a refrigerator at 4^oC, and the dried samples bulked at weekly intervals and stored for analysis.

2.6.3 Carcass parameters

After finishing the experiment, 2 representative ducks from each pen were slaughtered to determine carcass traits and abdominal fat.

2.6.4 Economic analysis

The cost of each diet was calculated based on the current prices in Vietnamese Dong of ingredients, and the economic benefits calculated.

2.6.5 Chemical analysis

Feed offered and refusals were prepared and analyzed for dry matter, organic matter (OM), and crude protein (CP) following the methods of AOAC (1990). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined according to Van Soest et al 1991. Ether extract (EE) was determined by Soxhlet extraction. Samples of taro silage were analyzed for minerals (Ca and P) following a HPLC-MS (High performance liquid chromatography - Mass spectrometry) method, and oxalate was determined by the method of Martz et al (1990).

2.7 Statistical analysis

Regression or ANOVA analysis in Minitab software (Minitab release 13.3, 2000) was applied to the data depending on the nature of the observed responses in growth and feed conversion ratio. Sources of variation were treatments and error.

3. Results

3.1 Experiment 1

3.1.1 Chemical composition of dietary ingredients

Table 4. Chemical composition of feeds

	Feed ingredient		
	Basal diet		**Fresh taro leaves**
	With premix	**Without premix**	
DM ,%	89.4	88.6	13.5
As % in DM			
Ash	5.70	7.00	19.8
CP	16.7	16.4	23.4
NDF			37.8
ADF			7.70
Ca	1.85	1.56	1.31
P	1.80	1.06	0.26
Calcium oxalate			0.76
Carotene, mg/kg DM	130	160	1280

The level of CP of the basal diets was consistent with the recommendation in the Nutrient Requirements of Poultry (National Academy of Sciences 1994) for White Pekin ducks from two to seven weeks of age(16% CP on DM basis) (Table 4). The CP content of the fresh taro leaves used in this study (23.4%) was higher than in the study of Malavanh Chittavong et al 2008b (22.5%). Fresh taro leaves were higher in neutral detergent fiber (NDF) but lower in acid detergent fiber (ADF) than in Giant taro leaves (Lylian Rodríguez et al 2006). The calcium oxalate content found in the fresh taro leaves was lower than that found in studies carried out by Malavanh Chittavong et al (2008b) and Du Thanh Hang and Preston (2010). The amount of carotene found in fresh taro leaves was higher than that in duckweed (Bui Xuan Men et al 1995)

3.1.2 Feed intake and live weight gain

Daily feed intake of the common ducks increased with the rise in the level of basal feed fed (as % of LW as DM). However, the proportion of CP consumed varied slightly due to the high CP content in fresh taro leaves (24.4% vs 16.7% in the basal diet, DM basis). There was a positive trend in the ADG, which increased with a decrease in fresh taro leaves intake, but the FCR did not significantly differ among treatments (Table 5).

It was very clear that there was no difference in the total DM intake as well as FCR and ADG between ducks fed the basal diet equivalent to 3% of LW with added premix (vitamins and minerals) and without premix and with taro *ad libitum* (Table 6). With equal feed level offered (7% of LW as DM), the ducks also consumed more taro leaves, but the FCR was poorer than when the ducks were fed the basal diet only. The result is similar to the report of Bui Xuan Men et al (1995) in which the FCR became poorer when the duckweed offered was increased. This can be explained by the high fibre content in fresh taro leaves causing low digestibility.

Table 5. Daily feed intake and performance traits of ducks fed restricted levels (% of LW as DM) of a basal diet (WP) and fresh taro leaves *ad libitum*

	W3PTL	W4PTL	W5PTL	W6PTL	W7PTL	SE/P
Intake, g/day						
Basal feed	31.0[a]	45.6[b]	60.5[c]	73.1[d]	83.6[e]	1.39/0.001
Taro leaves	53.5[a]	49.6[a]	41.7[b]	33.9[c]	26.4[d]	0.94/0.001
Total DM	84.4[a]	95.2[b]	102[b]	107[c]	110[d]	2.00/0.001
FCR, kg feed/ kg gain	4.15	3.96	3.91	3.79	3.78	0.09/0.100
ADG, g	20.4[a]	24.1[b]	26.1[c]	28.2[d]	29.1[d]	0.38/0.0001
As % in diet DM						
Taro leaves	63.3[a]	52.1[b]	40.8[c]	31.7[d]	24.0[e]	0.72/0.001
CP	22.6[a]	21.8[b]	20.9[c]	20.4[d]	19.4[e]	0.08/0.001

[abcde] *Mean values within rows without a common superscript are different at P<0.05*
W3PTL: ducks were fed equivalent 3% LW with basal feed mixed with premix, fresh taro leaves ad libitum
W4PTL: ducks were fed equivalent 4% LW with basal feed mixed with premix, fresh taro leaves ad libitum
W5PTL: ducks were fed equivalent 5% LW with basal feed mixed with premix, fresh taro leaves ad libitum
W6PTL: ducks were fed equivalent 6% LW with basal feed mixed with premix, fresh taro leaves ad libitum
W7PTL: ducks were fed equivalent 7% LW with basal feed mixed with premix, fresh taro leaves ad libitum

