Evaluation of Agro-Industrial By-Products as Protein Sources for Duck Production in the Mekong Delta of Vietnam

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Doctoral thesis
Swedish University of Agricultural Sciences
Uppsala 2005

Acta Universitatis Agriculturae Sueciae
2005: 81

ISSN 1652-6880
ISBN 91-576-6980-5

Tryck: SLU Service/Repro, Uppsala 2005

Abstract

Nguyen Thi Kim Dong, 2005. Evaluation of agro-industrial by-products as protein sources for duck production in the Mekong Delta of Vietnam. Doctor´s dissertation.
ISSN 1652-6880, ISBN 91-576-6980-5.

This thesis is based on four studies to determine the nutritive value and ileal and total tract amino acid digestibility of agro-industrial by-products, and the effects of inclusion of these by-products in diets on the biological performance of growing crossbred Muscovy and common ducks in the Mekong Delta, Vietnam.

The results show that brewery waste (BW) was characterised by high protein content, good balance of essential amino acids, but high crude fibre content. The best growth performance was observed when 50% of the concentrate was replaced by BW for both Muscovy and common ducks. The crossbred Muscovies had better performance and gave higher economic benefit than the local Muscovies, and common ducks gave the lowest profit. BW could be offered either in mixed or separate feeding systems without any effects on performance and carcass yield (Paper I and II).

Soya waste (SW) and ensiled shrimp waste (ESW) are good protein sources, but low in dry matter (DM) and methionine content (SW) and high in chitin content (ESW). The best performance in terms of growth rate and carcass quality was found with replacement of up to 60% of soybean meal by SW, and only 20% of fish meal by ESW, which gave the lowest feed costs (Paper III).

The inclusion of ESW in diets for adult crossbred common ducks resulted in a linear decrease of the apparent total tract digestibility of dry matter, organic matter, ether extract, N free extract and N retention with increasing levels of ESW. The digestibility of individual amino acids followed a similar pattern to the nutrient digestibility. The apparent total tract digestibility of most individual amino acids was higher than the apparent ileal value (Paper IV).

It can be concluded that from nutritive and economic aspects the three agro-industrial by-products evaluated have proven to be acceptable feed ingredients in duck diets. Replacement up to levels of 20% (ESW), 50% (BW) and 60% (SW) of fish meal, concentrate and soybean meal, respectively, in diets for growing crossbred ducks can be recommended under the conditions of the Mekong Delta.

Key words: Ducks, brewery waste, ensiled shrimp waste, soya waste, performance, profit, ileal digestibility, amino acids.

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To Prof. Dr. Brian Ogle, Prof. Dr. Jan-Erik Lindberg and Dr. Klas Elwinger, gratefully

Contents

Appendix

Papers I - IV

The present thesis is based on the following papers, which will be referred to by their Roman numerals:

I. Dong, N.T.K. & Ogle, R.B. 2003. Effect of brewery waste replacement of concentrate on the performance of local and crossbred growing Muscovy ducks. *Asian-Australasian Journal of Animal Sciences.* 16 (10): 1510-1517.

II. Dong, N.T.K. & Ogle, R.B. 2004. 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.

III. Dong, N.T.K., Elwinger, K., Lindberg, J.E & Ogle, R.B. 2005. Effects of replacing soybean meal with soya waste and fish meal with ensiled shrimp waste on the performance of growing crossbred ducks. *Asian-Australasian Journal of Animal Sciences.* 18 (6) 825-834.

IV. Dong, N.T.K., Elwinger, K., Lindberg, J.E & Ogle, R.B. 2005. Ileal and total tract digestibility of amino acids in ducks fed ensiled shrimp waste (Submitted).

List of abbreviations

AA	Amino acid
CATTD	Coefficient of apparent total tract digestibility
ADF	Acid detergent fiber
AIBP	Agro-industrial by-products
BR	Broken rice
BW	Brewery waste
BDG	Brewers dried grains
C	Concentrate
CM	Crossbred Muscovy duck
CF	Crude fibre
CP	Crude protein
DDGS	Distillers dried grain with solubles
DG	Daily gain
DM	Dry matter
DW	Duckweed
EAA	Essential amino acid
EE	Ether extract
ESW	Ensiled shrimp waste
FCR	Feed conversion ratio
FM	Fish meal
FS	Feeding system
GE	Gross energy
LM	Local Muscovy duck
ME	Metabolisable energy
M	Mixed
NDF	Neutral detergent fiber
NFE	Nitrogen-free extractives
OM	Organic matter
ULS	Urban and peri-urban livestock system
SBM	Soybean meal
S	Separate
SW	Soya waste
VND	Vietnamese Dong

Introduction

The Mekong Delta is situated in the South of Vietnam, and has a population of 22 million and an area of 39,551 km^2. It is the major agricultural region of Vietnam, and is also considered to be the most important rice granary for the country, accounting for about 48% of the total rice production. The delta is a four million hectare flat lowland plain of alluvial, acid and saline soils watered by the Mekong River and its canal networks. The ambient temperature fluctuates between 22 and 25 ^{0}C in the coolest months (December-January) and 32-33 ^{0}C in the warmest months (April-May). Annual rainfall is 1400-2400 mm, and the average humidity varies from 76 to 80%. Most of the arable land is used intensively for rice cultivation or other crops throughout the year, and yields are generally high. Therefore there are considerable quantities of agricultural by-products available throughout the year, many of which are potentially valuable as feed resources for livestock.

Duck production plays an important role in the Mekong Delta, providing meat and eggs in the diets of the people and income from local sales and in the markets of Ho Chi Minh City and abroad. The population of ducks has increased in recent years in Vietnam, and was estimated at 69 millions in 2003 (FAOSTAT data, 2004). Although ducks are raised throughout the country, production is concentrated to the Mekong Delta, which has more than 50% of the total population, made up of 80% common ducks (*Anas platyrhynchos*) and 20% Muscovy ducks (*Cairina moschata*) (Quac, 1990). In the Mekong Delta more than 95% of the total production is from smallholder farmers, who use different traditional systems, such as rearing around gardens, along canals, on the seashore and in the rice fields post-harvest. In these systems ducks forage for themselves and consume locally available feeds, and are normally only supplemented small amounts of rice or not at all. Because of the low or non-existent inputs these systems are therefore quite profitable. However, duck producers have a problem of limited scavenging, due to the introduction of intensive, high-yielding rice varieties. Also, in recent years some local governments in the Mekong Delta have campaigned to prohibit raising ducks in scavenging systems in order to protect irrigation systems and prevent water pollution and disease transmission. Therefore confinement systems have been developed, especially for resource-poor, peri-urban producers, who raise ducks on a small scale for income generation. However, they usually feed their birds concentrates or provide supplements of conventional protein feeds, such as fish meal or soybean meal, which are currently expensive. The producers have also been vulnerable to changes in the price of feed, and lose money when the price of the conventional feeds increases, and therefore have started to utilise alternative protein resources to reduce production costs.

Many cities and towns in the Mekong Delta have rapidly increasing human populations and consequently increasing demands for duck meat and eggs. Thus, to meet the increasing consumer demand, and increase profit margins, there is an increasing interest in confinement of improved breeds reared on cheap, locally available materials and unconventional feeds.

The environmental and hygienic impact of agro-processing industries in the cities has been strong due to the production of large amounts of waste, which is a problem that urgently requires solutions (Dalsgaard and Schiere, 2001)**.** However, agro-industrial by-products have contributed considerably to animal production in Vietnam, especially brewery waste, soya waste, and shrimp waste, which are protein-rich feed resources that are quite common and cheap in the Mekong Delta. They are produced almost all the year round in large quantities. According to Göhl (1998) and Westendorf and Wohlt (2002), brewery waste is a good feed resource for livestock with a reasonably high protein content of between 23-32% crude protein (CP, DM basis). Several studies have indicated that brewery waste included in diets improved the growth rate and feed conversion, and also increased fertility and hatchability in poultry (Thornton *et al.*, 1962; Kienholz *et al.*, 1967). Shrimp by-products are widely used as supplements for livestock, including ruminants, pigs and poultry (Evers and Carroll, 1996; Fanimo *et al.*, 2004; De Silva, 1998; Oduguwa *et al.*, 2004). Soya waste is another protein source available locally, with a CP content of around 22% (Dong *et al*, 2003a). However, information on the feeding and nutrient digestibility values of these by-products and their effects on the performance of ducks is very limited. Therefore, an improved understanding of feeding systems incorporating these products for duck production in the peri-urban and urban areas would be very useful for the producers in the Mekong Delta.

Objectives

The main objectives of this thesis were:

- To determine the chemical composition of brewery waste, soya waste and ensiled shrimp waste.
- To evaluate the effect of including these by-products in the diets on the performance and carcass traits of different breeds of growing duck.
- To determine ileal and excreta digestibility values of individual amino acids in these by-products in ducks.
- Also, to generate information on the economic impact for urban producers of using brewery waste, soya waste and shrimp waste in duck diets.

Background

Urban and peri-urban livestock systems (ULS)

Worldwide, the proportion of the population living in towns and cities had increased to around 45% in 1995, and is projected to reach 60% by 2025 (Rajorhia, 1999). In developing countries, the urban proportion is around 37% with marked differences between the regions, *e.g.*, 74% in Latin America and about 34% in Africa and Asia. Rapid urbanisation has greatly affected urban and peri-urban livestock production, which grew at an annual rate of 4.3% in comparison with 2.2% in rural mixed farming systems, and at more than six times the rate of grazing systems (Rajorhia, 1999). The continuing rapid increase of urban populations will be associated with the need for the development of innovative meat, milk and egg production systems, and processing, marketing and distribution schemes to meet the rising demands. Livestock seem to be recognized for the positive role that they can play in urban living conditions across the world. Indeed, livestock production has a variable and controversial, but often essential, role to play in and for cities (Rajorhia, 1999).

Efficiency and problems of ULS

Urban and peri-urban agriculture, including livestock, can have both positive and negative effects on the health and environmental conditions of the urban population. The positive aspects include reduction of urban food insecurity, improved access to food and improved diets of the urban poor, better physical and psychological health of the population due to greater physical activity, outdoor relaxation and better sanitation, and the greening of the direct environment (de Zeeuw, 2000). Thus, it can be said that: "urban and peri-urban agriculture has been used as a household strategy to respond to both chronic and emergency food insecurity" (Nugent, 2000). It offers opportunities for productive employment in a sector with low barriers to entry, and is estimated to involve 800 million urban residents worldwide in income-earning and/or food-producing activities. For the urban poor, livestock provide animal protein for the family, which it could not afford to buy. Urban livestock generate some income through sales of animals, milk and manure, and provide lower-cost food for urban dwellers, due to the fact that direct producer-consumer sales are possible, and there is little or no need for processing, packaging and storage. Peri-urban and urban livestock allow owners to save capital and provide part-time employment for family members, especially those without formal training. However, raising livestock in urban areas gives rise to problems, such as the proximity of animals to humans that increases the risk of transmitting diseases, high animal mortality, traffic accidents, and the noise and odours from livestock (Waters-Bayer, 2005).

Agro-industrial by-products as feeds for the ULS

In Vietnam, women, who can combine food production activities with childcare and other household responsibilities, often carry out urban livestock keeping on a part-time basis (Thanh, 2001). This enables them to use land more efficiently, and to make productive use of “free” resources such as food processing residues and kitchen wastes. Therefore, a key opportunity offered by urban livestock keeping, is waste recycling. One of the biggest problems in cities is garbage, which can be a resource for animals: organic wastes from households and markets and agro-industrial by-products can provide valuable feeds. The value of recycled wastes for livestock has long been recognised in Asian cities (Waters-Bayer, 2005). Available product residues from seafood factories and food industries, such as fish residues and shrimp wastes, as well as many kinds of fruit and vegetable wastes in Vietnamese urban areas can be useful sources of nutrients for livestock. Utilizing these by-products for feeding animals contributes to reduced environmental pollution. Studies, for example, reported that shrimp by-product could improve the supply of protein for livestock in Central Vietnam (An, 1999; Toan and Ngoan, 2003). Also, there are large amounts of market wastes available as potential livestock feeds in the cities. Ngu (2001) reported that market wastes from fruits and vegetables in Cantho City were promising feeds for urban goat production. Dong (1999) and Dong and Ogle (2003b) also found that poor duck producers in Cantho City in the Mekong Delta benefited economically from the utilization of brewery wastes, soya waste and shrimp waste produced in local factories.

Duck production systems

Ducks are raised under a wide variety of conditions in Vietnam, ranging from those provided for a single pet duck to those existing on a large commercial duck farm. Duck farming systems around the world range from the very extensive herding systems of the Orient, to the highly intensive modern commercial duck producing systems of the West, which are becoming much more common in the East as well (Sandhu and Dean, 2005). About 90% of the domesticated ducks in the world are found in Asia (FAO, 2005a), where the duck population was estimated at more than 1 billion birds in 2003 (FAOSTAT, 2005). Most of the duck systems found in rice producing countries are often closely integrated with other plants and animals (Scott and Dean, 1991).

Ducks are raised both in the peri-urban and rural areas of Vietnam. Production is mainly in smallholdings or integrated systems (Quac, 1990), but large, more intensive systems also exist. The rearing of ducks in urban areas has developed with the increasing demand for animal products in the cities (Thanh, 2001). However, urban livestock production, including ducks, in the Mekong Delta today has tended to move out from the city and town centres to peri-urban and rural areas. The production system that is most prevalent in a particular region depends on the agro-ecological zone and on conditions such as the availability of agro-industrial by-products or other locally available feed resources.

Scavenging systems

Duck farming based on scavenging is a particularly important activity in many countries in South-East Asia. Most local duck breeds are suitable for rearing in this way. Various systems have evolved in Vietnam, where duck production occurs either in full scavenging systems or under semi-scavenging conditions. Ducks might be kept in partial confinement or be enclosed during the nights only. The scavenging systems are characterized by low feed inputs and low standards of management and housing, and although resulting in low outputs can be quite profitable. Scavenging ducks in the Mekong delta can be found in several different environments. Often small group of ducks (common and Muscovy) are kept in backyards, eating natural feeds as well as kitchen wastes and purchased feed. These systems are common in peri-urban areas. The delta area is cluttered with rivers and canals and it is beneficial to keep ducks along the canal banks, although in some provinces problems with erosion have led to this practice being banned. Moreover, in the coastal areas shellfish are abundant, and are a good source of protein and minerals, and thus scavenging ducks kept for the production of table-eggs are mainly concentrated to the seashores (Becerra, 1994). However, a major disadvantage of this system is the difficulty in controlling health problems. Especially from early 2004 until now Avian Influenza outbreaks have occurred in Vietnam and other Asian countries, and there have been widespread H5N1 infections in ducks and chickens throughout the country, and in particular in the Mekong Delta. Considerable evidence indicates that most ducks in scavenging systems can carry the H5N1 virus without showing symptoms, and asymptomatic ducks can rapidly spread the virus to other flocks and humans (Recombinomics, 2005).

Integrated duck production systems

Many farming systems in Vietnam involve the integration of several components, including livestock, aquaculture, horticulture and rice cultivation. In common with producers in other Asian countries with experience of raising ducks (Kang *et al.*, 1995; Ketaren, 1998), farmers in Vietnam integrate ducks in many combinations such as: pigs-ducks-chickens-vegetables-fruit-aquaculture, pigs-ducks - goat-rice - vegetables - aquaculture and pigs - ducks - cattle - vegetables - aquaculture (Devendra, 1997). In the Mekong Delta these systems are common and are collectively called the VAC system, where the abbreviation stands for the Vietnamese words for garden, fishpond and animals (Ogle and Phuc, 1997). A VAC system can for example comprise ducks, fish, water plants and fruit trees, where the faeces from the ducks become feed for fish, and fertilizer for plants and trees, while the ducks can utilize part of the plants and fish as feed. The system implies an efficient utilization and circulation of nutrients and is better for the environment. Other systems based on the rice fields are integrated duck-rice cultivation, which has been shown to reduce or eliminate insects and weeds (Men *et al.*, 2001a), and to increase rice yields (Villamora *et al*., 2000). The fish-duck system is particularly beneficial as it is environmentally friendly, and results in improved feather quality for the ducks (Edwards, 1986).

