Effect of Supplementation, Breed, Season and Location on Feed Intake and Performance of Scavenging Chickens in Vietnam

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Doctoral thesis
Swedish University of Agricultural Sciences
Uppsala 2005

Acta Universitatis Agriculturae Sueciae
2005 :101

ISSN 1652- 6880
ISBN 91-576-6900- 7

Tryck: SLU Service/Repro, Uppsala 2005

Abstract

Do Viet Minh, 2005. Effect of Supplementation, Breed, Season and Location on Feed Intake and Performance of Scavenging Chickens in Vietnam.

Doctor's dissertation., ISSN 1652- 6880, ISBN 91-576-6900- 7

The aims of the studies were to evaluate the nutrient status of local and improved scavenging hens in different seasons and locations by crop content analysis (Paper I), and the effects of scavenging and supplementing energy, protein, lysine and methionine on feed intake, performance, carcass quality and economic efficiency of different breeds of growing chickens and laying hens (Paper II, III and IV).
In Paper I, the nutrient, metabolisable energy (ME) and amino acid intakes of scavenging Ri (local) and Luongphuong (improved) hens from scavenging feed resources (SFR) were estimated to be about 50 % higher for the rainy season compared to the dry season, and significant differences were found between breeds and locations.
In Paper II, III and IV, the nutrient intakes from SFR were estimated to be at least 12 and 31 % of the nutrient intakes of confined growing and laying chickens, respectively. Supplement feed conversion ratios (FCR) and feed cost (FCS) were reduced by 12 to 36 % for scavenging chickens compared to confined chickens, depending on production type. Feed intake, performance and economic efficiency of scavenging local and improved laying hens were not significantly different among diets with supplementation of energy (maize meal only) compared to the control diet. However, protein supplementation (soybean meal only) reduced feed intake and performance of both local and improved hens, which indicated that energy supplementation was more important than protein for scavenging hens in Northern Vietnam. Lysine and methionine supplementation of diets for growing chickens reduced the supplement FCR and FCS by 12 and 16 %, respectively, and improved performance and carcass quality. The production performance of scavenging pullets and laying hens was not affected by replacing soybean meal (SBM) with cassava leaf meal, and fish meal with SBM in the diets of scavenging chickens.

It is concluded that scavenging chicken systems are sustainable and economical for both local and improved chicken breeds in Northern Vietnam. Economic benefits were 12 to 36 % higher compared to total confinement, and locally available feed resources such as cassava leaf meal can be used as supplements for scavenging chickens.

Keywords: Amino acids, crop contents, energy, local and improved scavenging chickens, protein, scavenging feed resources.

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Affectionately dedicated to my parents, my wife and my children

Contents

Appendix

The thesis is based on the following studies, which will be referred to in the text by their Roman numerals:

I. Minh, D.V., Lindberg, J.E. & Ogle, B. 2005. Effects of Season and Location on the Crop Contents of Local and Improved Scavenging Hens in Northern Vietnam (Submitted).

II. Minh, D.V. & Ogle, B. 2005. Effects of Scavenging and Supplementation of Lysine and Methionine on the Feed Intake, Performance and Carcase Quality of Improved Dual-Purpose Growing Chickens. *Tropical Animal Health and Production*. 37 (2005) 1- 15.

III. Minh, D.V., Ly, L. V. & Ogle, B. 2004. Effects of Energy and Protein Supplementation on the Production and Economic Efficiency of Scavenging Improved (Tamhoang) and Local (Ri) Breed Hens under Smallholder Conditions in Northern Vietnam. *Tropical Animal Health and Production.* 36 (7) 703-714.

IV. Minh, D.V., Lindberg, J.E. & Ogle, B. 2004. Effects of Scavenging and Protein Supplement on the Feed Intake and Performance of Improved Pullets and Laying Hens in Northern Vietnam. *Asian-Australasian Journal of Animal Sciences.* 17 (11), 1553-1561.

Papers II, III and IV are included with the kind permission of the journals concerned.