Table 6. Effects on intake and performance of taro leaves compared with a mineral-vitamin supplement with a basal diet at 3% of LW

	W3PTL	W3TL	SE/P	W7P	W7PTL	SE/P
Intake, g/day						
Basal feed	31.0	30.3	0.46/0.388	84.3	83.6	1.66/0.781
Taro leaves	53.5	53.2	1.09/0.839	0.0	26.4	0.51/0.000
Total DM	84.4	83.5	1.48/0.678	84.3	110	1.94/0.001
FCR, kg/kg	4.15	4.23	0.20/0.770	3.01	3.78	0.07/0.001
ADG, g	20.4	19.8	0.70/0.598	28.0	29.1	0.31/0.063
As % of diet DM						
Taro leaves	63.4	63.7	0.57/0.815	0	24.0	0.41/0.000
CP	22.6	22.8	0.08/0.124	18.4	19.4	0.09/0.001

W3PTL: ducks were fed equivalent of 3% LW of basal feed mixed with premix, and with fresh taro leaves ad libitum
W3TL: ducks were fed equivalent of 3% LW of basal feed without premix, and with fresh taro leaves ad libitum
W7P: ducks were fed equivalent of 7% LW of basal feed mixed with premix
W7PTL: ducks were fed equivalent of 7% LW of basal feed mixed with premix, and with fresh taro leaves ad libitum

As shown in Figure 2, the proportion of fresh taro silage consumed of total DM intake (DMI) had a negative relationship with ADG (R^2=0.96).

3.1.3 Carcass traits

There were no differences in the carcass traits between the groups with and without premix supplied and the same group fed fresh taro leaves *ad libitum* vs basal diet alone (Table 8).

However, the feeding level (as % of LW) had an influence on the slaughter weight, carcass percentage and the caecum length (Table 7).

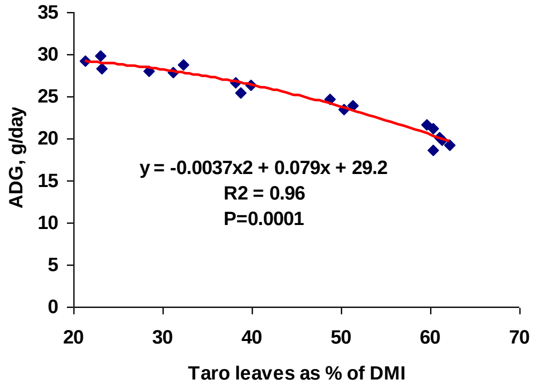

Figure 1. Relationship between proportion of fresh taro leaves and average daily weight gain **(ADG)**

Table 7. Performance traits of ducks fed restricted levels (% of LW as DM) of a basal diet (WP) and with fresh taro leaves supplied *ad libitum*

	W3PTL	W4PTL	W5PTL	W6PTL	W7PTL	SE/P
Slaughter weight, g	1627^{a}	1850^{ab}	1958^{ab}	2025^{b}	2052^{b}	80.8/0.024
Carcass weight, g	1095^{a}	1227^{ab}	1323^{ab}	1372^{b}	1422^{ab}	53.2/0.010
Carcass, %	67.4	66.3	67.5	67.8	69.4	1.41/0.667
Chest muscle#, g	182	187	186	189	186	4.25/0.839
Thigh muscle#, g	67.8	69.0	69.3	70.9	84.3	4.13/0.109
Heart#, g	15.0	15.3	15.0	15.6	14.3	0.57/0.483
Liver#, g	53.4	56.2	57.0	54.0	55.3	4.31/0.957
Gizzard#, g	65.7	59.3	59.4	58.6	57.0	4.53/0.868
Small intestine#, cm	178	187	191	201	200	9.70/0.748
Large intestine#, cm	13.1	11.9	13.2	11.9	11.3	1.01/0.603
Caecum#, cm	28.4^{a}	21.3^{b}	18.8^{b}	18.3^{b}	16.9^{b}	1.32/0.014
Abdominal fat#, g	5.8	11.4	16.8	17.0	25.3	3.03/0.085

 # Corrected for carcass weight by covariance

[ab] Mean values within rows without a common superscript are different at P<0.05

W3PTL: ducks were fed equivalent of 3% LW of basal feed mixed with premix, and with fresh taro leaves ad libitum

W4PTL: ducks were fed equivalent of 4% LW of basal feed mixed with premix, and with fresh taro leaves ad libitum

W5PTL: ducks were fed equivalent of 5% LW of basal feed mixed with premix, and with fresh taro leaves ad libitum

W6PTL: ducks were fed equivalent of 6% LW of basal feed mixed with premix, and with fresh taro leaves ad libitum

W7PTL: ducks were fed equivalent of 7% LW of basal feed mixed with premix, and with fresh taro leaves ad libitum

The length of caecum increased as the proportion of fresh taro leaves increased (Figure 2). The fresh taro leaves had a negative impact on the abdominal fat weight; the more taro leaves consumed, the less fat stored up (Figure 3). The results show that the increase in caecum length in response to increase in dietary fiber is linear. The caecum (2 ceaca in pair) in birds is fingerlike and mainly contributes to fibre digestion, but the effect is rather small. Inside the caeca there is a site for the breakdown and fermentation of cellulose that depends on microbial degradation (Clench and Mathias 1995). The fibrous bulk in the digestive tract could be the reason for the increase of caecum length. A similar result was found in a study carried out by Khieu Borin et al (2005), in which the cassava leaf meal had an interaction with the weight and the length of small intestine and caeca (per kg of live weight). The explanation is that ducks would develop larger intestines, allowing more rapid digesta passage and higher absorption efficiency. The increase length and weight of the ceaca would have been caused by the increase of digestive capacity as a result of the high fibre content in the feed.