Intensive confinement systems

In these systems ducks are kept in total confinement and all facilities are provided *i.e.* water and feed, in a sheltered area or pen. A well balanced ration is needed. Water pans should be designed such that the ducks cannot sprinkle the water. This system has mainly developed in peri-urban areas, due partly to limited possibilities to keep ducks in scavenging systems. In Vietnam this system is popular for raising exotic breeding ducks and for fattening growing meat-type ducks. High productivity can be achieved with intensive confinement systems, since the production, including feeding and management, is under controlled conditions, that thus optimise output. In this system ducklings are usually reared up to eight or nine weeks of age (Nho *et al.*, 1995; Quoc *et al*., 1995), which is the market age preferred by consumers. Only a relatively small number of improved breeds (Cherry Valley and Super-Meat ducks) are produced in confinement using commercial feeds, because the system requires high inputs, such as labour and capital investments for feed and housing (Scott and Dean, 1991). Intensive confinement systems for ducks have become more common in certain areas of Vietnam, for example around Ho Chi Minh City, but in the Mekong Delta the small-scale full or semi-confinement systems are still predominant. Especially in urban and peri-urban areas growing ducks are raised in these systems and fed unconventional feeds, such as locally available agro-industrial by-products, kitchen wastes and market wastes and thus should be more profitable, as a result of low feed costs. The meat from birds grown semi-intensively in unpolluted areas has a better taste and food value than from those grown intensively (Sandhu and Dean, 2005).

Duck breeds

All domesticated or farmed ducks originate from the Mallard, with the exception of the Muscovy, which has distinct origins in South America. Farmed ducks are therefore broadly divided into two types: the Mallard-type (*Anas platyrhynchos*) and the Muscovy duck (*Cairina moschata*) (Scott and Dean, 1991). Several breeds of duck are raised in Vietnam, including the Muscovy and so-called common duck, that are estimated to account for 20% and 80%, respectively, of the total duck population of the country (Quac, 1990). The common duck includes local ducks and their crosses with some exotic strains (*e.g*. Cherry Valley, Super-Meat ducks).

Muscovy ducks

Several different breeds are found in the Mekong delta, including local and exotic Muscovies and their crosses. Local Muscovy ducks have been raised on a small scale for a long time. They are commonly allowed to scavenge around the backyards and gardens or confined in simple shelters in small flocks of from 10-50 head, and have low performance due to their small body size. Their products, including a carcass with red meat, are mainly consumed within the family. French Muscovy ducks were imported into Vietnam and acquired by Cantho University in 1993. They have black and white coloration, and bright red caruncles on their face and over the base of their bill. The males can grow to be quite large, weighing 5-7 kg. Most females are 2.5-3.5 kg, and thus they have better growth performance, and higher live weight compared to local ducks at the same age. Crosses of French and local Muscovy ducks have been produced and raised on farms, and have a bigger body size and better growth rate than local Muscovy ducks (Phuoc *et al.*, 1994). Subsequently they were introduced to local producers who were advised to feed them with good quality concentrate in the urban and peri-urban areas and on local feed resources in the villages (Dong and Ogle, 1995). The Muscovy is characterised by the production of a less fatty carcass (Parkhurst and Mountney, 1988), large pectoral muscles, and sexual dimorphism which is in favour of the male. Optimum carcass quality requires that the female should be slaughtered at 10 weeks and the male at 11-12 weeks of age (Larbier and Leclercq, 1994).

Common ducks

Common ducks have been produced for example from male Cherry Valley (imported from Czechoslovakia in 1975) and female Pekin ducks, with a range of final weights from 1.84 to 1.99 kg when raised on local feeds (Toung, 1994). Other crossbred common ducks have been produced from male Super-Meat ducks (a meat-type duck that is a heavy breed specialised for meat production that was imported from the U.K. in 1989) crossed with female crosses between Cherry Valley and Pekin ducks. Their crosses are widely raised in the villages, where they scavenge in rice fields post-harvest and in canals. Alternatively they are confined and fed conventional feeds in peri-urban areas, usually giving lower benefits due to their high intake of concentrate feeds and lower price per unit of live weight at market age. They reach slaughter weight at an age of between 7-8 weeks (Wiseman, 1987) or around 10 weeks of age, 2 weeks younger than for Muscovy ducks (Toung, 1994; Dong and Ogle, 2004).

Protein and amino acid requirements of ducks

Global production of duck meat shows a continuous and rapid increase (FAOSTAT, 2003). The growth and protein accretion potential of ducks have been improved by selective breeding in recent decades with respect to changes in body composition and improvement in feed conversion ratio (Timmler and Jeroch, 1999). Studies on the requirements of the modern breeds for essential amino acids (EAA), however, are few, but do exist (Elkin, 1987). Recently, requirement studies have been conducted with White Pekin ducks for lysine, methionine, threonine and tryptophan (Bons *et al.*, 2002). The NRC (1994) requirements for some EAA were based on very few studies or even only one study, and were explicitly entitled "tentative dose-responses".

Many studies on the protein and amino acid requirements of chickens have been carried out, but very few on ducks. These values differ, depending on the kind and age of bird and the purpose of its production. However, the amino acid composition of the proteins of the various animal species varies little when considered in terms of amino acids as percentages of the carcass proteins.

Table 1. *Protein and amino acid requirements (% of diet) of young growing (0-2 weeks) and growing ducks (2-7 weeks)*

Item	Young growing ducks						Growing ducks	
	1	2	3	4	5	6	7	8
ME, MJ/kg	12.8	13.0	12.1	11.9	11.95	12.5	12.6	12.3
Crude protein	18.3	22.0	22.0	22.0	22.5	22.0	16.0	16.0
Lysine	0.86	1.10	0.90	1.10	1.20	0.86	0.65	0.80
Methionine	0.38	0.44	0.40	0.48	-	0.40	0.30	0.35
Meth. + cys.	0.68	0.79	0.70	0.83	0.80	0.69	0.55	0.60
Arginine	1.05	1.10	1.10	1.10	1.20	1.10	1.00	0.85
Tryptophan	0.22	0.25	0.23	0.22	0.23	0.23	0.17	0.20
Glycine+ Serine	1.05	-	-	-	1.53	-	-	-
Threonine	0.59	0.80	-	0.76	0.79	-	-	-
Isoleucine	0.67	0.88	0.63	0.84	0.92	-	0.46	0.65
Leucine	1.24	1.32	1.26	1.56	1.56	-	0.91	1.10
Phenylalanine	0.55	0.80	-	0.78	-	-	-	-
Histidine	0.32	0.44	-	0.44	-	-	-	-
Valine	0.78	0.88	0.75	0.93	1.07	-	0.56	0.60

1: Blair *et al.* (1983), 2: Scott & Dean (1991), 3 &7: NRC (1994), 4: Lesson & Summers (1997), 5 & 8: Rose (1997) and 6: Klasing (1998).

Ideal protein concept

The balance of a mixture of AA in the diet is very unlikely to exactly meet the requirements of each of the animal tissues. A deficiency of an AA is likely to cause a reduction in performance and excesses of AA can also be deleterious (Buttery and D´Mello, 1994). It has therefore been suggested that the most important single factor affecting the efficiency of protein utilisation for meat production is the dietary balance of AA (Cole and Van Lumen, 1994). In order to compare the pattern of AA in diets for monogastric animals, the ideal protein provides a simple and effective approach. The protein has a balance of essential amino acids that exactly matches a bird´s requirement, along with sufficient non-essential amino acid nitrogen to permit the synthesis of all of the non-essential amino acids, and is referred to as the ideal protein (Baker and Han, 1994; Cole and Van Lumen, 1994). For convenience, the proportion of each amino acid is expressed relative to the amount of lysine. Lysine is chosen as the standard because it is particularly well studied and because it is not used extensively for purposes other than protein synthesis. The amount of ideal protein needed to meet all of the bird´s amino acid requirements is equal to that bird´s minimum protein requirement, and the ideal protein in which amino acid needs could be proportioned one to another (Klasing, 1998). Today, ideal AA ratios, with lysine as the reference AA, are used throughout the world for diet formulation of pigs (Fuller, 1994; NRC, 1998) and increasingly for poultry (Emmert and Baker, 1997; Mack *et al*., 1999; Baker *et al*., 2002). The ideal balance of amino acids for growing ducks is shown in Table 2.

Table 2. *Ideal balance of amino acids for growing ducks (expressed as percent of lysine)*

Amino acid	ARC (1975)	Farrell (1990)	Rose (1997)
Lysine	100	100	100
Meth. + Cys.	83	30 (Meth.)	75
Tryptophan	19	-	19
Threonine	66	73	66
Leucine	132	131	130
Valine	89	98	89
Isoleucine	77	77	77
Phe + Tyr.	144	79 (Phe.)	120
Histidine	44	33	43
Arginine	94	118	100
Glycine + serine	-	156 (Glycine)	127
Tyrosine	-	62	-

Feeds for ducks

Conventional feeds

Broken rice and rice bran. The traditional diets for monogastric livestock, especially chickens and ducks, in the Mekong Delta are based on rice, either paddy rice or rice by-products, such as broken rice and rice bran. As reported by Lung and Man (1999), broken rice and rice bran are widely used, and provide up to 80-90% of the energy in diets for growing ducks, and rice bran commonly accounts for 20% of the energy for both growing and breeding ducks. With the recent expansion of animal production, the demand, and consequently the price, for these feeds have increased. Since the price of rice also fluctuates widely, the profitability of duck production varies (Becerra, 1994). Some producers use commercial concentrates for feeding in intensive confined duck systems, which can give good performance results, but low profits.

Soy bean meal is an important source of dietary protein and energy for poultry throughout the world. However, not so much soybean is grown in Vietnam, so the price is generally too high to use it in animal feeds. The raw soybean seeds contain a number of natural anti-nutritional factors for poultry, the most problematic being trypsin (protease) inhibitors. Thus, to increase the protein nutritive value (Balloun, 1980), these anti-nutritional factors must be destroyed. Trypsin inhibitors disrupt protein digestion, which results in decreased release of free amino acids, and their presence is characterised by compensatory hypertrophy of the pancreas due to stimulation of pancreatic secretions. Fortunately, the heat treatment done during processing is usually enough to destroy trypsin inhibitors and other toxins such as lectins (haemagglutinins) (Göhl, 1998). The growth depressant effect of lectins is believed to be due primarily to their damaging impact on intestinal enterocytes (Pustzai *et al.*, 1979) and to appetite depression (Liener, 1986). Moreover, Coon *et al*. (1990) reported that the oligosaccharides, raffinose and stachyose, in soybean might be anti-nutritional factors. Soybean meal with added DL-methionine is equivalent to fish meal in protein quality, and economic savings from the replacement of fish meal can be up to 30% in Vietnam (Lung and Man, 1999).

Fish meal. The fact that aquaculture is common in the Mekong Delta makes fish meal a readily available source of protein, and its excellent nutrient and energy values also complement those of other feedstuffs very well, provided that the fish meal has been properly processed (Scott and Dean, 1991). Fish meal is commonly supplemented at levels of from 10-20% in diets for ducks and chickens in the delta region (Lung and Man, 1999).

Agro-industrial by-products (AIBP)

The food trade and processing industry, as well as the manufacture of industrial products from agricultural raw materials, create large quantities of by-products in various regions of the world. Many by-products of milling, brewing, sugar and oil industries are traditionally used for livestock feeding. New processing and preparation techniques lead to new products which can be used as unconventional animal feeds. In view of the reported shortages of conventional feeds for livestock and poultry, there is a need to develop technologies for using more efficiently by-products obtained from food and agro-industries, and other non-conventional feeds as protein and energy supplements. The quantity and time period during which they are available, storage properties, cost of transport, preparation, and preservation are determining factors for their possible use (Rajorhia, 1999).

To develop duck production in the Mekong Delta in a sustainable way, it is important to further explore the possibilities of utilising locally available agro-industrial by-products, such as brewery-, shrimp- and soya waste. Protein and other commercial concentrates provided by feed companies are usually expensive, can vary considerably in price, and price changes can occur unexpectedly (Dong, 1999), and so by-products improve the stability of the production system.

Brewery waste (BW). Brewery waste (brewers grains) is a by-product of beer making, and contains 21-29% crude protein on DM basis (Su and Station, 1996; Westendrof and Wohlt, 2002). The wastes have been fed to livestock since the advent of beer production in many countries in the world. They consist largely of structural carbohydrates and the protein remaining when barley is malted and mashed to release sugars for brewing. Brewery waste, because of the removal of sugars and starches during the malting and mashing process, is higher in fibre (cell-wall carbohydrates), protein, and some minerals than are the foundation grains (Westendrof and Wohlt, 2002). It is a concentrated source of digestible fibre, with good amino acid, B-vitamin and phosphorus contents, but is low in other minerals. Fresh brewer´s grains contain about 700-760 g water/kg and have been fed to cattle, sheep and horses in fresh or silage form (McDonald, 2002), and to pigs in wet or dried form (Altizio *et al*., 2000; Calvert, 1991). The solubles have been incoporated into poultry rations (Stengel, 1991), and in diets for Pekin and Muscovy ducks (Farhat *et al.*, 2000).

In Cantho City around 15 tons of brewery waste is produced daily. It can be stored anaerobically for up to 2 weeks, for example in large plastic containers. The protein in brewery waste is of lower quality compared with other protein supplements, e.g, soybean meal and fish meal, but the cost is much lower. Hence, in peri-urban areas in the Mekong delta producers commonly use BW in diets for dairy cows, pigs, chickens and occasionally ducks and fish (a mixture of brewery waste with fresh ground shrimp waste). However, BW has sometimes caused serious pollution in the urban areas, especially before festivals and the New Year holidays. There is little information or recommendations available relating to field research on BW, especially for poultry in this area and the rest of Vietnam.

Soya waste (SW). Soya waste, a by-product from soybean processing, sometimes known as soybean-curd lees or tofu-cake, is left over when tofu is made from soybeans. The filtrate, which contains protein and fat, and is made from milled and boiled soybean mash, is called soy-milk, while tofu wastes are the residue. Soya waste is a low cost and nutritious feed for livestock which is widely available in several Asian countries. The product is both a source of energy and protein, and is an excellent feed for ducks and pigs, either fed alone or mixed with rice bran, limestone and salt to make a more complete supplement (Minh, 2000; Hong *et al*., 2003). Since

SW has a water content of over 80% and a high protein content, it quickly deteriorates.

Of the soybeans produced in Vietnam, approximately two-thirds are used directly for human food products, such as fresh tofu, fermented tofu, soya milk and soya sauce. The rest, soya waste, which generally has a lower quality, is used for animal feed (Carlén and Lansfors, 2002). It is estimated that about 5 tons/day of soya waste is produced by small artisans and large factories in Cantho City. Soybean meal is commonly used for chickens and ducks. However, it is fairly expensive, and therefore a much cheaper alternative in the Mekong Delta is to utilize the soya waste from the local food industries. Phuong (2001) reported that molasses proved to be better than broken rice in preserving the soya waste for up to four weeks under anaerobic conditions, without changing its nutritive value.

Shrimp waste. Traditionally the waste products from shrimp processing factories were dumped into the waterways, causing environmental pollution in Vietnam (Hieu, 2000). Ensiling shrimp waste with molasses is one way of preserving this product for feeding to ruminants, pigs and poultry. In recent years shrimp production for export has increased rapidly in Vietnam, resulting in large quantities of by-product from the shrimp processing industry. The by-product consists of head and shell, and constitutes on average about 50% of the total raw material (Ngoan, 2000) and 187,000 and 145,000 tons of shrimp were produced in 2002 in the country and the Mekong delta, respectively (FAOSTAT, 2004). Cuc *et al.* (2002) reported that after ensiling with molasses for about two weeks shrimp waste had a good smell and contained 32.9% crude protein compared to 23.7% on ensiling. Shrimp waste has high calcium and low phosphorus concentrations, which range from 5 to 15% and 1 to 2% (DM basis), respectively (Watkins *et al.*, 1982; Meyers, 1986). Meyers and Benjamin (1987) reported that the Ca content is reduced during ensiling, and for example a 70% reduction of exoskeleton calcium carbonate was observed in crayfish silage at a pH of 4.2, from acid/enzymatic hydrolysis, compared to non-treated material. The ensiled shrimp waste (ESW) can be stored up to 8 weeks without changing its nutrient contents. Ramachandran *et al*. (1997) reported that fresh shrimp waste could be ensiled with rice bran using 10% tapioca flour as additive. Ngoan *et al*. (2000a) indicated that the amino acid composition of shrimp waste was fairly balanced, but the low methionine content can limit its value for monogastric animals. Other factors, such as high chitin and calcium contents, could limit the amount of shrimp waste in monogastric diets.

Ensiling shrimp waste

Ensiling is the process by which wet fodder is preserved and stored, for later use, by the action of acids, which are added or produced in situ by bacterial action (Raa and Gildberg, 1982). The aim of ensiling is to reduce the pH of materials to a critical level, at which the materials can not be damaged by microbial actions. There are several methods of ensiling of raw materials such as acid silage and fermented silage.