List of abbreviations

AA	Amino acids
Ash	Total Ash
ADG	Average daily weight gains
AME	Apparent metabolisable energy
CLM	Cassava leaf meal
Ca	Calcium
CP	Crude protein
CPI	Crude protein intake
CF	Crude fibre
CW	Carcass weight
DM	Dry matter
DMI	Dry matter intake
EE	Ether extract
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed conversion ratio (supplement feed)
FCS	Feed cost per kg eggs or weight gain (supplement feed)
FM	Fish meal
GDP	Gross domestic product
HCN	Hydrogen cyanide
LW	Live body weight
ME	Metabolisable energy
MEI	Metabolisable energy intake
N	Nitrogen
NFE	Nitrogen free extract
P	Phosphorus
SFR	Scavenging feed resources
SFRB	Scavenging feed resource base
SBM	Soybean meal
TME	True metabolisable energy
Ctrl	Control diets
VND	Vietnamese Dong

Introduction

Poultry production in most developing countries in the tropics is based mainly on scavenging systems, and it has been estimated that more than 80 % of the total poultry population is kept in traditional family-based production systems (Permin & Pedersen, 2000, Gueye, 2005). The estimated population of rural poultry in Asia is reported variously as ranging from 50 to 85 % of the total poultry population (Aini, 1990), and in Vietnam the scavenging chicken population is estimated at 70-75 % of the total chicken population (Vang & Ly, 2000). Most poultry improvement programs in developing countries have been directed towards the introduction of specialized or exotic breeds, crossbreeding and management intensification (Kitalyi, 1998a, b). However, the high mortality of introduced breeds, low feed resource base at the village level and lack of understanding of the complex biological, cultural and socio-economic relationships involved have limited the success of improved village chicken production systems in developing countries in general, and in Vietnam in particular. Therefore, more information on the intake and nutritional status of scavenging chickens is needed in order to introduce efficient supplementation strategies. One possible technique to solve this problem is to estimate scavenging feed resources (SFR) by crop content analysis. A number of studies on the qualitative and quantitative characteristics of SFR in village poultry have been carried out in developing countries, such as in Sri Lanka, (Roberts & Gunaratne, 1992; Gunaratne *et al.,* 1993; Ravindran & Blair, 1993), Bangladesh (Huque, 1999; Ali, 2002; Rashid *et al.,* 2004, 2005), Ethiopia (Dessie, 1996), Tanzania (Mwalusanya *et al.,* 2002b), Nigeria (Olukosi & Sonaiya, 2003), and Burkina Faso (Pousga *et al.*, 2005). Practical, economical and technical advantages of the determination of SFR by crop content analysis are claimed, it being a flexible technique developed to estimate the various needs of different poultry breeds in different climates, seasons and regions.

Scavenging chickens also serve as an efficient waste disposal system, converting leftover grains and human foods and insects into valuable protein foods, such as eggs and meat. They are also useful for insect and weed control and supplying organic fertilizer for crops. The economic efficiency of poultry production is not only dependent on productivity but also on the relationship between inputs and outputs. Feed inputs, such as protein supplements, are usually expensive, especially for rural poultry producers in developing countries, because of an increasing human demand for protein, and the relatively high cost of imported ingredients. Rural producers usually have limited access to capital, and therefore, the exploitation of non-conventional ingredients and by-products has attracted attention, and these regions have these in abundance (D'Mello, 1995). Although there have been several studies in Vietnam on the use of non-conventional feed resources, such as cassava leaves for ruminants (Man & Wiktosson, 2001; Khang & Wiktorssson, 2000; Khang, 2004) and pigs

(Phuc *et al.,* 2000), there is limited experience of using these resources for poultry. Cassava leaf meals (CLM) are interesting as they are inexpensive and have high contents of protein, minerals and vitamins, and are also fairly high in lysine (Ravindran & Blair, 1993). However, the major limitation in using CLM is their toxicity due to the presence of anti-nutritional factors, such as hydrogen cyanide (HCN), and high crude fibre and low methionine contents (Ranvindran, 1993). Scavenging chickens however can use locally available feed resources of poor nutritional quality as they can balance nutrient deficiencies from SFR.