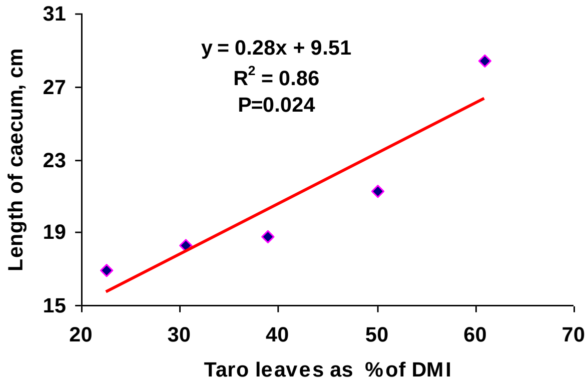

Figure 2. Effect of proportion of fresh taro leaves on caecum length

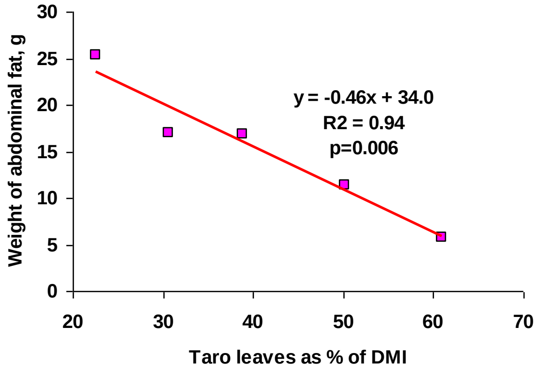

Figure 3. Negative relationship between the proportion of fresh taro leaves and abdominal fat weight

Table 8. Effects of taro leaves on carcass parameters compared with a mineral-vitamin supplement with a basal diet supplied at 3% of LW (W3TL vs W3PTL) and at 7% of LW (W7PTL vs W7P)

	W3PTL	W3TL	SE/P	W7P	W7PTL	SE/P
Slaughter weight, g	1627	1550	99.6/0.615	2133	2052	72.6/0.471
Carcass weight, g	1095	1040	69.2/0.606	1397	1422	33.8/0.628
Carcass, %	67	67	2.12/0.933	65.5	69.4	1.26/0.099
Chest muscle, g	154	151	11.4/0.846	208	205	6.87/0.749
Thigh muscle, g	55.0	51.3	6.00/0.688	76.7	93.2	7.48/0.194
Heart, g	14.0	12.8	1.42/0.592	15.0	15.0	0.02/1.000
Liver, g	55.0	55.0	4.08/1.000	56.7	54.2	3.17/0.607
Gizzard, g	62.5	59.2	2.76/0.442	55.0	59.2	2.12/0.238
Small intestine, cm	178	171	9.08/0.631	194	200	7.48/0.572
Large intestine, cm	12.9	14.3	0.53/0.123	11.8	11.4	0.35/0.449
Caecum, cm	26.7	22.6	1.08/0.055	17.1	18.1	0.69/0.364
Abdominal fat, g	9.67	8.67	0.67/0.349	20.0	24.7	2.80/0.305

W3PTL: ducks were fed equivalent of 3% LW of basal feed mixed with premix, fresh taro leaves ad libitum
W3TL: ducks were fed equivalent of 3% LW of basal feed without premix, fresh taro leaves ad libitum
W7P: ducks were fed equivalent of 7% LW of basal feed mixed with premix
W7PTL: ducks were fed equivalent of 7% LW of basal feed mixed with premix, fresh taro leaves ad libitum

3.1.4 Economic benefit

The economic analysis shown in Table 9 demonstrates that it is possible to feed confined common ducks with a basal feed (concentrate without a vitamin- mineral premix) equivalent to 3% of LW and with fresh taro leaves provided *ad libitum*, with the feed cost per kg weight gain decreasing in proportion to the amount of taro leaves consumed.