Fermented silage is the normal process for preserving animal products, usually involving mixing them with malt or malt-cereal meal mixtures and ensiling in the usual manner. De Silva (1998) recommended fermentation for shrimp waste, because of the high cost and danger of handling of acid silage. The principle of shrimp waste ensiling is based on the fermentation of micro-organisms to produce organic acids, especially lactic acid. Anaerobic conditions develop and naturally occurring bacteria convert sugar and starch to lactic acid, reducing pH to levels to about 4.5, at which spoilage organisms are inhibited. The bacteria are usually present in the fresh materials in the form of spores. The majority of bacteria are aerobes, but as soon as the conditions in the silage become anaerobic, they will be suppressed by facultative anaerobes. Clostridia and Enterobacteria will be suppressed by lactic acid bacteria, which start to multiply quickly by using soluble carbohydrates as substrate (Pahlow, 1991), and increase the production of organic acids, predominantly lactic acid. The acids produced increase the hydrogen ion concentration to a level at which the undesirable bacteria are inhibited (McDonald *et al.*, 2002). Shrimp waste alone is difficult to ferment due to the lack of easily available carbohydrates. Sugar cane molasses is cheap, locally available, and rich in fermentable carbohydrates, while shrimp waste is rich in protein. Thus, an appropriate mixture of these materials will promote lactic acid bacteria fermentation. An (1999) and Cuc *et al.* (2002) found that shrimp by-products ensiled with molasses at a ratio 3:1 in wet weight resulted in good quality silage.

Chitin and chitosan

Chitin falls in the category carbohydrate, with a fibre structure similar to that of the cellulose of plants, and is found in the shell of animals like shrimps, crabs, insects, silk worms, and the cell walls of fungi, yeast and many kinds of microbes. Chitin is one of the most abundant organic resources on earth. It is one of the most abundant polysaccharides, second only to cellulose, and is chemically a poly-N-acetylglucosamine, analogous to cellulose except that the hydroxyl group on the C-2 position of cellulose is replaced by an N-acetylamino group on the chitin molecule (White *et al.*, 1968). Chitin is natural, non-toxic, non-allergenic, anti-microbial and biodegradable (Austin, 2005). Chitosan is a useful derivative of chitin, formed through N-deacylation of the chitin molecule (Hudson, 1994). Chitin and chitosan especially have amino groups which possess many properties different from cellulose, such as solubility in dilute organic acid and its biological effects. Nowadays, chitin and chitosan are used in the in agricultural, medical and pharmaceutical sectors (Wanichpongpan, 2005).

Positive effects of adding chitin to animal feed were reported, for example that combinations of chitinous products and whey in isonitrogenous and isocaloric diets enabled broiler chickens to utilise whey more effectively (Zikakis *et al*., 1982). Ramachandran et al. (1986) showed that chitin prepared from prawn shells, mixed with a commercial broiler diet at 0.5%, after 60 days, resulted in increased weight gain and feed intake in birds of 10% and 5%, respectively, compared with those fed a commercial diet, indicating improved appetite. Fox *et al*. (1994) and Fagbenro and Bello-Olusoji (1997) found that the fermentation process reduced the chitin content in the shrimp wastes.

Duckweed (Lemna spp.) Duckweed (DW) is a monocotyledon species of the family Lemnaceae adapted to grow in water at temperatures between 6-33 ^{0}C (Leng et al., 1995). DW is small floating aquatic plant that grows on fresh or polluted water, and is common throughout the Mekong Delta. It is adapted to a wide variety of geographic and climate zones, and is a fast growing, high protein plant that can efficiently absorb nitrogen and phosphorus as well as heavy metals (Logsdon, 1989). Duckweed has high nutrient uptake rates, is cold tolerant and less sensitive than other aquatic plants to high nutrient stress, droughts, pests and diseases. DW reproduction is primarily vegetative and it can double its mass between 16 hours to 2 days under optimal nutrient supply, sunlight, and water temperature. When effectively managed under this practical condition DW yields 10-30 tons DM/ha/year, containing up to 43% crude protein and a highly digestible dry matter (Leng and Bell, 1995). The DM yields therefore vary, based on growth conditions, and the protein content of DW responds quickly to the availability of nutrients in the aquatic environment. DW protein has a better array of essential amino acids (especially lysine, methionine and threonine) than most vegetable proteins and more closely resembles animal protein (Hillman and Culley, 1978).

Agro-industrial by-products in diets for chickens and ducks

Agro-industrial by-products are commonly used in many parts of the world as supplementary feeds for monogastric animals include brewery, soybean and shrimp wastes. Nutritional evaluations of brewers dried grains (BDG) have been reported by Dung (2001), who stated that the typical CP content (DM basis) of brewery grains in the Mekong Delta was 31%. It was also reported by Bath *et al.* (2001) that total digestible nutrients (TDN), energy and CP in wet brewers grains were 66.0%, 0.68 Mcal/lb and 25.4%, respectively, on a DM basis. Traditionally BW has only been used for feeding ruminants, due to the high level of fibre (Cromwell *et al*., 1993; Shurson, 2003). However, research has shown that BW can be successfully fed to poultry (Parsons *et al.*, 1983; Noll *et al*., 2001). Branckaert (1967) evaluated BDG as a replacement for soybean meal and maize in broilers diets. The inclusion of 20% BDG slightly lowered body weight at 5 weeks of age, while at 12 weeks body weight was 11% higher than the control birds. Also, in broilers inclusion rates up to 20% of BW did not depress gains or feed conversion during early growth (0 to 4 and 4 to 8 weeks) and rates of up to 30% were not observed to decrease performance in broilers from 8 to 12 weeks old (FAO, 2005b).

Ngoan *et al.* (2000a) reported that fresh shrimp waste, including head and shell, contained 35.2% CP, 4.3% lipid, 16.1% chitin, 2.6% lysine and 1.1% methionine. Dried shrimp waste successfully replaced all the soybean meal in broiler diets without any negative effect on performance or carcass quality (Rosenfeld *et al*., 1997).

Minh (2000) indicated that a mixture of tofu waste (30%, as fed), rice bran (30%) and duckweed (DW) (40%), replacing 60% of the concentrate in laying duck diets, gave the best economic return.

In Vietnam DW is commonly fed to chickens, ducks and fish, and even pigs. Earlier studies in the Mekong delta showed that fresh DW could be used to partially or completely replace conventional protein supplements (soybeans) in diets of local, crossbred common and Muscovy ducks without reduction in performance, and giving considerable savings over purchased protein feeds (Becerra, 1994; Men, 1996). In another study, fresh DW also replaced 50% of the soybean meal in diets for growing chickens, giving better performance and the highest net incomes, and up to 100% of the soybean meal in diets for laying hens, improving egg production and profitability (Khang, 2003).

Digestibility

Measurements of digestibility are essential in order to define the efficiency of utilization of nutrients within foods, to classify the nutritional quality of food items, and to formulate diets for captive birds. Digestibility may be expressed in terms of apparent or true digestibility. Apparent digestibility is the relationship between the amount of nutrients consumed in the diets and the amount that disappears from the gastrointestinal tract: (nutrient intake -nutrient in faeces) / nutrient intake. Apparent digestibility indicates that the measurement is biased by the amount of a nutrient that was absorbed but then excreted back into the digestive tract, as well as by endogenous nutrient losses, such as those from the shedding of the intestinal epithelia and mucous secretions. True digestibility corrects for those components of the excreted nutrients that were not originally in the food. It corrects for the portion of nutrient in the faeces that is of endogenous origins. Thus the values obtained for true digestibility are always greater than those for apparent digestibility. The separation of endogenous losses arising from the digestive tract from the metabolic losses excreted in urine is difficult in birds, due to the simultaneous voiding of faeces and urine. In practical conditions in Vietnam measurements that include endogenous losses for poultry are lacking. Therefore apparent digestibility of nutrients and amino acids has been applied commonly for monogastric animals in Vietnam, especially chickens and ducks.

Availability and digestibility

Availability is a function of two processes: digestion and metabolism. The relationship between availability and digestibility is shown schematically in Figure 1. The most common recent approach to the measurement of available amino acids has been digestibility studies.

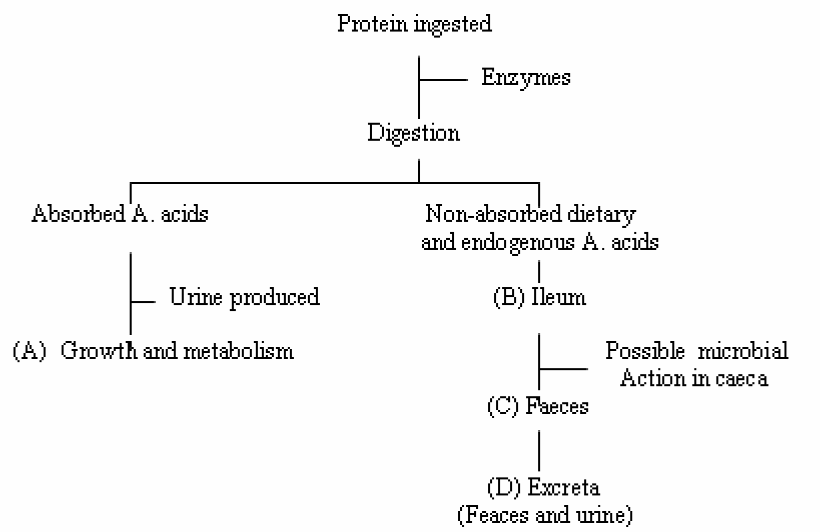

Figure 1. Schematic diagram of the digestion, absorption, and metabolism of the ingested protein in areas for the measurement of (A) amino acid availability, (B) ileal amino acid digestibility, (C) faecal amino acid digestibility and (D) excreta amino acid digestibility (Johnson, 1992).

Excreta digestibility

This was first used by Kuiken and Lyman (1948), who measured the difference between amino acids consumed in the feed and in the corresponding faeces. In birds, because of the mixing of faeces and urine (excreta), excreta digestibility (metabolizability) is employed unless birds are surgically modified. In digestibility studies with intact birds based on this technique most of the available published data have been derived from excreta analysis (Ravindran *et al*., 1999; Svihus and Hetland, 2001; Jamroz *et al*., 2002). Determination of apparent digestibility through analysis of excreta samples has been criticized because this approach fails to distinguish amino acids voided which are not of direct dietary origin (endogenous excretory losses) (Short *et al.*, 1999). Also, the major criticism of both the faecal and excreta digestibility methods of amino acid assessment is that microbial activity in the lower intestine, particularly in the caeca, may affect amino acid digestibility by deaminating undigested amino acid residues. If this occurs, the digestibility values will be higher than in birds in which microbial action has been prevented.

Ileal digestibility

To overcome potential problems of microbial action on amino acids in excreta digestibility studies with poultry, Payne *et al.* (1968) proposed the use of ileal digestibility. Two basic methods for determining ileal digestibility are to insert a cannula into the terminal ileum or to kill the birds and remove the ileal contents. Techniques for ileal cannulation have been described by Raharjo and Farrell (1984a) and Gurnsey and James (1985). The usefulness of ileal cannulation is limited by the surgical expertise required, variation in flow of digesta through the cannula (*e.g.* blockage) and rejection of the cannula. Payne *et al.* (1968) first proposed the method of collection and analysis of ileal contents after killing the birds, and this method has been used by many groups. The general procedure used usually involves feeding diets to chickens for approximately 2 weeks, killing the chickens (cervical dislocation, CO_2 gas, anaesthesia), and collecting the intestinal contents from the vitelline diverticulum to the ileal-caecal junction. Kadim and Moughan (1997) suggested that collecting material from the last 15-20 cm is preferred. The procedure requires use the of a digesta marker, with chromic oxide being the most common indigestible marker used for digestibility studies, or acid insoluble ash. However, acid insoluble ash requires bigger samples than chromic oxide. More studies, therefore, have used chromic oxide as indicator (Atteh and Leeson, 1985; Jamroz *et al.*, 2001). Three to five grams of chromic oxide are added per kilogram of feed (Jamroz *et al.*, 2002). Ileal digestibility assay after sacrificing the birds is becoming more frequently used. One reason is the increased interest in the effects of enzymes on AA digestibility in feed ingredients. The ileal assay is preferred over the precision-fed cockerel assay for enzyme evaluation (Zanella *et al.*, 1999). The main limitations of the ileal assay are time and expense, in that a 2-week feeding trial is required when using a digesta marker.

Gut microflora in poultry

There is evidence that microbial activity in the digestive tract of broilers is mainly affected by the diet in relation to nutrient digestion. In poultry, fermentation occurs mainly in the caeca. Relative to other parts of the intestinal tract of poultry, the caeca provide a stable environment for micro-organisms and, as a result, contain the largest and most complex ecosystem. Raharjo and Farrell (1984a) and Ravindran *et al.* (1999) reported that amino acid metabolism by the hindgut microflora in chickens may be substantial, and that digestibilities measured in the terminal ileum are more accurate measures of AA availability than those measured in excreta. The digestion and absorption of nutrients by an animal depend on the rate of hydrolysis by the animal´s enzymes and the activity of the microflora. There are many different bacteria species present in the gastrointestinal tract of poultry. It has been estimated that up to 10^{14} bacteria can be found in the lumen of the digestive tract of broiler chicks (Mead, 1989). Thus, bacteria in the digestive tract can play an important role in metabolism in the intestinal tract (Savage, 1986; Fuller and Cole, 1988). In the small intestine, the bacterial population appears to be established within approximately 2 weeks (Smith, 1965). However it takes much longer for the caecal ecosystem to develop (Bames *et al*., 1972; Mead and Adams, 1959).

The development of the microflora is also affected by the digestibility of the diet. Lee (1985) reported that dietary factors such as nutrient digestibility can influence the ecosystem of the intestinal tract, notably in the caeca and large intestine. It has been suggested that the microflora compete with the host animal for dietary nutrients. For a highly digestible diet this competition is usually in favour for the host. However, if birds receive poorly digestible diets rich in non-digestible carbohydrates, more substrate moves to the lower part of the intestinal tract, thus favouring the microflora. The digestive capacity of young animals is still not fully developed (Nitsan *et al*., 1991; Nir *et al*., 1993). This leaves more substrate for microbial fermentation. Several studies indicate that part of the reduction in N digestibility can be explained by the fact that the micro-organisms can incorporate dietary amino acids into microbial protein (Salter and Coates, 1974). Other evidence is that an increase in microbial activity stimulates proliferation of mucosal cells (Sakata, 1987; Goodlad *et al*., 1989), probably associated with increased losses of epithelial cells, which increases endogenous losses. This contributes to a greater faecal N output and, therefore, to a decrease in the apparent digestibility of N.

In poultry, much of the microbial fermentation takes place in the caeca (McNab, 1979), and because the caeca take the form of two blind sacs, it is possible for much of the feed residue to bypass them. Salter (1973) tabutated the possible effects of the microflora on nitrogen excretion and protein utilisation and concluded that the microflora can deaminate (Buraczewska and Buraczewski, 1985) and synthezise (Deguchi *et al*., 1978) AA and even alter the rates of mucosal cell proliferation and shedding (Khoury *et al*., 1969). Jamroz *et al*. (2001) found considerable AA synthesis by microbes in the caeca-colon of chickens, ducks and especially geese, and these AA are not absorbed and utilised in the body but excreted in the faeces. Consequently many assays for bioavailable AA involve procedures to reduce interference by microbial fermentation, particularly in the hindgut.

Summary of materials and methods

Experimental birds

Paper I includes on-station and on-farm trials, in which the performance of local and crossbred Muscovy ducks (male French Muscovy crossed with local female Muscovy ducks) was investigated from 28 to 84 days of age in both experiments. Ducklings after hatching were selected from a few smallholder breeding flocks and brooded up to 4 weeks before the experiments started. The average initial weight of local and crossbred Muscovies was around 810 g in both trials.

In **Paper II,** crossbred common ducks (Cherry Valley crossed with Pekin ducks) were started on experiment at 21days old, with average initial weights of around 810 g, and reared up to 70 days, the usual commercial market age.

Paper III includes two experiments with crossbred Super-Meat ducks (male Super-Meat crossed with female crosses between Cherry Valley and Pekin ducks), which are usually called common ducks. The trials started when the birds were 21 days of age, and finished at 70 days of age. One-day-old ducklings were purchased from a traditional hatchery and brooded up to 21 days of age, when average initial weights were 725 g and 850 g for Expt.1 and Expt. 2, respectively.

In **Paper IV,** ileal and total digestibility coefficients of amino acids were determined in crossbred Super-Meat ducks (the same breed as used in Paper III), and were started at 12 weeks at an average live weight of 1.8 to 1.9 kg.

Throughout all experiments all birds were healthy, and mortality was below 3.0%.

Experimental design

In **Paper I,** both on-station and on-farm experiments had factorial designs, with 2 factors: breed, including local and crossbred Muscovy ducks, and diet, with 5 dietary treatments and three replicates in the on-station experiment. However, in the on-farm trial the two optimal dietary treatments selected from the on-station experiment were applied on five small-holdings as blocks.