Improving the productivity of scavenging chicken systems can be achieved in number of ways: for example, improvement of the diets, the use of more productive birds, better management and disease control and new sources of inexpensive feeds. However, a difficulty with improving the overall diet of scavenging chickens is that it is not known exactly what feeds they are scavenging and what the birds are actually eating (Smith, 2001), and therefore what nutrients should be provided as supplements. For example, it was reported that energy was critical during the rainy season in Ethiopia (Dessie, 1996), whereas protein supplementation was considered to be necessary for scavenging chickens in Bangladesh (Rashid, 2003). Data on the nutrient status and supplementation of scavenging chickens are lacking in Vietnam, especially on the availability of amino acids in the scavenging feed resources, using non-conventional feed resources as supplements, and also on the effects of scavenging and supplementing of energy, protein and amino acids on feed intake, performance and economical efficiency of scavenging chickens. The objectives of the present studies were:

- To estimate the nutrient and amino acid status of scavenging feed resources (SFR) by crop content analysis, and the contribution of SFR to the overall dietary intake.
- To investigate the effects of season and location on the crop contents of scavenging local and improved hens
- To evaluate the effects of scavenging and supplementing energy and protein on the nutrient intake and performance of different breeds of scavenging chickens.
- To determine the effects of scavenging and supplementing different protein sources, lysine and methionine on feed intake, production performance and economical efficiency of scavenging chickens.

Background

Poultry production in Vietnam

Vietnam is a tropical, still primarily agricultural country. It stretches 2000 km from North to South, with a tropical monsoon climate. Its area of 329,566 square km supports a population of 80.9 million, of whom 67.3 % are involved with agriculture (Statistical Yearbook, 2004). During the last five years the agricultural output of Vietnam has grown at about 4 % annually, and contributes 24.3 % of gross domestic product (GDP), of which livestock production contributed 5.4 %. Livestock accounted for 22.5 % of the total agricultural output in 2003 (Statistical Yearbook, 2004; FAOSTAT, 2004).

Poultry production in Vietnam is a traditional sector at smallholder level, and has an important position in the rural household economy, supplying high quality meat and eggs, and increasingly income, for rural farmers. Poultry also have an importance for the religious and cultural life of society in general and rural people in particular. The total poultry population in the country was estimated at 254 million in 2003, including about 185 million chickens and 69 million waterfowl (ducks, muscovy ducks, geese etc). According to data in the Statistical Yearbook (2004) and Vang (2004), the poultry population has increased rapidly from 1995 to 2004 (Table 1), both in terms of quantity and quality, in order to meet consumption demands of 353,000 tonnes of poultry meat, and 216,000 tonnes of eggs (about 4 billion eggs) in 2004 (FAOSTAT, 2004). However, the poultry population decreased in 2004, as a result of Avian Influenza, when a total of 38.3 million birds (about 15 %) were culled. Poultry production is still ranked second behind pig production, and accounted for 19 % of the total livestock production in 2004. Poultry is present in almost all agricultural households, which comprise nearly 80 % of the total households of Vietnam. It is estimated that about 12 million households are actively involved in poultry production (Vang & Ly, 2000).

Vietnamese agriculture can be divided into eight agro-ecosystems on the basis of ecological and economical criteria: North East, North West, Red River Delta, North Central Coast, South Central Coast, Central Highland, North East of Southland and Mekong River Delta. Poultry production varies according to ecological zone. In 1999, the Red River Delta region produced 28 % of the total chicken meat in the country, followed by the North East 22 %, Mekong River Delta 16 %, North East of Southland 11 %, and 23 % for all other regions in the country combined (Vang & Ly, 2000).

Table 1. Poultry production in Vietnam between 1995 and 2004.

Animals & Products	Unit	1995	2000	2001	2002	2003	2004	Growth rate (%) 95-2000	2001-04
Chickens	Million head	108	147	158	159	185	159	7.24	2.07
Water - fowl	Million head	32	51	58	64	69	59	11.8	3.9
Poultry eggs	Million eggs	2,820	3,710	4,160	4,530	4,850	3,940	6.31	1.55
Meat	Million tonnes	0.21	0.29	0.318	0.342	0.373	0.331	7.3	3.9

(Sources: Statistical Yearbook, 2004; Vang, 2004)

The chicken breeds of Vietnam are diverse and can be divided into three main breed types: indigenous (local breeds), improved (exotic, coloured-feather breeds) and exotic breeds (commercial breeds). There are also crossbred strains of indigenous and exotic breeds, and hybrids developed from exotic breeds.