Table 9. Estimates of feed costs (VND/kg weight gain) assuming situations of purchase or farm-based production of taro leaves (in VND; about 17,800VND=1USD)

Feed cost/kg gain	W3TL	W3PTL	W4PTL	W5PTL	W6PTL	W7PTL	W7P
Experimental conditions (*)	18,250	18,547	18,211	18,505	18,316	18,635	15,652
Taro leaves harvested by farmer(**)	7,979	8,438	10,275	12,416	13,677	15,233	15,652

(*)1kg basal diet with premix=5200 VND; 1kg basal diet without premix=4800 VND; 1kg fresh taro leaves=600VND= 4,000 VND 90% air-dry basis)
(**)Farmers harvest and ensile taro by themselves: 1 kg taro=0 VND
W3TL: ducks were fed equivalent of 3% LW of basal feed without premix, fresh taro leaves ad libitum
W3PTL: ducks were fed equivalent of 3% LW of basal feed mixed with premix, fresh taro leaves ad libitum
W4PTL: ducks were fed equivalent of 4% LW of basal feed mixed with premix, fresh taro leaves ad libitum
W5PTL: ducks were fed equivalent of 5% LW of basal feed mixed with premix, fresh taro leaves ad libitum
W6PTL: ducks were fed equivalent of 6% LW of basal feed mixed with premix, fresh taro leaves ad libitum
W7PTL: ducks were fed equivalent of 7% LW of basal feed mixed with premix, fresh taro leaves ad libitum
W7P: ducks were fed equivalent of 7% LW of basal feed mixed with premix, no taro leaves

3.2 Experiment 2

3.2.1 Chemical composition of feedstuffs

Table 10. Chemical composition of feed ingredients

	Diet ingredients	
	Rice bran	**Taro silage**
DM ,%	89.3	24.7
As % in DM		
Ash	8.90	3.60
CP	13.2	18.7
EE	16.6	
NDF	40.9	30.9
ADF	6.60	6.11
Ca		0.15
P		0.12
Calcium oxalate		0.31

According to the values found for rice bran and taro silage (Table 10), all the experimental diets would supply enough protein to satisfy the demand for growing ducks (16% in DM, Siregar et al 1982). The rice bran had a higher nutritional value than Chhay Ty et al (2009) reported. The taro silage made from stems and leaves had a lower CP content than the ensiled product made from leaves only (Chhay Ty et al 2007 and Pheng Buntha et al 2008) but the value was similar to that reported by Nguyen Tuyet Giang (2008).

Ensiling can be the best solution, not only for feed preservation but also for reducing calcium oxalate. The calcium oxalate content was reduced 2.45 times in the silage product compared to the concentration in fresh taro leaf (Table 4). This data is in agreement with the studies of

Pheng Buntha et al (2008) and Du Thanh Hang and Preston (2010), who reported that ensiling taro leaves was more effective in reducing the calcium oxalate in fresh leaves than other processing methods.

3.2.2 Feed intake

Compared to the planned proportions of rice bran in the feed, the actual amounts consumed were lower in the mixed feeding system and higher in the “separate system” (Table 11).

Table 11. Percentage of rice bran in the diets: planned and consumed on the mixed and separate feed system (rest of diet was taro silage)

Planned	40	50	60	70	80
Mixed system	42.4	51.3	60.2	70.2	77.1
Separate system	34.6	40.9	57.7	62.5	67.9

The total DM intake and the proportion of the diet as taro silage were higher when the two feeds were mixed together (Table 12). This was probably because of the improved palatability when the rice bran was well mixed with taro silage. This result is different from that reported by Nguyen Thi Kim Dong (2005) when common ducks were fed a concentrate and brewer’s grains mixed or separately. Under a free-choice feeding (feeds supplied separately), the protein-rich component is acknowledged to be the target of the bird's selection (Pousga et al 2005). This may explain why ducks consumed more taro silage when they had free access to the taro silage than in the “separate” feeding system. The attractive smell of the taro silage may also have been favored by the ducks. Another explanation is that on the “separate” feeding system there were no residues from the rice bran, whereas in the mixed system there was a rice bran residue equivalent to 5% of the offer level. This implies that if the feeding level had been set higher than 6% of live weight, the ducks on the “separate” system might have eaten more rice bran and less taro silage.

Table 12. Daily intake of DM, CP and dietary ingredients of ducks fed taro silage (TS) mixed with a basal diet of rice bran (RB) or offered separately

	Feeding system		
	Mixed	**Separate**	**SE/P**
Feed intake, g/day			
DM RB	70.6	57.7	3.89/0.030
DM TS	48.8	52.1	5.70/0.696
Total DM	119	110	2.87/0.027
Total CP	18.3	17.1	0.56/0.138
As % in diet DM			
Rice bran	60.0	52.6	4.18/0.227
Taro silage	40.0	47.4	4.18/0.227
CP	15.4	15.6	0.14/0.212

As expected, the CP content of the diet decreased slightly as the proportion of rice bran was increased at the expense of the taro silage (Tables 13 and 14).

Table 13. Effect of ratio of rice bran (RB) and taro silage (TS) on the intake of dietary ingredients and feed constituents (DM and CP) of common ducks under a mixed feeding system

	Planned ratio of rice bran: taro silage					
	40:60	**50:50**	**60:40**	**70:30**	**80:20**	**SE/P**
Feed intake, g/day						
DM RB	56.5^{a}	64.0^{b}	74.3^{c}	81.8^{d}	76.5^{e}	0.81/0.0001
DM TS	76.7^{a}	60.8^{b}	49.2^{c}	34.8^{d}	22.8^{e}	0.79/0.0001
Total DM	133^{a}	125^{ab}	124^{b}	117^{b}	99.2^{c}	1.56/0.0001
Total CP	21.1	19.5	18.9	17.4	14.7	0.25/0.127
As % in diet DM						
Rice bran	42.4^{a}	51.3^{b}	60.2^{c}	70.2^{d}	77.1^{e}	0.18/0.0001
Taro silage	57.6^{a}	48.7^{b}	39.8^{c}	29.8^{d}	23.0^{d}	0.18/0.0001
CP	16.0^{a}	15.7^{b}	15.4^{c}	15.0^{d}	14.8^{e}	0.007/0.0001