In **Paper II,** the crossbred common ducks were randomly allotted to treatment in a 2 x 5 factorial experiment: the first factor was feeding system (brewery waste and concentrate fed mixed or separately), and the second factor was diet, with five treatments and three replicates for each treatment, with ten birds, balanced for sex, in each replicate group.

In **Paper III,** both experiments 1 and 2 were completely randomised designs with five dietary treatments, three replicates of ten birds per treatment, and balanced for sex in each group.

In **Paper IV,** ileal and total tract (excreta) digestibility of AA was determined in crossbred common ducks fed broken rice basal diets with inclusion of four different levels of ensiled shrimp waste. This investigation was conducted as a completely randomised design, with four dietary treatments and three replicates of four birds, balanced for sex, for each determination technique.

Diets and feeding

In all experiments in this thesis, in the brooding stage local and crossbred Muscovies, and crossbred common ducklings were offered a commercial diet *ad libitum*, which contained 12.2 MJ ME/kg DM and 19.5% CP (DM basis).

In **Paper I,** crossbred Muscovy ducks were fed diets consisting of concentrate and brewery waste. In the on-station experiment the control diet was a concentrate, which contained 18.8% CP and 12.9MJ ME/kg/DM and was offered *ad libitum*. In the four experimental diets the amount of concentrate was reduced by 25, 50, 75 and 100% of the amount of the control diet consumed, adjusted daily, and BW was supplied *ad libitum*. The control diet and the optimal diet in the on-station experiment were selected for the on-farm trial, and were concentrate only (control diet) and a restricted amount of concentrate of 50% of the control diet. Duckweed was supplemented at around 5 g (DM)/bird/day.

In **Paper II,** the crossbred common ducks were fed diets with similar feed ingredients as in the experiments in Paper I, but the ingredients were offered either separately or mixed. In the first feeding system concentrate only was offered (control diet) and contained 17.9% CP (DM) and 12.9 MJ ME/kg/DM. In the four experimental treatments concentrate was mixed with brewery waste in ratios of 75:25, 50:50, 25:75 and 0:100 on a DM basis, and then fed *ad libitum.* In the second system concentrate and brewery waste were fed separately. The feeding method applied in this system was similar to the on-station trial in Paper I. Duckweed was supplied to all groups at around 3.2 g (DM)/bird/day.

In **Paper III,** Expt.1, crossbred common ducks were fed five diets based on broken rice (BR) mixed with five different levels of soybean meal (SBM) (25, 20, 14, 8 and 0%), and with soya waste (SW) offered *ad libitum*. In Expt. 2, the five dietary treatments were based on broken rice (BR) and five levels of fish meal (FM) (14, 11, 8, 4 and 0% of diet DM), with ensiled shrimp waste (ESW) offered *ad libitum*. In both trials, duckweed (5.9 g DM/bird/day), bone meal (1%) and salt (0.3%) (Expt.1) were also supplied to all birds to provide vitamins and minerals**.**

In **Paper IV,** the diets were composed of broken rice, fish meal and ground dried ensiled shrimp waste (ESW). The basal diet contained 80% broken rice (BR) and 20% fish meal (FM); for the other three diets 25, 50 and 100% of the FM in the basal diet was replaced by ESW. A vitamin-mineral premix (0.3%) was added, and chromic oxide was included as an indigestible marker at 0.3 g per kg in all diets (Kadim *et al*., 2002). The experimental period was 20 days, comprising 7 days of dietary introduction, 7 days of adaptation to the respective diet, followed by 5 days of sample collection, and 1 day of ileal digesta collection. The birds were fed in groups of four and four times per day (8:00, 13:00, 17:00 and 21:00h) to minimize spillage.

Sample collection

During the collection period, diet samples were taken daily and total excreta were quantitatively collected three times daily, then frozen at - 20 ^{0}C. Four hours after the final feeding, the birds were killed by cervical dislocation (Kadim and Moughan, 1997; Martin *et al*., 1998; Sarmiento-Franco *et al.*, 2003). Ileal digesta samples were quantitatively collected from Meckel´s diverticulum to the ileo-ceacal junction (Short *et al*., 1999; Snow, *et al*., 2003), then frozen immediately. Prior to analysis, excreta and ileal samples were thawed, then mixed within each diet and replicate and dried in an oven at 55-60 ^{0}C for 24 hours to constant weight. The dried excreta and ileal samples were weighed, homogenized, ground and sub-samples taken, and then stored at - 4 ^{0}C for chemical analysis (Ravindran *et al*., 1999).

Ensiling technique (Papers III and IV)

Shrimp waste was supplied by a local seafood processing factory in Cantho City. The by-product was immediately finely chopped (Paper III) or ground to pass through a 5 mm screen (Paper IV), and mixed with sugarcane "B" molasses at a ratio of 3: 1 (wet weight basis) (Ngoan *et al.* 2000a and Cuc *et al.* 2002). The mixtures were placed in plastic bags and sealed to prevent air contamination. The bags were put in plastic containers and stored at room temperature (25-32 ^{0}C) and the ESW was first used at least two weeks after ensiling. The wet ESW was fed in the feeding trial (Paper III), and dried ground ESW was used in the digestibility experiment (Paper IV).

Housing and management

All feeding experiments were carried out at the experimental duck farm of Cantho University. The growing ducks were confined in sheds divided into pens constructed from bamboo (Paper I and II), or nylon nets (Paper III), with thatched roofs and concrete floors covered with rice straw for bedding, and with an average density of three ducks per m^2. The temperature in the house averaged 25- 32 ^{0}C. Natural light was used in the day and electric bulbs at night. The yards, feeders and drinkers were cleaned daily and duck manure was removed every one or two weeks. Water was always available to meet the drinking and bathing requirements of the birds.

In the on-farm trial (Paper I) ducks were housed in thatched sheds built in covered gardens or back yards with a sandy surface and partial rice straw cover for bedding, with an average density of three ducks per m^2. Birds were also raised on wire floors with a density sufficient for eating, drinking and resting but without an exercise yard.

In the digestibility experiment (Paper IV) ducks were distributed to 12 wire metabolism cages, with two males and two females with a similar mean weight per cage. Each cage was provided with a drinker and feeder, and a plastic tray was placed under the cage for total collection of excreta. The cages, drinkers, feeders and plastic trays were cleaned daily in the morning.

Birds used in all the experiments included in the thesis were vaccinated with Duck Plague and Pasteurellosis vaccines (FC3) at three and four weeks, respectively.

Chemical analyses (Papers I, II, III and IV)

All samples were dried at 55-60 ^{0}C and ground through a 1 mm screen before chemical analyses, which were performed according to standard methods (AOAC, 1990). Dry matter (DM) was determined by drying at 105 ^{0}C for 24 hours to a constant weight. Total nitrogen (N) was determined by a conventional macro-Kjeldahl method and crude protein (CP) content was calculated as N*6.25. Ether extract (EE) was measured by Soxhlet extraction, crude fibre (CF) and calcium and phosphorus were determined according to AOAC (1990). Ash was the residue after ashing the sample at 550-600 ^{0}C. Analyses of neutral detergent fibre (NDF) and acid detergent fibre (ADF) were done following the procedure of Goering and Van Soest (1991). Amino acids were analyzed according to Spackman *et al*. (1958) on an ion-exchange column using HPLC.

Diets, excreta and ileal digesta samples in Paper IV were also analyzed for Cr_2O_3 content (Masaaki Takemasa, 1992). The chitin content of the ESW was measured by an enzymatic method based on the use of purified chitinase (Jeuniaux and Voss-Foucart, 1997) (Paper III and IV).

Statistical analysis

The General Linear Models (GLM) Procedure of Minitab Statistical Software, Version 12 (1998) (Paper, I and II) and Version 13 (2000) (Paper III and IV) was used. Least-Squares Means were compared statistically using Tukey´s Test ($p< 0.05$). Linear regression analyses of the effects of total daily brewery waste intake on the FCR, total daily CF intake on gizzard weight, and ME intake on daily weight gain were performed (Paper I and II). Also, the effects of ADF and CP intakes on gizzard weight and daily gain were determined (Paper III).

Digestibilities of nutrients and amino acids were further analysed by the General Linear Model (GLM) procedure (SAS, 2003) (Paper IV).

Summary of results

Chemical composition of agro-industrial by-products

The chemical composition of BW, ESW and SW included in the experimental diets is shown in Table 3. The content of nutrient components varied among the by-products (Paper I, II, II and IV), which generally had a quite high CP content on DM basis, but rather low DM (SW and DW), high NDF and ADF concentrations (BW and SW), and high chitin and Ca contents (ESW). However, all the by-products had an acceptable amino acid profile in comparison to fish meal and soybean meal and the ideal protein for growing ducks (Table 4).

Table 3. *Chemical composition and range of the agro-industrial by-products (% DM) used in the experiments*

Item	BW*	ESW*	SW*
DM	25.0 (23.0-26.5)	22.1 (20.6-24.4)	8.4 (7.10-11.2)
CP	23.6 (23.0-28.1)	35.3 (31.2-37.3)	23.8 (22. 5-24.6)
EE	10.6 (5.8-11.9)	8.6 (7.02-9.60)	4.9 (3.40-5.71)
CF	14.5 (11.7-16.6)	7.04 (6.8-7.76)	-
NFE	47.9 (41.2-48.1)	28.4 (26.9-31.8)	47.0 (43.0- 48.0)
NDF	50.9 (50.6-56.2)	6.9 (6.01-7.53)	32.2 (25.4-34.4)
ADF	17.5 (17.3-22.5)	5.9 (5.56-6..20)	27.1 (20.6-29.1)
Ash	3.5 (3.1-3.5)	22.2 (17.4-23.2)	4.3 (3.70-4.80)
Ca	0.29	5.89	1.16
P, total	0.48	1.39	0.86
ME, MJ/kg	7.3	10.3	11.2

* BW: brewery waste, ESW: ensiled shrimp waste, SW: soya waste.

Table 4. *Essential amino acid composition of feed ingredients and ideal protein*

Item	BW*	ESW*	SW*	FM*	SBM*	Ideal protein**
Lysine	100	100	100	100	100	100
Isoleucine	103	105	121	67	109	77
Leucine	212	127	190	77	154	130
Methionine	51	51	25	43	28	75 (Meth.+ Cys.)
Threonine	92	76	85	69	99	66
Valine	150	93	110	59	86	89

BW: brewery waste, ESW: ensiled shrimp waste, SW: soya waste, FM: fish meal, SBM: soybean meal.
*Analysed values (lysine as 100).
** Ideal protein for growing ducks, Rose (1997). Absolute values of lysine were 0.99, 1.72, 1.67, 4.37 and 2.10% in DM for BW, ESW, SW, FM and SBM, respectively.

Effect of inclusion of agro-industrial by-products on nutrient intakes

Ducks readily consumed BW, and daily intake of BW and total DM increased significantly with reductions in the amount of the concentrate in the diets, indicating a high level of palatability for both Muscovy and common ducks (Paper I and II). This resulted in increased intakes of crude protein and crude fibre in the BW diets ($p < 0.001$). Corresponding to increased CP intakes among BW diets, contents of EAA also increased (Paper I and Paper II). The results of the feed and nutrient intakes in the on-farm trials confirmed those from the on-station experiment.

In the comparison between breeds, the intakes of all nutrients were significantly higher ($p < 0.001$) in the crossbred Muscovies than in the local Muscovy ducks, with similar results found in both on-station and on-farm trials (Paper I). However, the total daily DM and nutrient intakes were not significantly different between the mixed and separate feeding systems ($p > 0.05$), the only exception being for BW, the intake of which was higher when fed separately ($p < 0.001$) (Paper II).

Total daily DM and SW intakes were higher ($p < 0.001$) in ducks fed the SW diets than the control. Significantly increased intakes of SW ($p < 0.001$) as the SBM supplied was progressively restricted, resulted in total intakes of CP and EAA being higher for diets that included SBM and SW ($p < 0.001$). Due to the high fibre content in SW, total intakes of NDF and ADF increased corresponding with SW intake ($p < 0.001$) (Expt. 1, Paper III).

Daily intakes of DM linearly decreased as the level of ESW increased ($p < 0.001$), leading to reductions in CP, EE and NDF intakes ($p < 0.001$) on the ESW treatments compared to the control group. Essential amino acid intakes significantly decreased ($p < 0.001$) with increasing ESW intakes, due to the low content of essential amino acids in ESW (Expt. 2, Paper III).

Effect of inclusion of agro-industrial by-products on biological performance

Feeding BW *ad libitum* to growing Muscovy (Paper I) and common ducks (Paper II) resulted in the highest daily weight gains and highest final live weights in the control diet and diets including BW that replaced up to 50% of concentrate. Daily gains thus were not significantly changed when up to 50% of the concentrate was replaced by BW (Paper I and II). Rate of gain however was significantly depressed as BW intakes increased above 50% of diet DM intake ($p < 0.001$).

The results from both the on-station and on-farm trials (Paper I) demonstrated that the crossbred Muscovy ducks had significantly higher ($p < 0.001$) daily gain than the local Muscovies. In the comparison between the two feeding systems (Paper II), the daily gains of the birds offered feeds either in mixed or separate form were very similar.

Supplying SW *ad libitum* to replace SBM in diets for growing common ducks, did not result in significant differences in growth rate and final live weight among the diets containing SBM, although there were significantly lower gains on the diet without SBM ($p < 0.01$). Maximum growth rates were obtained when SW accounted for approximately 20% of the total DM intake, and 32% of the dietary protein.

When replacing FM by ESW *ad libitum* in diets for crossbred growing common ducks, the highest daily gains and final live weights were observed when birds were fed the 100% and 75% FM diets, but gains then decreased ($p < 0.001$) with each further reduction in FM content. Maximum growth rates were found when ESW accounted for only 4% of the total DM intake, and around 10% of the dietary protein.

In general, feed conversion ratios were significantly poorer on the diets containing these by-products ($p < 0.01$) (Paper I, II and III).

Effect of inclusion of agro-industrial by-products on carcass quality

When reducing the supply of concentrate and offering BW *ad libitum* to both Muscovy and common ducks (Paper I and Paper II), the mean carcass and breast muscle weights were found to be lowest on the diet with only BW ($p < 0.001$), and were higher on the control diet, and the 75 and 50% concentrate diets. The crossbred Muscovies had higher carcass and breast muscle weights than the local Muscovies ($p < 0.001$ and $p < 0.01$, respectively) (Paper I). Nevertheless, similar carcass and breast muscle weights were found in the common ducks supplied BW in the mixed and separate feeding systems (Paper II).

Growing common ducks fed the control diet had the highest carcass weights and carcass percentages (Expt.1, Paper I), which were lowest on the diet in which SBM was completely replaced by SW ($p< 0.001$ and $p< 0.01$, respectively). Corresponding to reduced carcass weight, the weight of breast muscle was significantly lower ($p< 0.01$) on the diet without SBM.

The mean carcass and breast muscle weights were significantly lower on the diet without FM ($p< 0.001$), and were approximately equal on the control diet and diets in which 25 and 50% of FM was replaced by ESW. In general, the results from Papers I, II and III indicated there were no significant differences in weights of the components of the digestive tract, except that the weight of the gizzard tended to increase on the by-product diets ($p< 0.05$).

Total tract digestibility of nutrients and nitrogen retention in ESW

The coefficients of apparent total tract digestibility (CATTD) of DM, OM and EE were highest for the basal diet, then linearly decreased with increasing levels of ESW in the diets ($p< 0.01$). The estimated apparent digestibility of nutrients in ESW from regression equations was substantially lower than in the experimental diets. Also, N retention had the same trend as the nutrient digestibility, and N retention as a proportion of N intake from ESW was estimated at 41% (Paper IV).

Apparent ileal and total tract digestibility of amino acids (AA)

Comparisons between the two measurement techniques showed that the apparent total tract digestibility of most individual AA was higher ($p< 0.05$) than the ileal value. The dietary treatment effects indicated that the digestibility values of most individual AA were significantly higher in the basal diet and diet containing 25% of ESW than in the diets with higher levels of ESW ($p< 0.05$). There were linear decreases ($p< 0.05$) in individual amino acid digestibility as the dietary level of ESW increased. The estimated apparent digestibility of AA in ESW from regression equations ranged from 40% to 60%, and the highest digestibility was noted for lysine and threonine and the lowest value for methionine.