Several indigenous breeds have been selected for many years, such as the Ri, Mia, Ho, Dongtao and Tauvang. Some breeds are raised for specific purposes, such as: Choi and Tre for cockfights, and the Ac (black boned breed for medicine) and H'mong for traditional dishes. The indigenous breeds have low productivity, and are not suitable for intensive systems. However, these breeds are very suitable for low-input scavenging and semi-scavenging systems. The Ri breed is popular and is widely raised in all ecological zones of Vietnam, especially in Northern Vietnam, as it is easy to keep under smallholder conditions. Some of its main characteristics are shown in Table 2.

Improved breeds: So-called coloured-feather breeds have been recently imported, such as the Tamhoang and Luongphuong (from China), Kabir (from Israel), and the Sasso and Isa-JA57 (from France). They are dual-purpose breeds, selected for both meat and eggs, and are often raised in semi-scavenging systems. The main production characteristics of some of these improved breeds are shown in Table 2.

Exotic breeds have been imported recently, including high yielding meat breeds, such as: Hubbard, Cornish, Plymouth Rock, Hybro, BE, ISA-Vedehe, ISA- MPK, Arbor Acres, Lohmann Meat, Ross- 308, Ross- 208, etc, and egg- type breeds, such as: Leghorn, Goldline, Hyline, Hisex Brown, Brown Nick, and ISA Brown.

Table 2. Main production criteria of Ri (local), Tamhoang and Luongphuong (improved) breeds in intensive systems

Characteristics	Breed	
	Ri (local)	Improved
Age at first egg (days)	144	140- 154
Egg production up to 67 weeks of age (eggs)	122	155- 178
Average egg weight (g)	41.4	51- 58
Feed conversion per 10 eggs (kg feed)	3.7	3.1- 2.8
Feed conversion per kg weight gain (kg)	3.55	3.2- 2.6
Age at 5 % lay (weeks)	23	21- 23

(Sources: Vang & Son, 2000; Dat *et al.*, 2001; Man & Son, 2001)

Crossbreds include F1 crosses between local and exotic breeds, such as the Rhode-Ri which is a cross between Rhode Island x Ri breeds, and crosses between Kabir x Luongphuong, between Kabir x Tamhoang (Jiangcun), and between Ri x Kabir, etc. They generally have superior characteristics compared to indigenous breeds, such as higher body weight gains and productivity (Vang, 2003).

Commercial feeds are increasingly used for poultry production, even in small-scale systems. However, commercial feed is very expensive, especially for farmers in remote rural areas. Although Vietnam is the second biggest rice exporter in the world, feed ingredients such as wheat bran, soybean meal and cake, maize, and feed additives are still imported. For example about 300,000 tonnes of maize were imported in 2003 (FAOSTAT, 2004), and the maize price is 1.5 times higher than in the United States (Vang & Son, 2000). About 2.6 millions tonnes of broken rice and rice bran were used for poultry feed in 2001 (FAOSTAT, 2002). Soybeans and soybean products are the main protein sources in poultry feeds and are mainly imported, and therefore they are expensive for rural farmers. Fish meal and other protein sources are scarce and expensive for farmers, especially in remote areas.

Veterinary, extension service and marking systems for poultry production are developed widely from central to village levels in Vietnam. However, active capability is rather limited, especially in remote areas.

Poultry production also depends on economic and social conditions and the ecological environment, and there are a number of major constraints and opportunities for development in Vietnam: Disease is considered to be a major current threat to poultry production. In particular, Avian Influenza outbreaks in 2004 and 2005 exposed the lack of necessary diagnostic capacity to deal with the disease. However, poultry movement and live-

poultry markets are now controlled carefully, and stringent disinfection and other bio-security measures have been introduced. Other diseases, such as Newcastle disease, fowl cholera, fowl typhoid and fowl pox are also common, and the Vietnamese government has encouraged farmers to actively participate in vaccination campaigns against the major infectious diseases of poultry, especially Avian Influenza and Newcastle disease. In addition to infectious diseases, parasites and nutritional disorders are serious problems in village chickens.
Other constraints include the high price of commercial feed in Vietnam, which is reported to be 1.5 to 2 times higher compared to world market prices (Vang & Ly, 2000). Veterinary service is poor, especially in mountainous and remote areas, and there is a low capacity in research with respect to genetics and breeding. Also the cost of day-old chicks is too high for many rural farmers (Vang & Ly, 2000). In addition, lack of knowledge of bio-security, poor meat and egg processing technology and problems of obtaining rural credit are all major constraints to development.