^{abcde} *Mean values within rows without a common superscript are different at P<0.05*

Table 14. Effect of ratio of rice bran (RB) fed separately from taro silage (TS) on the intake of dietary ingredients and feed constituents (DM and CP) of common ducks

	Planned ratio of rice bran: taro silage					
	40:60	**50:50**	**60:40**	**70:30**	**80:20**	**SE/P**
Feed intake, g/day						
DM RB	38.9^{a}	45.9^{b}	59.7^{c}	67.0^{d}	76.7^{e}	0.24/0.0001
DM TS	73.5^{a}	66.4^{b}	43.9^{c}	40.2^{d}	36.3^{e}	1.38/0.0001
Total DM	112^{a}	112^{a}	104^{b}	107^{ab}	113^{a}	1.31/0.013
Total CP	18.2	17.9	16.0	16.4	17.0	0.24/0.1110
As % in diet DM						
Rice bran	34.6^{a}	40.9^{b}	57.7^{c}	62.5^{d}	67.9^{e}	0.75/0.0001
Taro silage	65.4^{a}	59.1^{b}	42.3^{c}	37.5^{d}	32.1^{e}	0.75/0.0001
CP	16.2	16.0	15.5	15.3	15.1	0.03/0.0001

^{abcde} *Mean values within rows without a common superscript are different at P<0.05*

3.2.3 Live weight gain and feed conversion ratios

The average daily gain (ADG) and feed conversion ratio (FCR) were improved when the two feed ingredients were mixed together compared with giving them separately (Table 15). This may have been due to the higher CP content of the diets in the mixed system and the expected higher energy content of the mixed diets, which had higher proportions of rice bran compared with the taro silage.

Table 15. Effect of feeding system on the growth performance of common ducks

	Feeding system		
	Mixed	**Separate**	**SE/P**
Initial weight	1085	1090	13.5/0.797
Final weight	2208	2170	13.9/0.078
DMI, g/day	119	110	2.87/0.027
ADG, g	26.3	24.5	0.32/0.002
FCR, kg/kg	4.56	4.48	0.14/0.661

Despite the very wide range in the proportions of taro silage and rice bran there was little variation in the growth rates and feed conversion ratios (Tables 16 and 17) and no relationship between the proportion of rice bran and performance criteria (R^2 =0.09 for ADG and 0.30 for FCR).

Table 16. Effect of ratio of rice bran : taro silage on live weight change and feed conversion of common ducks under the mixed feeding system

	Planned ratio of rice bran: taro silage					
	40:60	**50:50**	**60:40**	**70:30**	**80:20**	**SE/P**
Initial weight, g	1113	1075	1075	1063	1100	28.5/0.727
Final weight, g	2238	2163	2225	2175	2238	29.0/0.320
DMI, g/day	133^{a}	125^{ab}	124^{b}	117^{b}	99.2^{c}	1.56/0.0001
ADG, g	25.7	26.6	25.0	26.9	27.2	0.74/0.329
FCR, kg/kg	5.18^{a}	4.69^{ab}	4.95^{ab}	4.35^{bc}	3.65^{c}	0.13/0.002

^{abc} *Mean values within rows without a common superscript are different at P<0.05*

Table 17. Live weight change and feed conversion ratio of common ducks given rice bran separately from taro silage

	Planned ratio of rice bran: taro silage					
	40:60	**50:50**	**60:40**	**70:30**	**80:20**	**SE/P**
Initial weight, g	1100	1013	1138	1088	1113	29.6/0.168
Final weight, g	2163	2088	2225	2213	2163	27.4/0.083
DMI, g/day	112^{a}	112^{a}	104^{b}	107^{ab}	113^{a}	1.31/0.013
ADG, g	25.1	24.3	24.6	23.9	24.7	0.58/0.686
FCR, kg/kg	4.48	4.63	4.22	4.49	4.58	0.11/0.211

^{ac} *Mean values within rows without a common superscript are different at P<0.05*

3.2.4 Carcass parameters

There were no differences in live weight at slaughter, carcass percentage and the weight of abdominal fat between the ducks on the mixed and separate feeding systems (Table 18).

Table 18. Effect of ingredient ratio (rice bran : taro silage) in two feeding systems on carcass traits and the weight of abdominal fat of common ducks

	Feeding system		
	Mixed	**Separate**	**SE/P**
Live weight, g	2158	2146	16.6/0.615
Carcass weight, g	1453	1444	14.7/0.671
Carcass, %	67.3	67.3	0.29/0.962
Abdominal fat, g	15.4	14.4	1.05/0.523

In contrast, there were positive linear relationships between the proportion of rice bran in the diet and the weight of abdominal fat (Figure 4).