General discussion

Efficient utilization of agro-industrial by-products, BW, ESW and SW to replace conventional feeds for duck production is necessary and useful in the peri-urban areas in the Mekong Delta. Other authors have also stressed the importance of utilizing local agro-industrial by-products for livestock, and have called for more studies on how to utilize them more efficiently (Ha *et al*., 1996; Su and Station, 1996). BW effectively replaced concentrate in diets for growing Muscovy and common ducks (Paper I and II), a result that is in agreement with the conclusion that BW is good source of CP with a high fibre content (50% NDF), and thus can be a pivotal ingredient in combination with traditional cereal grains and protein supplements in diets for animals (Westendorf and Wohlt, 2002). BW was used in the fresh state in the present study due to the high cost of drying of wet BW and higher palatability. Keeping wet BW sealed in plastic containers was also found to be effective in preventing aerobic spoilage in other studies (Göhl, 1998; Westendorf and Wohlt, 2002).

SW contains relatively high levels of crude protein, but is high in fibre and low in DM (Dung, 2001), and was investigated as a replacement for SBM (Expt. 1, Paper III). The product was fed fresh, which reduced production costs, as was confirmed in other studies in Vietnam (Minh, 2000; Hong *et al.,* 2003).

ESW is rich in protein, and thus was used to replace FM in Expt. 2, Paper III. Ensiling with molasses at a ratio of 3:1 (wet weight) is consistent with a recommendation that ensilage of shrimp by-products with molasses was effectively preserved and was readily accepted by growing pigs under the practical conditions of Vietnam (An, 1999).

Chemical composition of the feeds

Data presented in Table 3 show that there are important differences in chemical composition among the by-products. The proximate composition values of BW used in Paper I and II fall into the range of results of other studies. The contents of CP, NDF, ADF, Ca and P of BW are close to those of wet brewers grains reported by DePeters *et al*. (2000) and NRC (2001). Similar contents of DM, CP, NDF, ADF and ash in wet brewers grains were found by Ridla and Uchida (1997). However, lower CP, EE and higher ADF contents of brewers grains were reported by Farhat *et al*. (1998) and Altizio *et al*. (2000b). The reason for this could be that different basic materials are used in beer production. A low metabolisable energy content in brewers grains was reported by Westendorf and Wohlt (2002) and FAO (2005b). The contents of the most important EAA in BW are higher than those of the ideal protein reported by Rose (1997) and close to those given by DePeters *et al.* (2000) and NRC (2001).

The SW used in Expt. 1, Paper III, had approximately equal DM, but higher CP concentrations compared to values reported by Hong *et al*. (2003). However, Farhat (1998) indicated that soy bean residue, which is similar in composition to SW, had a higher content of CP, but rather low NDF and ADF contents. The explanation for the difference could be differences in soy bean variety and processing method. Except for methionine, the contents of most EAA in SW are higher than those of the ideal protein for ducks reported by Rose (1997).

The ESW (Expt 2, Paper III and IV) had higher CP and EE contents, but quite similar ash, Ca and P contents to those of ensiled shrimp by-products reported by Ngoan *et al.* (2000a). The chitin content of ESW (11.3-13.9%) in Paper III and IV falls within the range of other studies (11-27%) (Chau *et al.*, 1997), but was slightly lower than the values (14-18%) in shrimp by-products reported by Watkins (1982). However, a lower chitin content (10.6%) in ensiled shrimp by-product, preserved using a similar ensiling technique, was reported previously by Ngoan *et al.* (2000a).

The EAA contents of ESW (Paper III and IV) were rather close to the values reported by Ngoan *et al.* (2000a), and were lower than those of FM. Most of the EAA concentrations in ESW meet the requirements of the ideal protein for growing ducks (Rose, 1997).

Effect of inclusion of agro-industrial by-products on feed intakes

Using BW to replace concentrate in diets for growing ducks is consistent with recommendations of Morrison (1956) and Westendorf and Wohlt (2002), who reported that BW should be used primarily as a protein source to replace concentrate feeds in rations for livestock and poultry. Data in Paper I and II show that both growing Muscovy and common ducks had substantially increased BW intake, which indicates a high palatability (Westendorf and Wohlt, 2002; Archer, 2005). The results are consistent with previous findings of Savory and Gentle (1976 a,b) that a greater weight and volume of food was necessary to meet the requirements for energy and other nutrients at higher dietary concentrations of fibrous ingredients. Also, Shim *et al.* (1989) and Onifade and Babatunde (1998) reported higher food intakes of broilers given diets based on high levels of fibrous brewer dried grains. This increasing BW intake was necessary to meet the energy requirement, as a result of the low metabolisable energy content in BW (7.3 MJ ME/ kg DM). This is in agreement with Scott *et al.* (1959) and Dean (1978), who reported that ducks have a well developed ability to consume more feed to maintain near normal weight gain even when given a very poor diet in terms of metabolisable energy. The increased intakes in the BW diets resulted in high CP intakes. However, the digestibility of the protein in BW is likely to have been low, and FAO (2005b) reported a CP digestibility in brewers grains of around 65%.

Both on-station and on-farm trials show that crossbred Muscovies had higher daily feed consumption than the local ducks, probably due to genetic differences (Paper I). Our findings are in accordance with an earlier study done in the Mekong Delta where it was found that crossbred Muscovy ducks consumed larger amounts of locally available feeds *e.g.* paddy rice, fish waste and water plants, than the local Muscovy (Dong, 1996). In Paper I and II, an interesting observation is the ingestion capacity of the crossbred common ducks compared with the Muscovies, to consume feeds including concentrate and BW. A strict comparison of the two breeds is not possible as they were not included in the same experiment, but the data in Table 3 and Table IV of Paper I and II, respectively, clearly indicate that common ducks consumed considerably more concentrate and BW than Muscovy ducks per kg live weight under the same feeding and management, probably due to genetic differences. This is confirmed in an earlier study by the observation that common ducks ate almost twice the amount of duckweed offered *ad libitum* as Muscovies (Men, 1996).

Similarly, when offered boiled soya waste *ad libitum* replacing roasted SBM in broken rice basal diets, crossbred common ducks readily consumed large amounts of SW, resulting in increased total daily intakes of DM and CP (Expt. 1, Paper III). These results are supported by Hong *et al.* (2003), who found that boiled SW had a more attractive smell than raw SW and was very palatable for pigs. Furthermore, boiling decreases the concentration of anti-nutritional factors contained in the raw material (Sarria and Preston, 1992). Also, previous studies show that the heat treatment of soy bean products increased the nutrient utilization, largely due to the removal of anti-nutritional factors which reduced protein, energy and fibre digestion of raw soy beans (Coon *et al.*, 1990; Parsons *et al.*, 2000; Batal and Parsons, 2003).

The results in Expt. 2, Paper III, show that the linear reduction of ESW, CP, EE and NDF intakes with increasing the levels of ESW in the diet, could have been a result of the high concentration of chitin in ESW (11.3-13.9%), which is a limiting factor in its utilization. These findings are supported by Mohan and Sivaraman (1993) and Ngoan *et al.* (2001c), who reported that feed refusals increased as the level of ensiled shrimp by-products increased, and thus daily feed intake decreased in growing pigs fed dried shrimp waste meal and ensiled shrimp by-products. However, our results are in disagreement with Rosenfeld *et al.* (1997), who fund no significant differences in feed consumption of broilers fed diets with shrimp meal. Also, no significant differences in DM intake were found for adult common ducks fed the basal diet and diets with ESW in the digestibility trial (Paper IV), probably because the ESW offered was in dried ground form mixed with other feed ingredients, and the daily allowances were set slightly below *ad libitum* feed intake.

Effect of replacement of concentrate with agro-industrial by-products on duck performance and carcass traits

The results from the three experiments in Paper I and II clearly indicate similar biological performance in terms of daily gain, final weight, and carcass, breast and thigh muscle weights of both Muscovy and common ducks between the control diet and diets in which 25 and 50% of the concentrate was replaced by BW. This indicates that replacing concentrate by BW did not lead to any reduction in the intake of available nutrients. However, when concentrate supplied was reduced by more than 50% significantly lower daily gain and carcass quality resulted, as the ducks were unable to fully compensate for the lower ME and digestible CP in the diets. Previous studies have reported similar performance in fattening chickens between dried and wet brewers grains (FAO, 2005b), and it was found that 10% of dried brewers grains can be fed to young poultry (0-8 weeks) and up to 30% in diets for older birds (8-18 weeks) without affecting growth (Ademosun, 1973). Lumpkins *et al*. (2004) reported that distillers dried grains with solubles could be safely used at 6% in the starter period and 12 to 15% in the grower and finisher stages of broilers, without reduction in performance or carcass yield. In an experiment with laying hens, including brewers grains at up to 30% of the diet had no effect, but higher levels depressed performance (FAO, 2005b). However, in a feeding trial with layers, brewer´s dried grains (BDG) replaced up to 50% of the maize in a standard commercial diet and gave significantly higher egg production at lower cost than the control diet (Iyayi and Aderolu, 2004). Another study indicated no statistical differences in egg production and egg quality in laying hens fed a commercial diet with 15% distillers dried grains plus solubles (DDGS), but a significant reduction in egg production was found when hens were fed low-density diets with 15% DDGS. The maximum inclusion level of DDGS was suggested to be 10 to 12% in laying hen diets (Lumpkins *et al*., 2005). However, in Paper I and II up to 50% BW (DM) could be included in the diet without adverse effects on performance and carcass parameters, which indicates that ducks can consume and digest high-fibre by-products more efficiently than chickens, as suggested by Jamroz *et al.* (1996). Borin *et al.* (2005) found that ducks had significantly higher dry matter intake and digestible dry matter intake than chickens fed high fibre diets including 20% cassava leaf meal.

The present results in both the on-station and on-farm trials also demonstrate significantly higher performance in terms of daily gain and carcass quality of the crossbred Muscovies than those of the local birds, which can be explained by genetic improvements as a result of crossing with the high performance pure French Muscovies. This is supported by the findings that the crossbred Muscovy has a bigger body size and better growth rates than local Muscovy ducks (Phuoc *et al*., 1994). Average slaughter market weight was 2.51 vs 2.13 kg and daily gain and 31.3 vs 25.0 g for crossbred and local Muscovies, respectively (Dong , 1996).

The Muscovy drake is almost twice the size of the female, while in the Pekin duck, the difference is small (3-5%) (Sauveur, 1990). Also, Stevens *et al*. (1985) and Wiseman (1987) reported that a feature of the Muscovy duck breed is the large sexual dimorphism, and after 10-12 weeks of age, the body weight of the female is only 65% of that of the drake. These observations are in an agreement with a Vietnamse study where male and female live weights at 12 weeks of age were 3.28 and 1.86 kg, respectively (Lien, 1997). Another important characteristic of the Muscovy is the difference in growth rate between the sexes, which is maximum at 30 days of age for the female and 35 days for the male (Leclerq, 1990). Muscovy males continue to grow after 10 weeks (Wiseman, 1987). Thus, in Paper I, the age of ducklings at the beginning of the trials was 4 weeks, and the slaughter age 12 weeks.

The results in Paper II show no differences in weight gain and carcass parameters with the inclusion of BW provided separately or mixed with the other dietary ingredients, which demonstrates that ducks can select a balance of feedstuffs to meet their nutrient requirements. Common ducks had similar daily gains to those of Muscovies offered the same diets that included concentrate and BW (Dong and Ogle, 2004). In Paper II DG were higher than those in a previous study carried out in the Mekong Delta in which local common ducks fed a mash consisting of broken rice, fine rice bran and fish meal, or broken rice plus duckweed, had much lower DG as compared to the weight gain of crossbred common ducks fed concentrate diets containing 20, 17 and 14% CP (Men *et al.*, 2001b). These differences were probably due to differences in breeds and the composition of feeds offered. Although in Paper II crossbred common ducks had lower DG than in the study of Men et al. (2001b), final live weights, and carcass and breast muscle weights were approximately equal, as a result of higher CP intakes of ducks fed diets that included concentrate with BW in our experiment.

Using SW to replace SBM in diets for crossbred common ducks indicated no significant treatment influence on the performance and carcass traits, except for lower performance of birds fed the diet with complete replacement of SBM. The explanation is that the birds could not consume sufficiently large amounts of SW to meet nutrient requirements due to its bulkiness and high moisture content. Another important reason was that the high crude fibre intake on this diet resulted in lower nutrient digestibility (Jamroz, 2001; El Beeli *et al.*, 2002). The approximately similar performance among the treatments with SW is explained by the increased intakes of DM, CP, and ME, which compensated for the reduction of nutrient intakes from SBM. Although SW has low DM (8.38%) and high fibre contents (32.2% NDF and 27.1% ADF) normal performance was still obtained when 60% of SBM, or 32% of the dietary protein, was replaced by SW. The performance in terms of DG, final weight, carcass and breast muscle weights was higher than of crossbred common birds given duckweed and roasted soybean meal diets (Men *et al.*, 2001c), the difference being explained by differences in breeds and feeding method. Another study carried out in Vietnam concluded that soy bean residue can replace up to 66% of the fish meal protein in pig diets without adversely affecting performance, but resulting in superior economic returns (Hong *et al.*, 2003).

Inclusion of ESW in diets of crossbred common ducks had no significant effects on performance and carcass quality when 25% of the FM was replaced by ESW. Optimum growth rates were obtained when ESW accounted for nearly 10% of the dietary protein, and Tuan (1996) found no effect of replacing FM by up to 10% of ESW on the performance of growing-finishing pigs. However, there were linear decreases in performance with higher levels of ESW, as a result of reductions of CP, ME and total DM intakes (Paper III). Oduguwa *et al.* (2004) reported that when sun-dried shrimp waste meal protein replaced 7% FM protein or 24% soybean meal protein in broiler diets there were reductions in growth rate and feed efficiency. This is in agreement with observations by Fanimo *et al*. (2004) that feeding shrimp waste meal at a high level to replace FM had detrimental effects on pig performance. Furthermore, the high chitin content in ESW (13.9%) would have influenced nutrient digestibility (Razdan *et al*., 1997), and reduced metabolisable energy content (Gernat, 2001), resulting in low growth performance. These results are also supported by the data in Paper IV, which showed linear decreases in the digestibility of nutrients and amino acids in diets with ESW. In accordance with findings reported by Ngoan *et al.* (2001b) the high chitin content of ESW compared to other animal protein sources may lead to lower animal performance when high levels of ESW are included in diets. This is in contrast to the results of earlier studies, which showed that shrimp meal could replace SBM in broiler diets without negatively affecting performance or carcass quality, and did not significantly affect egg production or egg weight, but increased yolk pigmentation (Rosenfeld *et al*., 1997; Gernat, 2001, respectively), possibly due to differences in nutrient concentrations in the by-products. Also, Toan and Ngoan (2003) found that replacement of 50% of a concentrate by ensiled shrimp by-product or shrimp by-product meal had no influence on rate of lay, egg quality, fertility or hatchability, but resulted in higher economic benefits. According to Göhl (1998) the inclusion level of shrimp meal in cereal-based diets for pigs should be limited to 5% of the diet, and a higher level of inclusion of around 20% of ESW in growing pig diets reduced daily feed intake and body weight gain (Ngoan *et al*., 2001b). In Paper III replacement of around 20% of FM by ESW had no adverse effects on performance, but gave the lowest feed costs.

Generally, feed conversion ratios (FCR) for both growing Muscovy and common ducks fed by-products (BW, SW and ESW) (Paper I, II and III) were significantly poorer than for the control diets, as was confirmed by earlier studies (Dong *et al*, 2003a; Oduguwa *et al*, 2004; Fanimo *et al,* 2004). The higher FCR in the by-product diets can be explained by the higher fibre and lower ME contents in BW (Paper I and II), and in SW (Expt. 1, Paper III), and the high chitin content in ESW (Expt. 2, Paper III). The resulting fibre contents were elevated in by-product diets, while the recommendation is from 3.5- 4% of crude fibre in diets of growing ducks (Scott and Dean, 1991).

Effects of the high fibre by-products on digestibility and development of the digestive tract

When ducks were offered by-products with high contents of fibre, the digestibility of all nutrients and amino acids decreased with increasing fibre content in the diet, as was also found in other studies (Jorgensen *et al.*, 1996; Sarmiento-Franco *et al.*, 2003; Borin *et al.*, 2005). Consumption of large amounts of bulky BW, SW and ESW would also have stimulated active peristalsis in the digestive tract, resulting in faster rates of passage of digesta (Onifade *et al.*, 1998).

Another effect of high fibre consumption on the BW, SW and ESW by-product diets was increased gizzard weights in both Muscovy and common ducks, probably related to volume of feed, increased time spent grinding the feed and increased frequency of mechanical contraction of the gizzard muscle (Roche, 1981; Svihus *et al.*, 2002) for further feed digestion in the intestine. Also, Eruvbetine *et al.* (2003) and Borin *et al.* (2005) found higher gizzard weights in chickens and ducks given diets that included high levels of cassava leaf meal. Our result is also in agreement with the findings of Hetland *et al.* (2005), who reported that layers on litter with access to coarse wood shavings showed up to 60% higher weight of the gizzard than caged layers fed the same diets, but without access to wood shavings.