However, there are several opportunities for expansion of poultry production. The demand for poultry meat in the domestic market is growing rapidly as the population, incomes and urbanisation increase; the technical skill of farmers is improving; the short production cycle of poultry means more rapid returns on capital investment; there is a large pool of cheap labour in the rural areas (including women, older people and children); and there is a strong policy of government for the development of livestock and poultry production.

Poultry farming systems

In Vietnam, there are three main feeding and management systems of poultry: Traditional systems (scavenging or extensive systems), semi-industrial systems and industrial systems (Vang & Ly, 2000). Scavenging chickens are raised in every village in Vietnam, and about 75 % of the national flock of 139 million in 2003 is kept under traditional village systems. Villagers use free range, backyard or semi-intensive systems, but not usually the intensive system (FAO, 2002). Smith (2001) distinguished three main ways of keeping poultry in tropical areas: *Traditional scavenging*, *improved semi-scavenging* and *intensive poultry farming*. According to Sonaiya (1995) in Nigeria the two main poultry management systems are extensive and intensive. The extensive, or scavenging system, has two subsystems: the *free-range system*, also called the traditional or village system, in which birds are free to roam around the homestead, and the *backyard system,* also called the family or subsistence system, in which birds are partly confined within a fenced yard. The intensive system also includes two subsystems: the *small-scale intensive system,* in which a small number of birds are produced in complete confinement, and the *industrial system*. The types of management system used for rural poultry would depend on the ecological and climatic conditions and the socio-economic status of the farmers.

Traditional farming systems: These systems have existed for a long time in virtually all developing countries. The village poultry production systems are traditional farming systems based on the scavenging domestic fowl (*Gallus domesticus*). The main characteristics of this system are that capital, labour and technology inputs are extremely low, as the birds are scavenging freely without fences, and do not need commercial feeds. The number of scavenging chickens in traditional systems of Vietnam is considerable and accounts for about 65 % of the total number (Vang & Ly, 2000). However, egg and meat production are still low because most are kept in small households and are local breeds. The productivity of scavenging chickens in Vietnam is quite variable, and depends on scavenging feed resources, feed supplementation, season and breed, and is also related to agro- ecological conditions. The body weight of a 5 months old local chicken is 1.3 to 1.5 kg and local laying hens produce only 70 to 80 eggs per year (FAO, 2002). However, scavenging chicken meat is preferred by consumers for its taste and brings a high price (Vang & Ly, 2000). The productivity is weak, given the low initial production base, and the potential for increased productivity through better nutrition and cross breeding is high (FAO, 2002). In general, rural farmers in Southeast Asia keep between 5 and 50 indigenous chickens per household, while less than 20 birds per flock is typical for Bangladesh (Bessei, 1990). Flock sizes in the village chicken production systems in Africa are similar to those observed in Asia (Kitalyi, 1998a). Flock sizes can also be described in terms of the flock structure, that is the proportions of the different age groups and sexes in a flock. The scavenging system is easily combined with systems of fish and crop production (eg. rice-fish-duck system in Vietnam), and/or fruit trees, fish and other livestock, such as, pigs and cattle (garden-fish pond and animal system, which is called the VAC-system in Vietnam).