Table 19. Effect of ingredient ratio (rice bran: taro silage) of confined common ducks under a mixed feeding system on carcass parameters

	Planned ratio of rice bran: taro silage					
	40:60	**50:50**	**60:40**	**70:30**	**80:20**	**SE/P**
Live weight, g	2125	2088	2200	2163	2213	26.8/0.089
Carcass weight, g	1405[abc]	1395[b]	1480[abc]	1470[abc]	1515[c]	20.0/0.032
Carcass, %	66.1[a]	66.8[ab]	67.3[ab]	68.0[ab]	68.5[b]	0.40/0.042
Abdominal fat, g	12.5	11.6	17.4	17.0	18.5	1.48/0.067

[abc] *Mean values within rows without a common superscript are different at P<0.05*

Table 20. Effect of ingredient ratio (rice bran: taro silage) on the carcass traits of ducks in a separate feeding system

	Planned ratio of rice bran: taro silage					
	40:60	**50:50**	**60:40**	**70:30**	**80:20**	**SE/P**
Live weight, g	2175[a]	2210[a]	2090[b]	2140[a]	2113[b]	14.7/0.012
Carcass weight, g	1445	1493	1410	1458	1415	22.2/0.193
Carcass, %	66.4	67.6	67.5	68.1	67.0	0.60/0.439
Abdominal fat, g	12.7	11.1	12.7	18.4	17.1	1.41/0.054

[ab] *Mean values within rows without a common superscript are different at P<0.05*

The increase in abdominal fat would appear to be the consequence of the increase in metabolizable energy content of the diets. A similar result was reported in the study by Nguyen Thi Kim Dong (2005) in which the abdominal fat of growing crossbred ducks increased as the fat content of the diet increased.

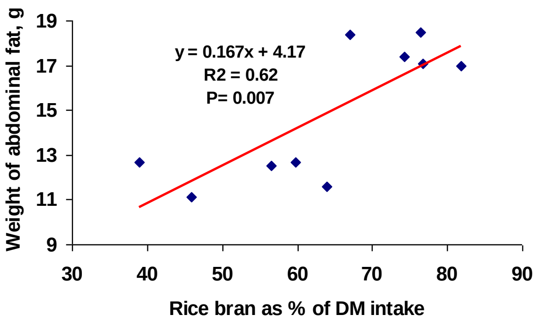

Figure 4. Effect of the proportion of rice bran in the diet on the weight of abdominal fat

3.2.5 Economic benefit and health aspects

The market price of rice bran (3,600 VND/kg) is around half the price of commercial duck feeds (7,800VND/kg). Taro collected by local farmers was valued at VND 500/kg and an extra VND 500 was added for the cost of ensiling. On a 90% air-dry basis this is equivalent to VND 3,644/kg – the same price as the rice bran but half that of the commercial feed. On this basis the feed cost per kg live weight gain is the same irrespective of the proportion of taro silage (Table 21). However, if collection and ensiling of the taro were to be done by household labour (considered as zero cost), then there would be an economic advantage from using taro foliage to replace rice bran.

Table 21. Economic analysis of the effect of level of rice bran supplemented by taro silage for growing common ducks offered mixed or separately (in VND; about 17,800VND=1USD)

Feed cost/kg gain	Mixed system					Separate system				
	40:60	**50:50**	**60:40**	**70:30**	**80:20**	**40:60**	**50:50**	**60:40**	**70:30**	**80:20**
Experimental conditions (*)	18,779	16984	17,907	15,717	13,190	16,257	16788	15,271	16,238	16,553
Home-made taro silage (**)	7,907	8,661	10,728	10,993	10,131	5,580	6,817	8,766	10,103	11,195

(*)1kg rice bran=3600 VND; 1kg taro silage=500 VND (fresh form)+500 VND (ensiling costs)= VND 3,644 on 90% air-dry basis)
(**)Farmers harvest and ensile taro by themselves: 1 kg taro silage=0 VND

There were no health problems on any of the diets and mortality was zero. From the consumer standpoint, the reduction in abdominal fat and the darker yellow colour of the legs and skin, in the ducks fed the higher levels of taro silage, would be considered as an advantage.

4. Discussion

4.1 Experiment 1

The DM and CP intakes were significantly different among treatments (P<0.05) in which ducks were offered the basal diet with five feeding levels and fresh taro leaves were offered *ad libitum*. The increasing fresh taro leaves intake was to compensate for the reduced amount of basal diet. The result is consistent with the study carried out by Nguyen Thi Kim Dong (2005). The minerals and vitamins content of the fresh taro leaves can meet the requirement of ducks. This could explain why the growth performance of the confined common ducks (FCR and ADG) was similar between the two diets (with and without a premix of vitamins and minerals).

In spite of the fact that ducks can consume high amounts of bulky and fibre-rich feeds, the growth rate was poorer than when ducks received a lower fibre and a higher energy diet. The growth performance of the ducks in this study was lower than when ducks were fed "A" molasses substituted for broken rice and rice bran at 15 or 30% in the diet (Bui Xuan Men and Vuong Van Su 1990).