Effect of inclusion of ESW on total tract digestibility of nutrients

At total tract level the results from Paper IV show linear decreases in the apparent digestibility coefficients of DM, OM and EE with increasing levels of ESW in the duck diets, which would have been due to the relatively high chitin concentration in ESW. The present results agree with those reported by Fanimo *et al*. (2004), who found that inclusion of shrimp waste meal in pig diets, decreased apparent digestibility of DM, CP and CF, which might have been a result of the high level of chitin. Also, Ngoan and Lindberg (2001b) reported that inclusion of ensiled shrimp by-product in growing pig diets reduced the apparent total tract and ileal digestibility of nutrients, due to its high chitin content.

Effect of inclusion of ESW on ileal and total tract digestibility of amino acids

Apparent AA digestibility measured by two methods indicated a linear decrease of individual AA digestibility as the dietary level of ESW increased. These data support the findings that in poultry elevated dietary fibre intake increased AA excretion and thus decreased apparent AA digestibility (Raharjo and Farrell, 1984b; Just *et al.*, 1985). Ngoan and Lindberg (2001b) found lower ileal digestibility of most AA in ensiled shrimp by-products in pigs. The results also showed that the total tract digestibility of most individual AA was higher than the ileal values, probably due to AA metabolism by microflora in the hindgut. The output of amino acids in excreta thus will decrease, resulting in increasing total tract AA digestibility. This is consistent with Ravindran *et al*. (1999) and Kadim *et al*. (2002), who also reported that AA ileal digestibility was substantially lower than that measured in excreta.

Economic returns of feeding by-products

Using agro-industrial by-products as partial or complete replacement for concentrate and SBM and FM protein supplements in diets for both growing Muscovy and common ducks considerably reduced feed costs, resulting in improved net benefits, as was also found in other studies (Ha *et al.*, 1996; Minh, 2000; Hong *et al.*, 2003; Lumpkins *et al*., 2004 and 2005). The Muscovies always gave higher profits than common ducks, due to lower feed intake and much higher market price per kg at slaughter (Dong and Ogle, 1995 and 2003b).

General conclusions

- Marked differences in nutritive properties were found among the potentially useful agro-industrial by-products studied, especially in their content of CP and NDF.

- Brewery waste can replace up to 100% of the concentrate in diets for growing ducks. A level of 50% concentrate replaced did not depress biological performance or affect carcass traits and resulted in the best economic benefits for Muscovies. However in common ducks complete replacement of concentrate by brewery waste gave the highest net economic benefits.

- Crossbred Muscovies had better performance and gave higher profits as compared to local Muscovies when fed diets containing agro-industrial by-products.

- The performance of ducks on the two feeding systems studied was similar, indicating that producers can mix the brewery waste with concentrate, or feed it separately, and still ensure that nutrient requirements are met at any level of brewery waste replacement.

- Soya waste can replace around 60% of the soybean meal in diets for growing ducks without reducing biological performance or carcass quality, and a complete replacement of soybean meal gave the lowest feed cost.

- Replacement around 20% of the fish meal in the diet by ensiled shrimp waste did not affect growth performance and resulted in the lowest feed costs.

- The apparent total tract digestibility of nutrients, and N retention linearly decreased with increasing levels of dietary ensiled shrimp waste.

- The apparent total tract digestibility of most amino acids was higher than the apparent ileal value. The apparent digestibility of individual amino acids had a similar pattern to the nutrient digestibility. The estimated digestibility coefficient of amino acids in ensiled shrimp waste ranged from 40-60%.

- Using these by-products in diets for growing ducks increases the sustainability and profitability of the system.

Practical considerations

- Our research has demonstrated that under the conditions of the Mekong Delta ducks make better use of agro-industrial by-products than expected. However, the high moisture content in the by-products and the high transportation cost restrict their use to production units close to the factories.

- Feeding in the wet form soon after production maintained palatability and resulted in the lowest cost.

- These by-products contain high levels of fibre, and in the case of shrimp by-product of chitin, that are limiting factors in their utilization in duck diets.

- More efficient utilization of by-products for peri-urban producers will not only reduce feed costs and increase net profits, but also contribute to solving some of the environmental problems of the cities and towns in the Mekong Delta.

Further studies

- Studies on agro-industrial by-products should be continued to identify other potentially useful alternative feed resources to replace conventional feeds to minimize feed cost in duck production.

- Further experiments could be conducted to determine the extent to which agro-industrial by-products can contribute to the total supply of nutrients for different species of animal in the Mekong Delta.

- Research should be carried out to develop appropriate technologies for the preservation of seasonal by-products in order to store them for efficient utilization year-round as animal feeds.

- Further studies on digestibility of nutrients and amino acids of the by-products by different measurement methods should be done to provide more data on nutrient availability and optimum levels in duck diets.

- Development of poultry (ducks and chickens) is one of the important tools in the Mekong Delta of Vietnam to improve farmers´ incomes. Hence, on-farm applied research should be conducted to evaluate these by-products under practical conditions.

References

Ademosun, A.A. 1973. Evaluation of brewers´s dried grains in the diets of growing chicks. *British Poultry Science*. 14: 463-468.

Agriculture Research Council. 1975. *The nutrient requirements of farm livestock*. In: Poul., 2nd ed. London, Her Majesty´s Stationary Office.

Altizio, B.A, Wohlt, J.E, Schoknecht, P.A. & Westendorf, M.L. 2000a. Replacement value of wet microbrewery grains in swine finishing diets. *Journal of Animal Science*. 78: 130.

Altizio, B.A., Wohlt, J.E. & Schoknecht, P.A. 2000b. Nutrient content of spent microbrewery grains and variation with pub and brew type. *Journal of Animal Science*. 78: 223.

An, L. V. 1999. *Ensiling of Shrimp By-product and Its Utilization in Diets for Pigs under Farm Conditions.* M.Sc. Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden..

Archer, D. M. 2005. *Evaluating undegradeable intake protein sources*. In alliance nutrition dairy. http://www.admani.com/alliancedairy/TechBulletins/Evaluating%20undegradable%20protein%20sources.htm; pp. 1-4 (accessed June 20, 2005).

Association of Official Agricultural Chemists (A.O.A.C.). 1990. *Official Methods of Analysis*. 15th edn. Washington, DC. Volume 1: 69-90.

Atteh, J.O. & Leeson, S. 1985. Response of laying hens to dietary saturated and unsaturated fatty acids in the presence of varying dietary calcium levels. *Poulry Science*. 64: 520-528.
Austin, P.R. 2005. *Chitin Research*. http://www. ocean.udel.edu/horseshoecrab/Research/chitin.html; pp. 1-3. (accessed April 19, 2005).
Baker, D.H. & Han, Y. 1994. Ideal amino acid profile for broiler chicks during the first three weeks posthaching. *Poultry Science.* 73: 1441-1447.
Baker, H.D., Batal, A.B., Parr, T.M., Augspurger, N.R. & Parsons, C.M. 2002. Ideal ratio (relative to lysine) of tryptophan, threonine, isoleucine and valine for chicks during the second and third week of life. *Poultry Science*. 81: 485-494.
Balloun, S. L. 1980. Effect of processing on the nutritional value of soybean meal for poultry. Pages 36-55 in Soybean meal *In Poultry Nutrition*. K.C. Lepley, ed. Ovid Bell Press, Fulton, MO.
Bames, E.M., Mead, G.C., Barnum, D.A. & Harry, E.G. 1972. The intestinal flora of the chicken in the period 2 to 6 weeks of age, with particular reference to the anaerobic bacteria. Competitive exclusion of salmonellas from the newly hatched chick. *British Poultry Science*. 12: 311-326.
Batal, A.B. & Parsons, C.M. 2003. Utilization of different soy products as affected by age in chicks. *Poultry Science.* 82: 454-462.
Bath, D., Dunbar, J., King, J., Berry, S. & Olbrich, S. 2001. By-products and unusual feedstuffs. *In: Feedstuffs 2001*. 73: 30-37.
Becerra, M. 1994. *Evaluation of feeding systems for growing ducks based on aquatic plants and sugar cane juice*. MSc thesis, Swedish University of Agricultural Sciences, Uppsala, 1994.
Blair, R., Daghir, N.J., Morimoto, H., Peter, V. & Taylor, T.G. 1983. *Nutrition Abstracts Reviews* – Series B. 53: 669-713.
Bons, A., Timmler, R. & Jeroch, H. 2002. Lysine requirement of growing male Pekin ducks. *British Poultry Science*. 43: 677-686.
Borin, K., Lindberg, J.E. & Ogle, R.B. 2005. Digestibility and digestive organ development in indigenouss and improved chickens and ducks fed diets with increasing inclusion levels of cassava leaf meal. *Journal of Animal Physiology and Animal Nutrition*. (In press).
Branckaert, R. 1967. Feeding brewer´s dried grains. *In Poultry Feed from Waste*, 1994. El Boushy, A.R.Y. Publ. By Chapman & Hall, Lodon UK. Pp.322.
Buraczewska, L. & Buraczewski, S. 1985. Deamination of amino acids in the intestinal digesta of pigs. Pp. 268-271 in Just, A., Jorgensen, H: & Fernandez, eds. Proc. 3rd. Seminar on Digestive Physiology in the Pig. Copenhagen, Denmark.
Buttery, P.J. & D´Mello, J.P.F. 1994. Amino acid metabolism in farm animals: An overview. In: D´Mello, J.P.F. (ed.) *Amino Acids in Farm Animal Nutrition.* CAB International, Wallingford, UK. Pp. 1-10.
Carlén, E. & Lansfors, B. 2002. *Duck production in the Mekong Delta of Vietnam _ A survey with emphasis on the development and the sustainability.* Minor Field Studies No. 209. Swedish University of Agricultural Sciences, Uppsala, Sweden.
Calvert, C.C. 1991. Fiber utilization in swine. In: Miller ER, Ullrey, D.E., Lewis, A.J. editors. *Swine nutrition.* Stoneham (UK): Butterworth-Heinemann. 1991.
Chau, P.T.T., Bang, L.K. & Ngoan, N.V. 1997. Preparation of technology of use of shrimp by-product from frozen shrimp processing. Final report of the KN. 04.17 Project, Minis. *Science Technology Environment.* Hanoi, Vietnam.
Cole, D.J.A. & Van Lumen, T.A. 1994. Ideal amino acid patterns. *Amino acids in farm animal nutrition*. (Ed) D´Mello, J.P.F. CAB international, Wallingford, United Kingdom, p. 37-62.
Coon , C.N., Leske, K.L., Akavanhican, O. & Cheng, T.K. 1990. Effect of oligosaccharide-free soyabean meal on true metabolisable energy and fibre digestion in adult rooster. *Poultry Science.* 69: 787-793.
Cromwell, G.L., Herkelman, K.L. & Stahly, T.S. 1993. Physical, chemical, and nutritional characteristics of distillers dried grains with solubles for chicks and pigs. *Journal Animal Science.* 71: 679-686.

Cuc, P.T., Tram, T.T.B. & Thuy, N.T.T. 2002. A study of chitin, N-acetyl glucosamine and other compounds in ensiled shrimp waste. *Research publication of the Agricultural College, Cantho University*.

Dalsgaard, A. & Schiere, H. 2001. *Peri-urban animal production systems & general veterinary medicine.* Livestock Community and Environment. Proceedings of the 10th Conference of the Association of Intitutions for Tropical Veterinary Medicine, Copenhagen, Denmark. 2001.

De Silva, L.L.S.S.K. 1998. *Poultry feeds prepared from fermented prawn waste silage*. Ph.D. Thesis, Loughborough University, Loughborough, UK.

Dean, W.F. 1978. *Nutrient requirements of ducks*. Proc. 1978 Cornell Nutrition Conf. pp. 132-140.

Deguchi, E., Niiyama, M., Kagota, K. & Namioka, S. 1978. Role of intestinal flora on incorporation of N from dietary, N urea and N diammonium citrate into tissue proteins in pigs. *Journal of Nutrition.* 108: 1572-1579.

DePeters, E.J., Faedl, J.G., Arana, M.J. Ohanesian, N. Etchebarne, M.A. Hamilton, C.A. et al. 2000. Variability in the chemical composition of seventeen selected byproduct feedstuffs used by the California dairy industry. *Prof Animal Science.* 16(2): 69-99.

Devendra, C. 1997. *Improvement of livestock production in crop-animal systems in rainfed agro-ecological zones of South-East Asia*. International Livestock Research Intitute, Nairobi, Kenya. Pp. 116.

De Zeeuw, H. 2000. Urban and Peri-urban Agriculture, Health and Environment. Electric conference "Urban and Peri-urban Agriculture on the Policy Agenda". http://ruaf.org/info_market.html; (accessed March 13, 2004).

Dong, N.T.K. & Ogle, B. 1995. On-farm trial on the use of locally available feed resources for Muscovy ducks in the Mekong Delta of Vietnam. Paper presented at the *International SAREC Workshop, 12-15 Sept. 1995, University of Agriculture and Forestry, Ho Chi Minh City, Vietnam*. Pp. 24-26.

Dong, N.T.K. 1996. A study on feeding Muscovy ducks by locally available feed resources to improve the incomes of poor farmers (Vietnamese). *Science and Technology. Special Publication in Agriculture,* Cantho University. Pp. 24-26.

Dong, N. T. K., 1999. *Studies on the performance of growing ducks fed brewery waste in the Mekong Delta*. M.Sc. Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.

Dong, N.T.K., Nha, P.T., Ogle, B. & Preston, T.R. 2003a. Effect on performance of replacing broken rice by molasses with supplementation of soya waste in diets for growing ducks. *In Proceedings of a SAREC/Sida Workshop on Sustainable Livestock Production on Local Feed Resources, March 25-27, 2003, Hue, Vietnam* (Ed. Preston, T.R. & Ogle, B.)

Dong, N.T.K. & Ogle, B. 2003b. Effect of Brewery Waste Replacement of Concentrate on the Performance of Local and Crossbred Growing Muscovy Ducks. *Asian-Australasian Journal of Animal Sciences*. 16: 1510-1517.

Dong, N. T. K. & Ogle, R. B. 2004. An evaluation of brewery waste as a replacement for concentrates in diets for growing crossbred common ducks. J. *Tropical Animal Health and Production.* 36: 715-729.

Dung, N.N.X. 2001. *Digestibility and digesta retention in pigs fed different tropical fibre sources and the estimation of in vivo digestibility by laboratory methods.* Ph.D. Thesis. Swedish University of Agricultural Sciences, Uppsala.

Edwards, P. 1986. Duck-fish integrated farming system. *Duck production science and world practice*. (Eds) Farrell, D.J. & Stapleton, P. University of New England, Australia. Pp. 267-291.

El Beeli, M.Y., Musharaf, N.A., Abdalla, H.O. & Bessei. W. 2002. Crude fibre digestibility in scavenger ducks. *Arch. Geflugelk.* 66: 169-172.

Elkin, R.G. 1987. A review of duck nutrition research. *World´s Poultry Science.*43: 84-106.

Emmert, J.L. & Baker, D.H. 1997. Use of the ideal protein concept for precision formulation of amino acid levels in broiler diets. *Journal of Applied Poultry Science.* 6: 462-470.