Semi-intensive systems: These systems combine some of the features of traditional farming systems with more advanced technologies. These systems in Vietnam are based on the improvement of traditional production systems by a combination of using improved or imported breeds, such as Tamhoang and Luongphuong (from China); Kabir (from Israel); Sasso and ISA-JA57 (from France) etc. Crossbreeding is a useful tool, and according to Host (1988), the genetic resource base of the indigenous chickens in the tropics is rich and should form the basis for genetic improvement and diversification to produce breeds adapted to the tropics. These have potentially higher productivity that can be achieved by improving the diets by suitable combinations of conventional feeds and non-conventional foodstuffs, making better use of locally available feed resources and better management and disease control. The chicken population in these systems in Vietnam was estimated at about 14 millions in 2000, and accounted for about 10 % of the total chicken population. Poultry flock size in these systems is higher compared to the traditional systems. Chickens are batch reared, each batch usually containing 200 to 500 birds, or even as many as 1000 birds (Vang & Ly, 2000). The system requires investments in cages, and facilities such as feeders, drinkers and brooders for young birds, and at least 100 to 200 m^2 per head for the scavenging areas, depending on the flock size. Fences are necessary for protection against predators. This system has been widely adopted in the delta and peri-urban areas of Vietnam, where households have sufficient capital and land (Vang & Ly, 2000). When compared with traditional systems, poultry in semi-intensive production systems have higher growth and survival rates and better resistance to diseases, and the time for rearing is shorter and more feed efficient (Vang & Son, 2000). Because of the higher inputs, it should be profitable to use improved breeds in Vietnam, such as exotic coloured breeds or crosses between improved and indigenous breeds. However, better management, feeding and disease control are required compared to the traditional systems. The scavenging and semi-scavenging systems are often combined in integrated farming systems with fish, and other livestock and crops, such as the rice-fish-duck system in Indonesia, China and Vietnam, and in general are common in Southeast Asia.

Intensive production systems: Intensive systems are based on commercial feeds and breeds, and can be rapidly expanded to meet increased demands for animal protein in Vietnam. These systems use exotic breeds with very high productivity, for example: meat types, such as Arbor Acres, Ross- 308 and Ross-208 from the United States, ISA- MPK from France, and BE from Cuba; egg types include Goldline from the Netherlands, Hyline and Brown Nick (US), and ISA Brown from France. The productivity is very high, through selection and cross-breeding techniques that have enabled laying hens to produce over 300 eggs a year, as compared to the 100 eggs or less from unimproved poultry. A broiler enterprise in Vietnam can produce birds of 2 kg body weights at six weeks of age that have consumed only 3.5 kg of a balanced diet. The flock size is usually higher compared to other systems, with flock sizes of over 5,000 layers and 10,000 broilers being common in commercial farms. According to Smith (2001) intensive poultry production should be adopted by a developing country only when one or more of the following conditions prevail: The country produces a large surplus of vegetable foodstuffs over and above the needs of the human population; the country has a large manufacturing base which bring it sufficient foreign exchange to purchase animal foodstuffs; the country has an exportable commodity (such as oil) which it can exchange for animal foodstuffs. If none of these conditions prevails, the intensive poultry industry will become a liability rather than an asset and governments would be better advised to pursue a policy of encouraging scavenger poultry production. Intensive poultry systems were introduced in Vietnam over 30 years ago (in 1974), but the integration between the production levels has been poor, and they have not developed successfully (Vang & Ly*,* 2000).

The foodstuffs used for commercial poultry are often of a quality that could be fed directly to humans, so if food is in short supply, the effect of intensive poultry production is to convert food that poor people can afford into a much smaller quantity of food that only rich people can afford, but almost certainly do not need (Smith, 2001). Thus, if adequate supplies of grains do not exist within a country, intensive forms of poultry production should not be practiced (Smith, 2001). Other important constraints of these systems are low acceptance of the products, because the meat and egg quality, particularly the taste, is not attractive to the consumers. In Vietnam, the commercial meat and egg market price is often 40 to 60 % lower compared to products from indigenous poultry kept in scavenging systems.

Feeds for chickens in Vietnam

Feed supply is always a major constraint for poultry production in Vietnam, especially protein feed sources. Feed cost often accounts for 60 to 65 % of layer production costs under small farm conditions using purchased feed (Ravindran & Blair, 1993). In Vietnam, feed costs account for 70 to 75 % of the production cost of chicken meat and eggs (Vang & Son, 2000). The main ingredients of diets for chickens in Vietnam are paddy rice (*Oryza sativa*), rice bran and broken rice, maize (*Zea mays*), soybean, cassava (*Manihot esculenta* Crantz) and fish meal.