4.2 Experiment 2

After three weeks, it was observed that ducks on the high taro silage diets had difficulties in walking, that could have been due to deficiencies in Calcium and Phosphorus uptakes, which have been shown to increase in diets with high contents of phytates, fat (in rice bran), and oxalates (in taro silage) (Carol Highfill 1998). In addition, the fully confined conditions inhibit the formation of vitamin D, which requires contact with sun light. Another factor which would reduce the Calcium and Phosphorus absorption is the acidity of the diet (taro silage). A similar syndrome (lameness) was also observed in pigs fed distiller grains (pH<4) (farmers' observation). Therefore, it was decided to include the vitamin-mineral premix and the problem disappeared.

Increasing the proportion of rice bran in the diet, at the expense of the taro silage, should have led to an increase in the concentration of metabolizable energy in the diets, and therefore to improved performance in terms of growth rate and feed conversion. In fact, there were no differences in growth performance, but there were major effects on the carcass, with linear decreases in carcass percentage and in abdominal fat as the level of taro silage in the diet was increased. These responses can be considered as positive in terms of carcass quality of the product and the opportunity to use a locally available forage which grows wild in the Mekong Delta.

It is apparent that the ensiled taro foliage (leaf plus stem) has a relatively high nutritive value. The observations in this experiment do not permit conclusions to be made as to the relative nutritional values of the leaf and stem in the ensiled product. Rodríguez and Preston (2009) concluded that ensiling the combined leaf and stem of New Cocoyam (*Xanthosoma sagittifolium*) was a simpler process than ensiling only the leaf. When leaves were ensiled alone a source of fermentable carbohydrate (sugar cane juice) had to be added. However, it was found that the stem contained appreciable amounts of soluble sugars, and thus there was no need for an additive when the leaves and stems were ensiled together. Dao Thi My Tien et al (2010, unpublished data) also observed that the stems of taro (*Colocasia esculenta*) contained high levels of soluble sugars (up to 40% in the DM) and that this facilitated the ensiling process of the combined taro leaves and stems.

The other important characteristic of the taro stem is that it has a lower content of structural carbohydrates compared with the leaf (30.9 vs 37.8 % NDF in DM and 6.11 vs 7.70% ADF in stem and leaf, respectively). These differences together with the high sugar content will result in a higher energy value for the stem compared with the leaf.

5. Conclusions

- Live weight gain was reduced from 30 to 20 g/day, and FCR was poorer, when the basal diet of rice bran, broken rice and SBM, was restricted to 3% of LW (as DM) with fresh Taro leaves *ad libitum*
- There was no effect on ADG and FCR of including a mineral-vitamin premix when Taro leaves were also fed
- Growth rates of the ducks were:
    - The same over a range of ratios of rice bran and taro silage from 80:20 to 40:60
    - 8% higher when the feeds were given as a mixture rather than separately
- Calcium oxalate in taro leaf-stem silage was lower than in fresh taro leaves
- There was a positive effect on carcass quality (lower abdominal fat) from supplementing rice bran with taro silage.
- Smallholders in the Mekong Delta can get significant economic benefits from fattening common ducks using local feed resources (rice bran and taro foliage) that are very cheap compared with commercial feeds and widely available in the region and are safe for ducks.

6. Acknowledgements

The senior author would like to sincerely thank: Sida-SAREC and the MEKARN Program for financial support; all the people who helped to carry out this study; and the Animal Husbandry and Veterinary Department, Faculty of Agriculture and Natural Resources, Angiang University, for support.

7. References

An Giang Statistical Yearbook 2009: Statistical office of An Giang Province.

AOAC 1990: Official methods of analysis. Association of Official Analytical Chemists, Arlington, Virginia, 15th edition, 1298 pp.

Bui Xuan Men and Vuong Van Su 1990: "A" molasses in diets for growing ducks, from http://www.lrrd.org/lrrd2/3/vietnam2.htm

Bui Xuan Men, B Ogle and T R Preston 1995: Use of duckweed (*Lemna spp*) as replacement for soya bean meal in a basal diet of broken rice for fattening ducks, from http://www.lrrd.org/lrrd7/3/2.htm

Bui Xuan Men, Ogle B and T R Preston 1998 Studies on Duck Production in the Mekong Delta, Vietnam. http://www.ardaf.org/NR/rdonlyres/DE8C434A-E246-48CA-B67A-5AE1E0A4DBEC/0/19969BuiXuanMen.pdf

Carol Highfill 1998: Calcium, Phosphorus & vitamin D3 In your bird's diet, from http://www.birdsnways.com/wisdom/ww22eii.htm

Chein Tai and Jui-Jane Liu Tai 2001: Future Prospects of Duck Production in Asia. J. Poult. Sci., Vol. 38: 99-112. (2001), from http://www.jstage.jst.go.jp/article/jpsa/38/1/99/_pdf

Chhay Ty, Khieu Borin and T R Preston 2009: Effect of processing taro foliage on growth of pigs fed two grades of rice bran, from http://www.lrrd.org/lrrd21/11/chha21200.htm

Chhay Ty, Khieu Borin, T R Preston and Mea Sokveasna 2007: Intake, digestibility and N retention by growing pigs fed ensiled or dried Taro (*Colocasia esculenta*) leaf as the protein supplement in basal diets of rice bran/broken rice or rice bran/cassava root meal. Livestock Research for Rural Development. Volume 19, Article #137, from http://www.cipav.org.co/lrrd/lrrd19/9/chha19137.htm