Eruvbetine, D., Tajudeen, I.D., Adesun, A.T. & Olojede, A.A. 2003. Cassava (Manihot esculenta) leaf and tuber concentrate in diets for broiler chickens. *Bioreouce Technology*. 86: 277-281.
Evers, D. J. & Carroll, D.J. 1996. Preservation of crab or shrimp waste as silage for cattle. Animal feed Science and Technology. 59: 233-244.
Fagbenro, O.A. & Bello-Olusoji, O.A. 1997. Preparation, nutrient composition and digestibility of fermented shrimp head silage. *Food Chemistry*. 60(4): 489-493.
Famino, A. O., Oduguwa, O.O., Jimoh, Y.O. & Faronbi, A.O. 1998. Performance and carcass evaluation of broiler chicks fed shrimp waste meal supplemented with synthetic amino acid. *Nigerian Journal of Animal Production*. 25: 17-21.
Fanimo, A.O., Oduguwa, B.O., Oduguwa, O.O., Ajasa, O.Y. & Jegede, O. 2004. Feeding value of shrimp meal for growing pigs. *Arch. Zootechnology.* 53: 77-85.
FAOSTAT data, 2003. FAO Statistical Database. *Food and Agriculture Organization of the United Nations*. http:// apps.fao.org; (accessed February 22, 2003).
FAOSTAT data, 2004. FAO Statistical Database. *Food and Agriculture Organization of the United Nations*. Rome. http:// faostat.fao.org/default. Jsp; (accessed October 17, 2004).
FAOSTAT data, 2005. FAO Statistical Database. *Food and Agriculture Organization of the United Nations*. Rome. http:// faostat.fao.org/faostat/servlet; (accessed July 14, 2005).
FAO, 2005a. Duckling the issue? New Agriculturist On-line. http:/7www.new-agri.co.uk/00-1/focuson/focuson4.html; pp. 1-2 (accessed April 17, 2005).
FAO, 2005b. Brewers grains, Wet brewers grains, Dried brewers grains, Brewers spent grain, Brewers Dried Yeast. *In Animal Feed Resources Information System*. http://www.fao.org/ag/aga/agap/frg/afris/Data/468.htm; pp. 1-3 (accessed April 20, 2005).
Farhat, A., Normand, L., Chavez, E.R. & Touchburn, S.P. 1998. Nutrient digestibility in food waste ingredients for Pekin and Muscovy ducks. *Poultry Science*. 77: 1371-1376.
Farhat, A., Normand, L., Chavez, E.R. & Touchburn, S.P. 2000. Comparison of growth performance, carcass yield and composition, and fatty acid profiles of Pekin and Muscovy ducklings fed diets based on food waste. Pp. 107-113.
Farrell, D.J. 1990. Nutrition and carcass quality in ducks. *Recent Advances in Animal Nutrition.* 1990. pp. 177-197.
Fox, C.J. Blow, P., Brown, J.H. & Watson, I. 1994. The effect of various processing methods on the physical and biochemical properties of shrimp head meals and their utilization by juvenile *Penaeus monodon* Fab. *Aquaculture*. 122: 209-226.
Fuller, M.F. 1994. Amino acid requirements for maintenance, body protein accretion and reproduction in pigs. In: D´Mello, J.P.F. (ed.) *Amino Acids in Farm Animal Nutrition*. CAB International, Wallingford, UK. pp. 155-184.
Fuller, R. 1984. Microbial activity in the elimentary tract of birds. *Proceedings of the Nutrient Society*. 43:55-61.
Fuller, R. & Cole, C.B. 1988. The scientific basis of the probiotic concept. In: *Probiotics-Theory and Applications* (Stark, B.A. and Wilkinson, J.M., eds.) Chalcombe Publications, Marlow. Pp. 1-14.
Gernat, A.G. 2001. The effect of using different levels of shrimp meal in laying hen diets. *Poultry Science.* 80: 633-636.
Goering, H.K. & Van Soest, P.J. 1991. *Forage fibre analysis* (apparatus, reagents and some applications). USDA Agric. Handbook. No. 379, National Academic Press, Washington DC. Pp. 1-19.
Göhl, B. 1998. *Tropical Feeds*. FAO Software Developed by Speedy, A. & Waltham, N. Version 8.
Goodlad, R.A., Ratcliffe, B.R., Fordham, J.P. & Wright, N.A. 1989. *Does dietary fibre stimulate intestinal cell proliferation in germ-free rats*? Gut. 3:820-825.
Gurnsey, M.P. & James, K.A.C. 1985. An improved method of ileal cannulation of adult cockerels. *Research in Veterinary Science*. 39: 390-391.
Ha, J.K., Kim, S.W. & Kim, W.Y. 1996. *Use of agro-industrial by-products as animal feeds in Korea*
Hetland, H., Svihus, B. & Choct, M. 2005. Role of insoluble fiber on gizzard activity in layers. *Journal of Applied Poultry Research*. 14: 38-46.

Hieu, L.T. 2000. Sustainable livestock production on local feed resources. *Sustainable livestock production on local feed resources.* Proceedings National seminar-workshop. Ho Chi Minh City, Vietnam, January 18-20, 2000, pp. 5-10.

Hillman, W.S. and Culley, D.D. 1978. The uses of duckweed. *Amecican Scientist.* 66: 442-451.

Hong,T.T.T., Thanh, V.T.K., Phuong, P.T., Luu, P.T. & Orskov, R. 2003. Utilisation of by-product from soya bean for growing pigs. *In proceedings of SAREC/Sida Workshop on Sustainable Livestock Production on Local feed Resources in March 25 to 27, 2003 in Hue, Vietnam*. (Ed. Preston, T.R. & Ogle, B.) pp. 173-176.

Hudson, S.M. 1994. Review of chitin and chitosan as fibre and film formers. *Journal Material Science.* 34(3): 375-437.

Iyayi, E.A. & Aderolu, Z.A. 2004. Enhancement of the feeding value of some agro-industrial by-products for laying hens after their solid state fermentation with Trichoderma viride. *African Journal of Biotechnology*. 3 (3): 182-185.

Jamroz, D.A., Wilickiewicz, J., Orda, J. & Skorupinska, J. 1996. Parameter des Verdauungstrakts und der N-und P- Verdaulichkeit der Aminosauren bei Verfutterrung von triticale und Enzymen an Hahnchen, Enten und Ganse. *Journal Animal Physiology Animal Nutrition*. 79: 123-134.

Jamroz, D., Jakobsen, K., Orda, J., Skorupinska, J. & Wiliczkiewicz, A. 2001. Development of gastrointestinal tract and digestibility of dietary fibre and amino acids in young chickens, ducks and geese fed diets with high amounts of barley. *Comparative Biochemistry and Physiology* Part A, 131: 657-668.

Jamroz, D., Jakobsen, K., Knudsen, K.E.B., Wiliczkiewicz, A. & Orda, J. 2002. Digestibility and energy value of non-starch polysaccharides in young chickens, ducks and geese, fed diets containing high amounts of barley. *Comparative Biochemistry and Physiology* Part A, 130: 643-652.

Jeuniaux, C. & Voss-Foucart, M.F. 1997. A specific enzymatic method for the quantitative estimation of chitin. In: *Chitin Handbook,* Muzzarelli, R.A.A. and Peter, M.G. eds. European Chitin Society. Pp. 3-6.

Johnson, R.J. 1992. Principles, problems and application of amino acid digestibility in poultry. *World´s Poultry Science Journal*. 48: 231-246.

Jorgensen, H., Zhao, X.Q., Knudsen, K.E.B. & Eggum, B.O. 1996. The influence of dietary fibre source and level on the development of the gastrointestinal tract, digestibility and energy metabolism in broiler chickens. *British Journal of Nutrition.* 75: 379-395.

Just, A., Jorgensen, H. & Fermander, J. A. 1985. The influence of differently treated straw on the ileal and faecal digestibility of nutrients and the utilisation of digested protein and energy. Pages 211-214 in Just, A., Jorgensen, H. & Fermander, J.A., eds. Proc, 3rd. Int. *Seminar Digestive Physiology in the Pig*. Denmark.

Kadim, I.T. & Moughan, P.J. 1997. Development of an ileal amino acid digestibility assay for the growing chicken-effects of time after feeding and site of sampling. *British Poultry Science*. 38: 89-95.

Kadim, I.T., Moughan, P.J. & Ravindran, V. 2002. Ileal amino acid digestibility assay for the growing meat chicken- comparison of ileal and excreta amino acid digestibility in the chicken. *British Poultry Science.* 44: 588-597.

Kang, J.S., Kim, J.I. & Park, J.H.1995. Influence of rice-duck farming system on yield and quality of rice. *Korean Journal of Crop Science*. 40. 437-443.

Ketaren, P.P. 1998. Feed and feeding of duck in Indonesia. *Indonesian Agricultural Research and Development Journal*. 20:51-56.

Khang, N.T.K. 2003. *Use of duckweed (Lemna minor) as a protein supplement for local (Tau Vang) chicks, and growing and laying hens.* M.Sc. Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.

Khoury, K., Floch, M.H. & Hersh, T. 1969. Small intestinal mucosal cell proliferation and bacterial flora in the conventionalization of the germ free mouse. *Journal Experimental Medicine.* 130: 659-670.

Kienholz, E. W. & Jones, M. L. 1967. The effect of brewers´dried grains upon reproductive performance of chicken and turkey hens. *Poultry Science.* 46: 1280.

Klasing, K. C. 1998. *Comparative Avian Nutrition.* CAB International, University Press at Cambrige, United Kingdom. Pp. 125-170.

Kuiken, K.A. & Lyman, C. M. 1948. Availability of amino acids in some foods. *Journal Nutrition.* 36: 359-68.

Larbier, M. and Leclercq, B. 1994. *Nutrition and Feeding of Poultry.* Nottinggham University Press. Pp. 162-164.

Leclerq, B. 1990. Effect of sex on growth, technological and organoleptic characteristics of the Muscovy duck breast muscle. Baeza, E., Salichon, M.R. & March, G. In *British Poultry Science* (1998). 39: 398.

Lee, A. 1985. Neglected niches: The microbial ecology of the gastrointestinal tract. *Advanced Microbial Ecology*. 8: 115-162.

Leeson, S. & Summers, J.D. 1997. *Commercial Poultry Nutrition*, 2nd edn. University Books Press, Guelph, Ontario, Canada. Pp. 302.

Leng, R.A. & Bell, R. 1995. *Duckweed- a potential high-protein feed resource for domestic animals and fish.* Centre for duckweed research & development university of New England Armidale, NSW. Australia. _http://www.cipav.org.co/Irrd.Irrd7/1/3.htm: Accessed October first, 1995.

Leng, R.A. Stambolie, J.H. & Bell, R. 1995. *Duckweed. A potential high-protein feed resource for dometic animals and fish.* Proc. 7th AAAP Animal Science Congress. *Improving anuimal Production Systems Based on Local Feed Resources.* Pp 103-117.

Lien, N.T.B. 1997. *Growth performance of crossbred Muscovy ducks*. Graduate Thesis, Faculty of Agriculture, Cantho University.

Liener; I.E. 1986. Nutritional significance of lectins in the diet. Pages 527-547 in *The Lectins: Properties, Functions and Applications in Biology and Medicine*. Liener, I.E., Sharon, N. and Goldstein, I.J., ed. Academic Pr, Orlando, FL.

Logsdon; G. 1989. *Is duckweed the ultimate waste water purifier*? BioCycle. Pp.70-71.

Lumpkins, B.S, Batal, A.B. & Dale, N.M. 2004. Evaluation of distillers dried grains with solubles as a feed ingredient for broilers. *Poultry Science.* 83: 1891-1896.

Lumpkins, B.S., Batal, A.B. & Dale, N.M. 2005. Use of distillers dried grains plus solubles in laying hen diets. *Journal Applied Poultry Research.* 14: 25-31.

Lung, B.D.& Man, L.H. 1999. *Feeds and feeding poultry*. Agricultural Publishing House, Hanoi, Vietnam. Pp. 211.

Mack, S., Bercovici, D., De Groote, G., Leclercp, B., Lippens, M., Pack, M., Schutte, J.B. & Van Cauwenberghe, S. 1999. Ideal amino acid profile and dietary lysine specification for broiler chickens of 20 to 40 days of age. *British Poultry Science*. 40: 257-265.

Martin,E.A., Nolan, J.V., Nitsan, Z. & Farrell, D.J. 1998. Stategies to improve the nutritive value of rice bran in poultry diets. IV. Effects of addition of fish meal and a microbial phytase to duckling diets on bird performance and amino acid digestibility. *British Poultry Science*. 39: 612-621.

Masaaki Takemasa. 1992. *Improvement of the method for chromic oxide determination with potassium phosphate reagent*. Annual Research Report of N.I.A.I. 52: 7-13.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. & Morgan, C.A. 2002. *Animal Nutrition*. 6th Edition. Longman Scientific and Technical. New York. Pp. 560-570.

McNab, J. 1979. The concept of amino acid availability in farm animals. In: Haresign, W. and Lewis, D. (eds). *Recent Advances in Animal Nutrition*- 1979. Butterworths, London. Pp. 1-9.

Mead, G.C. 1989. Microbes of the avian cecum: types present and substrates utilized. *The Journal of Experimental Zoology Supplement*. 3:48-54.

Mead, G.C. & Adams, B.W. 1975. Some observations on the caecal micro-flora of the chick during the first two weeks of life. *British Poultry Science.*16: 169-176.

Men, B.X. 1996. *Improvement of local duck production systems in the Mekong Delta of Vietnam*. MSc thesis. Swedish University of Agricultural Sciences. Uppsala, Sweden. ISSN 0347-9838.

Men, B.X., Ogle, R.B. & Lindberg, J. E. 2001a. Studies on integrated duck-rice systems in the Mekong Delta of Vietnam. *Journal of Sustainable Agriculture.*

Men, B.X., Ogle, B. & Lindberg, J.E. 2001b. Effect of diet and management system on growing duck performance in the Mekong Delta of Vietnam.

Men, B.X., Ogle, B. & Lindberg, J.E. 2001c. Use of duckweed as a protein supplement for growing ducks. *Asian-Australasian Journal of Animal Sciences*. 14(11):
Meyers, S.P. 1986. Utilisation of shrimp processing wastes. INFOFISH *Marketing Digest*. 4/86: 18-21.
Meyers, S.P. & Benjamin, G. 1987. Feeding values of crustacean wastes can be improved through proper ensilage treatment. *Aquaculture.* March 30:12-13.
Minh, N.T. 2000. Using tofu waste for laying ducks. *In Proceeding of Sustainable Livestock Production on Local Feed Resources Sarec Workshop*. (Ed. Preston, T.R., Ogle, R.B., Ly, L.V. and Hieu, L.T). Hanoi/Ho Chi Minh City, Vietnam, Nov. 22-27, 1993. pp. 50-52.
Minitab, 1998. Minitab Reference Manual Release 12 for Windows, Minitab Inc. USA.
Minitab, 2000. Minitab Reference Manual Release 13 for Windows, Minitab Inc. USA.
Mohan, S.K.M. & Siravaman, E. 1993. The feeding value of dried prawn waste in the rations for swine. *Journal of Veterenary Animal Science.* 24: 103-108.
Morrison, F.B. 19556. *Feeds & feeding*. 22nd revised edition. Clinton (IA): The Morrison Publishing Company. 1956.
National Research Council. 1994. *Nutrient Requirements of Poultry*, 9th edn. National Academy Press, Washington, DC.
National Research Council. 1998. *Nutrient Requirements of Swine,* 10th edn. National Academy Press, Washington, DC.
National Research Council (NRC). 2001. *Nutrient requirements of dairy cattle.* 7th revised edition. Washington. DC: National Academy Press.
Ngoan, L.D. 2000. *Evaluation of shrimp by-products for pigs in Central Vietnam*. Dotoral thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.2000.
Ngoan, L.D., An, L.V., Ogle, B. & Lindberg, J.E. 2000a. Ensiling techniques for shrimp by-products and their nutritive value. *Asian-Australasian Journal of Animal Sciences.* 13: 1278-1284.
Ngoan, L.D. & Lindberg, J.E. 2001b. Ileal and total tract digestibility in growing pigs fed cassava root meal and rice bran diets with inclusion of fish meal and fresh or ensiled shrimp by-products. *Asian-Australasian Journal of Animal Sciences*. 14: 216-223.
Ngoan, L. D., Ogle, B. & Lindberg, J. E. 2001c. Effect of replacing fish meal with ensiled shrimp by-product on the performance and carcass characteristics of growing pigs. *Asian-Australasian Journal of Animal Sciences*. 14: 82-87.
Ngu, N. T. 2001. *Improving Utilization of Market Wastes from Fruits and Vegetables in Goat Feeding*. M.Sc. Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.
Nho, L.T., Tieu, H.V., Dung, D.T., Tho, L.X., Xuan, D.V. & Trong, N.D. 1995. *Growth and performance of C.V Super Meat duck under management conditions in the Red River Delta.* Selection of scientific works on animal production. Agricultural Publishing House, Hanoi, Vietnam. Pp. 143-151.
Nir, J., Nitsan, Z. & Mahagna, M. 1993. Comparative growth and development of the digestive organs and some enzymes in broiler and egg type chicks after hatching. *British Poultry Science.*34: 523-532.
Nitsan, Z., Ben-Aviaham, G., Zoref, Z. and Nir, J. 1991. Growth and development of the digestive organs and some enzymes in broiler chicks after hatching. *British Poultry Science.*32: 515-523.
Noll, S., Stangeland, V., Speers, G. & Brannon, J. 2001. *Distillers grains in poultry diets.* 62nd Minnesota Nutrition Conference and Minnesota Corn Growers Association Technical Symposium, Bloomington, MN
Nugent, R. 2000. Urban and Peri-urban Agriculture, Household Food Security and Nutrition. Electronic conference "Urban and Peri-urban Agriculture on the Policy Agenda". http://wwwRuaf.org/info_market.html; (accessed March 13, 2004).
Oduguwa, O.O., Fanimo, A.O., Olayemi, V.O. & Oteri, N. 2004. The feeding value of sun-dried shrimp waste-meal based diets for starter and finisher broilers. *Arch. Zootechnology*. 53: 87-90.
Ogle, R.B., & Phuc, B.H.N. 1997. Sustainable intensive livestock-based systems in Vietnam. *IRDC*. No. 13/14. pp. 16-22.