Paddy rice (*Oryza sativa*). Rice is the staple food of humans in Vietnam, and about 35.5 million tonnes are produced annually, of which about 4.9 million tonnes of paddy equivalent are exported (Statistical Yearbook, 2004, FAOSTAT, 2004). Paddy rice has a thick fibrous husk or hull like that of oats. The hulls are high in fibre content and rich in silica, with a content of up to 210 g/kg DM (McDonald *et al.,* 1995). Therefore this must be removed from paddy rice if it is to be used for chicken feed. Typical crude protein (CP) and crude fibre (CF) contents of paddy rice are 78 to 87 g/kg, and 90 to 120 g/kg, respectively (Giang *et al.,* 2001), the high fibre content being the most important constraint in poultry diets. Small amounts are used in laying diets, after the hull has been removed, giving polished rice with a low CF (40 to 80 g/kg) and CP content (70 to 87 g/kg). The protein is relatively high in lysine, arginine and tryptophan (Giang *et al.*, 2001).

Rice bran and broken rice are the main by-products of rice processing and are used widely in poultry diets in Vietnam (Lung & Man, 1999). It is estimated that in 2004 from 35.5 million tonnes of rice, 5.3 million tonnes of bran were produced, and of this about 2.3 million tonnes were used as poultry feed (FAOSTAT, 2004). CP and ether extract (EE) contents are high in rice bran, up to 120 to 140 g/ kg, and 110 to 180 g/ kg, respectively (Giang *et al.,* 2001). Rice bran is recognized as being variable in its composition, depending on the efficiency with which the rice is threshed and the extent to which the oil is extracted. The oil contain highly unsaturated fatty acids and may become rancid very quickly. It is therefore removed to produce a product with better keeping quality (Daghir, 1995). Both rice bran and broken rice can be used in poultry rations at fairly high levels if they are low in rice hulls. In scavenging systems in Vietnam, producers often use up to 70 to 100 % of whole rice grain or rice bran and broken rice as a supplement for both scavenging growing and laying poultry (Men, 2001).

Maize (*Zea mays*): There are a number of different varieties grown in Vietnam, such as yellow, white and red maize, although, recently yellow maize has become popular and is most widely used in poultry diets. The total output of the country in 2004 was about 2.5 million tonnes, almost all of which was used for animal feed. However, about 300,000 tonnes were imported in 2003, mostly for poultry and pigs (Statistical Yearbook, 2004, FAOSTAT, 2004). Maize is a crop grown throughout the country, and can be harvested two or three times per year depending on the climate and farming system. However, the yield of maize in Vietnam is only 60 % of the average maize yield in the United States (Vang & Son, 2000). Maize contains about 730 g starch/ kg DM, is very low in fibre and has high metabolisable energy (ME) content, although the crude protein (CP) is very variable. ME and CP contents of maize varieties in Vietnam vary from 3300 to 3900 Kcal/kg DM, and 80 to 120 g/kg DM, respectively, depending on variety (NIAH, 2001). Maize protein is deficient in the indispensable amino acids lysine and tryptophan (McDonald *et al.,* 1995), and is poor in calcium (0.03 %), potassium (0.45%), manganese (7.3 mg/ kg) and copper (5.4 mg/ kg) (Giang *et al.,* 2001). Maize meal quickly becomes rancid and is attacked by fungi under the conditions of high temperatures and humidity that are typical in Vietnam. A particular problem is the development of aflatoxins, that can induce loss of nutritive value and reduced palatability of the feed (Men, 2001). Yellow maize contains a pigment, cryptoxanthin, which is a precursor of vitamin A and is useful in diets for laying hens, where it contributes to improved colour of egg yolk. However, pigmented grain tends to colour the carcass fat, which in some countries is not considered desirable (McDonald, *et al.,* 1995). However, in Vietnam, maize is still the main ingredient in commercial diets of poultry and pigs.