Clench H M and M R John 1995: The avian cecum: a review, from http://elibrary.unm.edu/sora/Wilson/v107n01/p0093-p0121.pdf

Dao Thi My Tien, Nguyen Tuyet Giang and T R Preston 2010: A note on ensiling banana pseudo-stem with Taro (*Colocasia esculenta*) leaves and petioles

Du Thanh Hang and T R Preston 2010: Effect of processing Taro leaves on oxalate concentrations and using the ensiled leaves as a protein source in pig diets in central Vietnam, from http://www.lrrd.org/lrrd22/4/hang22068.htm

Duong Thanh Liem 2001: Biodiversity Approach in Poultry Breeding in Vietnam , University of Agriculture and Forestry - Ho Chi Minh City.

Edan M, Luthi N Bourgeois, Gautier P and Guerne-Bleich E 2006: Free ranging ducks and risks in Avian Flu disease in Vietnam.

FAO 2008: Biosecurity for Highly pathogenic Avian influenza, from http://www.fao-ectad-nairobi.org/IMG/pdf/Biosecurity_and_HPAI.pdf

Houston D F 1972: Rice bran and polish. p. 272-300.

Khieu Borin, J E Lindberg and R B Ogle 2005: Digestibility and digestive organ development in indigenous and improved chickens and ducks fed diets with increasing inclusion levels of cassava leaf meal**.** Doctoral thesis No. 2005:82

Le Thanh Phong, Henk M J Udo, Martinus E F van Mensvoort, Roel H. Bosma, Le Quang Tri, Dang Kieu Nhan and Akke J van der Zijpp 2007: Integrated Agriculture-Aquaculture Systems in the Mekong Delta, Vietnam: An Analysis of Recent Trends. Asian Journal of Agriculture and Development, Vol. 4, No. 2, from http://www.searca.org/ajad/archives/v-04/02/ajad_v4_n2_phong.pdf

Malavanh Chittavong, T R Preston and B Ogle 2008a: Effect of replacing soybean meal with a mixture of Taro (Colocasia esculenta (L.)Schott) leaf silage and water spinach on apparent digestibility in Mong Cai gilts at two stages of gestation. Livestock Research for Rural Development. Volume 20, supplement, from http://www.lrrd.org/lrrd20/supplement/mala3.htm

Malavanh Chittavong, T R Preston and B Ogle 2008b: Ensiling leaf of Taro (*Colocasia esculenta* (L.) Shott) with sugar cane molasses. Livestock Research for Rural Development. Volume 20, supplement, from http://www.lrrd.org/lrrd20/supplement/mala1.htm

Martz F A, Weiss M F and Belyea R L 1990: Determination of oxalate in forage by reverse-phase high pressure liquid chromatography. Journal of Dairy Science 73; p474-479, from http://jds.fass.org/cgi/reprint/73/2/474.pdf

National Academy of Sciences 1994: Nutrient Requirements of Poultry. Ninth Revised Edition, 1994, page 42-43, from http://www.nap.edu/openbook.php?record_id=2114&page=42

Nguyen Thi Kim Dong 2005: An evaluation of brewery waste as a replacement for concentrates in diets for growing crossbred common ducks. Tropical Animal Health and Production. 36 (7): 715-729

Nguyen Tuyet Giang 2008: Taro (*Colocasia esculenta*) silage and water spinach as supplements to rice bran for growing pigs, from http://www.mekarn.org/msc2008-10/miniprojects/minpro/giang.htm

Pheng Buntha, Khieu Borin, T R Preston and B Ogle 2008: Digestibility and nitrogen balance studies in pigs fed diets with ensiled taro (*Colocasia esculenta*) leaf as replacement for fish meal. Livestock Research for Rural Development. Volume 20, supplement, from http://www.cipav.org.co/lrrd/lrrd20/supplement/bunt2.htm

Pousga S, Boly H and B Ogle 2005: Choice feeding of poultry: a review, from http://www.lrrd.org/lrrd17/4/pous17045.htm

Rodríguez L and T R Preston 2009: A note on ensiling the foliage of New Cocoyam (*Xanthosoma sagittifolium*). Livestock Research for Rural Development. Volume 21, Article #18, from http://www.lrrd.org/lrrd21/11/rodr21183.htm

Siregar A P, Cumming R B and Farrell D J 1982: The nutrition of meat-type ducks. 1. The effects of dietary protein in isoenergetic diets on biological performance, from http://www.publish.csiro.au/paper/AR9820857.htm

Tahira R, Ata-ur-Rehman and Muhammad Anwar Butt 2007: Characterization of rice bran oil, from http://www.jar.com.pk/pdf/45-3-9.pdf

Teo S S 2001 Evaluation of different duck varieties for the control of the golden apple snail (Pomacea canaliculata) in transplanted and direct seeded rice, from http://pestalert.applesnail.net/conferences/icam07/malaysia.pdf

Van Soest P J, Robertson J B and Lewis B A 1991: Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74: 3583-3597, from http://jds.fass.org/cgi/reprint/74/10/3583