Onifade, A.A. & Babatunde, G. M. 1998. Comparison of the utilization of palm kernel meal, brewers´dried grains and maize offal by broiler chicks. *British Poultry Science*: 39: 245-250.
Pahlow, G. 1991. Role of microflora in forage conservation. In:*The proceedings of a Conference on Forage Conservation towards to 2000*, Germany. Pp. 26-36.
Parkhurst, C. R. & Mountney, G. J. 1988. *Poultry Meat and Egg Production.* Published by Van Nostrand Reinhold Company, New York. USA. Pp. 227-236.
Parsons, C.M., Baker, D.H. & Harter-Dennis, J.M. 1983. Distillers dried grains with solubles as a protein source for the chick. *Poultry Science.* 62:2445-2451.
Parsons, C.M., Zhang, Y. & Araba, M. 2000. Nutritional evaluation of soybean meals varying in oligosaccharide content. *Poultry Science.* 79: 1127-1131.
Payne, W.L., Combs, G.F., Kifer, R.R. & Snider, D.G. 1968. *Investigation of protein quality-ileal recorvery of amino acids*. Federation Proceedings 27, 1199-1203.
Phuoc, T.H., Men, B.X. & Dong, N.T.K. 1994. Research results on Muscovy ducks in the Mekong Delta. *Science and Technology Information*, No 2, pp. 22-25.
Phuong, D.V. 2001. *Preservation of soya waste with molasses for animal feeds.* B.Sc. thesis. Facult of Agriculture, Cantho University.
Pustzai, A., Clarke, E.M.W., King, T.P. and Stewart, J.C. 1979. Nutritional evaluation of kidney beans (Phaseolus vulgaris): Chemical composition, lectin content and nutritional value of selected cultivars. *Journal of Science Food Agriculture*. 30:843-848.
Quac, V. A. 1990. Pig and Duck Rearing- Rural Production in the Mekong Delta. *Workshop on Sustainable Agriculture in the Lowlands*. Sep. 24- Oct. 7, Bangkok, Thailand.
Quoc, N.C., Tuyen, D:X., Dien, N.V. & Bac, N.V. 1995. Study on establishment of system for breeding and rearing of C.V Super Meat duck breed in southern provinces. *Selection of scientific works on animal production*. Agricultural Publishing House, Hanoi, Vietnam. Pp. 160-166.
Raa, J. & Gildberg, A. 1982. Fish silage: A review. CRC Critical Reviews in *Food Science and Nutrition.* 16(4): 383-419.
Raharjo, Y. & Farrell, D.J. 1984a. A new biological method for determining amino acid digestibility in poultry feedstuffs using a simple cannula, and the influence of dietary fibre on endogenous amino acid output. *Animal Feed Science and Technology.* 12: 29-45
Raharjo, Y. & Farrell, D.J. 1984b. Effects of caecectomy and dietary antibiotics on the digestibility of dry matter and amino acids in poultry feeds determined by excreta analysis. *Australian Journal Agriculture Animal Husbandry*. 24: 516-521.
Rajorhia, G.S., 1999. Analysis of aga studies on peri-urban livestock production systems in Asia, West Asia and Near East, Africa and Latin America. In: *Food and Agriculture Organization* Vialle Delle Terme Di Caracalla. Rome, Italy. December, 1999.
Ramachandran, K.G., Madhavan, P. And Gopakumar, K. 1986. *Novel use of chitinous waste from crustacean processing plants.* INFOFISH Marketing Digest. 4: 20-22.
Ramachandran, P., Viswanathan, T.V., James, P.C., George, M.C. & Mercy, A.D. 1997. Nutritive and microbiological evaluation of prawn waste- rice bran silage for ruminants. *Journal Veterenary Animal Science*. 28(1): 1-5.
Ravindran, V., Hew., L.I., Ravindran, G. & Bryden, W.L. 1999. A comparison of ileal digesta and excreta analysis for determination of amino acid digestibility in food ingredients for poultry. *Britsh Poultry Science.* 40:266-274.
Razdan, A., Petterson , D. & Pettersson, J. 1997. Broiler chicken body weights, feed intakes, plasma lipid and small-intestinal bile acid concentrations in response to feeding of chitosan and pectin. *British Journal Nutrition.* 78: 283-291.
Recombinomics. 2005. Widespread bird flu infections in the Mekong_Delta. Recombinomics Commentary. April 13, 2005. http://www.recombinomics.com/News/04 130503/H5N1 Widespread_Mekong_Delta.html;_pp. 1-2 (accessed July 23, 2005).
Ridla, M. & Uchida, S. 1997. Effects of cellulose and brewers´grains addition on the fermentation quality and nutrition value of barley straw silage. *Asian-Australasian Journal Animal Sciences.* 10(6): 575-580.
Roche, M. 1981. Feeding behaviour and digestive motility of birds. *Reproduction, Nutrition, Development.* 21: 781-789.

Rose, S.P. 1997. *Principles of Poultry Science*. CAB International, printed and bound by Biddles Ltd, Guildford, United Kingdom.

Rosenfeld, D.J., Gernat, A.G., Marcano, J.D., Murillo, J.G., Lopez, G.H. & Flores, J.A. 1997. The effect of using different levels of shrimp meal in broiler diets. *Poultry Science*. 76: 581-587.

Sakata, T. 1987. Stimulatory effect of short chain fatty acids on epithelial cell proliferation in the rat intestine: a possible explanation for tropic effects of fermentable fibre, gut microbes and luminal throphic factors. *British Journal of Nutrition.* 58: 95-103.

Salter, D.N. 1973. The influence of gut micro-organisms on utilization of dietary proteins. *Proc. Nutr. Soc*. 32: 65-71.

Salter, D.N. & Coates, M.E. 1974. The utilization of protein and excretion of uric acid in germ-free and conventional chicks. *British Journal of Nutrition.* 31: 307-318.

Sandhu, T. S. & Dean, W.F. 2005. *Basic Duck Care*. http://www.duckhealth.com/basecare.html; pp. 1-5 (accessed February 24, 2005).

Sarmiento-Franco, J. M., McNab, J.M., Pearson, A. & Belmar-Casso, R. 2003. The effect of chaya (Cnidoscolus aconitifolius) leaf meal and of exogenous enzymes on amino acid digestibility in broilers. *British Poultry Science*. 44: 458-463.

Sarria, P. & Preston, T.R. 1992. Reemplazo parcial de jugo de cana con vinaza y uso del grano desoya a cambio de torta en dietas de credos de engorde. Livestock Research for Development (4)1. http://www.cipav.org.co/Irrd/Irrd4/1/sarria.htm

SAS, 2003. SAS Institute Inc., Cary, NC, USA.

Sauver, B., 1990. Effect of sex on growth, technological and organoleptic characteristics of the Muscovy duck breast muscle. Baeza, E., Salichon, M.R. & March, G. *British Poultry Science.* 1998. 39: 389-403.

Savage, D.C. 1986. Gastro-intestinal micro-flora in mammalian nutrition. *Annual Review Nutrition*. 6: 155-178.

Savory, C.J. & Gentle, M.J. 1976a. Effects of dietary dilution with fibre on the food intake and gut dimension of Japanese quail. *British Poultry Science.* 17: 561-570.

Savory, C.J. & Gentle, M.J. 1976b. Changes in food intake and gut size in Japanese quail in response to mainipulation of dietary fibre content. *British Poultry Science*. 17: 571-580.

Scott, M.L. and Dean, W.F. 1991. *Nutrition and Management of ducks*. Cornell University Ithaca Press, New York, USA.

Scott, M.L., Hill, F.W., Parsons, E.H., Bruckner, Jr. J.H. & Dougherty, E. III. 1959. Studies on duck nutrition **7**. Effect of dietary energy:protein relationships upon growth, feed utilization and carcass composition in market ducklings. *Poultry Science*. 38:497-507.

Shim, K.F., Ghen, T.W., Teo, L.H. & Khin, M.W. 1989. Utilisation of wet spent brewer´s grains by ducks. *Nutrition Reports International*. 40: 261-270.

Short, F.J., Wiseman, J. and Boorman, K.N. 1999. Application of a method to determine ileal digestibility in broilers of amino acids in wheat. *Animal Feed Science and Technology*. 79: 195-209.

Shurson, G. C. 2003. Distiller´s dried grains with solubles (DDGS) suited for swine, may help ileitis resistance. *Feedstuffs*. 26:11-13.

Smith, H.W. 1965. The development of the flora of the alimentary tract in young animals. *Journal of Pathology and Bacteriology*. 90: 495-513.

Snow, J.L., Douglas, M.W. & Parsons, C.M. 2003. Phytase effects on amino acid digestibility in molted laying hens. *Poultry Science.* 82: 474-477.

Spackman, D.H., Stein, W.H. & Moore, S. 1958. Automatic recording apparatus for use in chromatography of amino acids. *Analytical Chemistry*. 30:1190-1206.

Stengel, G. 1991. Brewers grains: the industry. In: Jordan ER, editor. *Proceedings of the Alternative Feeds for Dairy and Beef Cattle Symposium.* Columbia (MO): University of Missouri. P. 86-89.

Stevens, P. & Sauveur, B. 1985. Duck production and management in France. *Duck production Science and World Pratice.* Farell, D.J. & Stapleton, P. (Ed). University of New England. Pp. 248-257.

Su, An-Kuo. & Station, Heng-Chun. 1996**.** *Utilization of agricultural by-products in Taiwan*. http://www.fftc.agnet.org/ library/article/eb422.html; pp. 1-6 (accessed April 20, 2005).

Summers, D.J. & Robblee, A.R. 1985. Comparison of apparent amino acid digestibilities in anesthetized versus sacrificed chickens using diets containing soybean meal and canola meal. *Poultry Science.* 64:536-541.
Svihus, B. & Hetland, H. 2001. Ileal starch digestibility in growing broiler chickens fed on a wheat-based diet is improved by mash feeding, dilution with cellulose or whole wheat inclusion. *British Poultry Science.* 42: 633-637.
Svihus, B. & Hetland, H., Chot, M. & Sundby, F. 2002. Passage rate through the anterior digestive tract of broiler chickens fed on diets with ground and whole wheat. *British Poultry Science*. 43: 662-668.
Swatland, H.J., 1981. Effect of sex on growth, technological and organoleptic characteristicd of Muscovy duck breast muscle. Beaza, E., Salichon, M.R., and March, G. In *British Poultry Science* (1998). 39, pp. 398.
Thanh, N. K., 2001. *Surveys on Urban and Rural Livestock Systems in Central Vietnam*. M.Sc. Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.
Thornton, P. A. & McPherron, T. A., 1962. Controlling body weight and liver lipid accumulation in the chicken with dietary brewers´dried grians. *Fed. Proc.* 21: 397.
Timmler, R. & Jeroch, H. 1999. Nutrition of meat type ducks-latest advances and development trends. *Proceedings 1st World Waterfowl Conference,* Taiwan. Pp. 283-291.
Toan, N.H. & Ngoan, L.D. 2003. Evaluation of shrimp by-product for laying hens in smallholder systems in Thua Thien Hue province. In: *Proc. Final National Seminar Workshop on Sustainable Livestock Production on Local Feed Resources* (Eds: Preston, R. & Ogle, B.) HUAF-SAREC, Hue City, 25-28 March, 2003.
Toung, Naren. 1994. Optimum protein supply and level of inclusion of water spinach (Ipomea aquatica) in sugar cane juice based diets for growing ducks. M.Sc. Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.
Tuan, D.T. 1996. *Ensiling techniques for shrimp by-products and their utilization for Landrace growing pigs*. MSc. Thesis, National Institute for Agriculture, Hanoi, Vietnam.
Villamora, M.A., Ogaro, N.O., Guevarra, A., Barcala, D.P. Jr, Rupa, R.M., Mesias, R., Bautista, A., Besa, Z., Partoza, N., Payod, D. & Daroy, S. 2000. *Techenology demonstration project on rice-duck farming.* PCARRD-DOST, Los Banos, Laguna, Philippines. Pp.143.
Wanichpongpan, P. 2005. *Chitin and Chitosan*. http://www.kmutt.ac.th/organization/Research/Intellect/best32e.htm; pp. 1-4 (accessed April 20, 2005).
Water-Bayer, A. 2005. Living with Livestock in Town: *Urban Animal Husbandry and Human Welfare*. http://www.ruaf.org/1-1/16-18.html; pp. 1-9 (accessed April 20, 2005).
Watkins, B.E., Adair,J. & Oldfield, J.E. 1982. Evaluation of shrimp and king crab processing by-products as feed supplements for mink. *Journal of Animal Science.* 55: 578-589.
Westendorf, M. L. & Wohlt, J. E., 2002. Brewing by-products: their use as animal feeds. In: *The Veterinary Clinics Food Animal Practice*. 18: 233- 252.
White, A., Handler, P. & Smith, E.L. 1968. *Principles of biochemistry.* 4th Ed., McGraw-Hill, New York.
Wiseman, J. 1987. *Feeding of Non-Ruminant Livestock.* Butterworths, pp. 102-109.
Zanella, I., Sakomura, N.K., Silversides, F.G., Fiquerdo, A. & Pack, M. 1999. Effect of enzyme supplementation of broiler diets based on corn and soybeans. *Poultry Science*. 78: 561-568.
Zikakis, J.P., Saylor, W.W. & Austin, P.R. 1982. Utilisation of chitin products and whey in animal nutrition. In: *The proceedings of Second International Conference on Chitin and Chitosan,* Sapparo, Japan. Pp. 233.

Acknowledgments

The studies presented in this thesis were carried out at the Department of Animal Sciences of the College of Agriculture and Applied Biology of Cantho University, and on smallholdings in the Mekong Delta, Vietnam; and the Department of Animal Nutrition and Management of the Swedish University of Agricultural Sciences (SLU). The support from these organizations is gratefully acknowledged.

I am grateful to the Swedish International Development Authority (SIDA), Department for Research Cooperation (SAREC) for their financial support, which made this study possible.

My deepest thanks to my main supervisor, Prof. Dr. Brian Ogle, who was the first scientist to support me at the beginning of my research career, and who gave invaluable advice as well as much useful guidance, particularly patient correction of my English throughout my M.Sc. and Ph.D. programs. I am greatly indebted to him.

Prof. Dr. Jan Erik Lindberg and Dr. Klas Elwinger, my associate supervisors, who provided me with useful guidance, enthusiastic review and valuable comments on my papers and my gereral discussion.

Special thanks to Prof. Dr. Inger Ledin, former Head of the Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences (SLU) for devoted and careful support during my time in Sweden.

I wish to express my sincere gratitude to:

Prof. Dr. Hans Wiktorsson, Dr. Hans Pettersson., Assoc. Prof. Dr. Peter Uden and staff at the Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences (SLU) for their kind help and encouragement.

Mr. Börje Ericson, Head of the Laboratory at the Kungsängen Ruminant Research Centre and Mrs Anna-Greta Haglund for their valuable help relating to laboratory techniques.

Professors, lecturers and assistant lecturers in courses which I have attended during my studies for sharing their valuable knowledge.

Professors Luu Trong Hieu and Le Viet Ly, Assoc. Prof. Drs. Tran Thuong Tuan, Le Quang Minh, Nguyen Bao Ve and Vo Van Son, who gave me permission to take part in my Ph.D. program, and their valuable advice. Special thanks to Assoc. Prof. Trinh Huu Phuoc for his enthusiasm and guidance in my field research.

My assistants and former students, Tam, Hoe, Phuong, Mo, Nha, Binh, Thang, Nghiep, Quang, Tai, Minh and Loi for their valuable contributions to this thesis.

Dr. Ngo Van Man, Dr. Bui Huy Nhu Phuc, Dr. Mai Van Sanh, Dr. Bui Xuan Men, Dr. Le Duc Ngoan, Dr. Nguyen Thi Mui, Dr. Nguyen Nhut Xuan Dung, Dr. Le Van Tho, Dr. Tran Kim Tinh, Dr. Le Van An, Dr. Duong Nguyen Khang and Dr. Arnd Bassler for their great support and encouragement during my studying.

My friends, Minh, Van, Borin, Nadir, Van Thong, Alice, Salimata, Hadja, Salifou, Thieu, Len, Hong, Oudom, Kerya, Malin, Tong Anh, Nhut, Sen, Daiga, Karin, Mai, Khai, Xuan, Nghia… for their friendship, sharing all the interesting aspects of student life away from home and their kind help.

Last, I greatly appreciate my beloved parents for their support and encouragement.

All my love to my husband, Nguyen Van Thu, for his valuable assistance and useful discussions in my research work and unceasing encouragement, and, my good children, Nhu Ha and The Hien, for their love and inspiration to my study.