Soybeans: Soybean meal is the main protein source in poultry diets in Vietnam. However, it is produced for both human consumption as well as animal feed, and thus the soybean price is high for inclusion in poultry feeds, and availability varies according to season. The total output of the country is about 240,000 tonnes, and an additional 49,400 tonnes of soybean, and 620,000 tonnes of soybean cake were imported for use as animal feed in 2003 (FAOSTAT, 2004). Soybeans are excellent sources of both protein and energy, with CP, EE and ME contents are vary from 370 to 430 g/ kg DM, 160 to 180 g/kg DM, and 3300 to 3900 Kcal/kg DM, respectively (Giang *et al.,* 2001). The protein contains all the essential amino acids, but the concentrations of cystine and methionine are sub-optimal (McDonald *et al.,* 1995). However, anti-nutritional factors are present in the raw material, such as trypsin inhibitors and haemagglutinins. The protease inhibitors are partly responsible for the growth retarding property of raw soybeans or unheated soybean meal. Lectins have also been shown to cause inhibition of brush border hydrolases and to encourage colonization of the small intestine coliforms. The inhibitors are inactivated by heating, which accounts for the preference for toasted meals for the simple-stomached animals (McDonald *et al.,* 1995). Full fat soybean meal can be used at levels of 15 to 35 % in diets of growing poultry without any depressing effects on performance, and if DL-methionine is added in soybean meal, it is equivalent to fish meal in protein quality. Economic savings from replacement of fishmeal by soybean meal can be up to 30 % in the poultry diets (Lung & Man, 1999).

Cassava and cassava leaf meal (*Manihot esculenta* Crantz). According to FAO (FAOSTAT, 2004), the cultivated area of cassava in 2003 in Vietnam was 371,700 ha, with a total tuber yield of about 5.4 million tonnes. The most important use of cassava is as a starch source for humans, with a production of 2 million tonnes compared with 0.3 million tonnes for animal feed (FAOSTAT, 2004). Cassava leaf meal (CLM) is a non-conventional animal feed and in Vietnam CLM and tops are sometimes included in diets for pigs (Phuc *et al.,* 2000) and cattle (Man & Wiktorsson, 2001; Khang, 2004). The most important constraint in using CLM is toxins such as hydrogen cyanide (HCN). Sun-drying or ensiling reduces cyanide content in cassava foliage to levels which are considered safe for animals (Ravindran *et al.,* 1986; Ravindran & Ravindran, 1988; Ravindran, 1993; Phuc, 2000; Man & Wiktorsson, 2001, Khang, 2004). Unlike the tubers, cassava leaves are rich in protein, minerals and vitamins and the CP content of cassava leaves reportedly ranges from 230 g to 350 g/kg DM (Phuc, 2000, Khang, 2004). CLM was included in layer diets at up to 25 % of DM without adverse effects on egg production, egg quality or feed efficiency (Ravindran, 1990). Cyanide and tannin contents in cassava foliage can be reduced by sun-drying and ensiling, and for example the cyanide content was reduced by 90 % in sun-dried cassava foliage and by 68 % in ensiled cassava foliage (Ravindran *et al.,* 1987; Khang, 2004).

Fish meal. The total annual output of fish meal is estimated at about 20,000 to 25,000 tonnes in Vietnam. However, the requirement of fish meal for the total of 4.5 million tonnes of commercial feeds produced annually is calculated to be about 200,000 tonnes, which means domestic fish meal accounts for only about 10 % of the total requirement. Therefore it is scarce and expensive for livestock producers in Vietnam, especially for rural poultry. In addition, the processing technology of fish meal in Vietnam is not well developed, and therefore the nutrient contents of fish meals vary over wide ranges, for example 35 to 60 % in CP content and 20 to 35 % in ash content (Giang *et al.,* 2001). Fish meals have a high proportion of calcium, phosphorus and trace minerals, including manganese, iron and iodine, and are a good source of B-complex vitamins, particularly choline, B_{12} and riboflavin (McDonald *et al.,* 1995). This means that fish meal is also useful as a source of minerals and B-vitamins for poultry producers.

Scavenging feed resources

Scavenging feed resources: Potential scavenging feed resources (SFR) can be categorized into four main groups: (1) household wastes (including the waste from households which do not keep chickens); (2) materials from the environment, such as, protein sources (worms, snails, termites insects, grasshoppers and frogs), grain products from cultivating, harvesting and processing (rice, maize and rice and maize bran), green leaves and seeds; (3) cultivated and wild fodder materials such as grasses, herbs, fodder trees and aquatic plants (Lemna, Azolla, duckweed, water spinach etc); and (4) non-conventional feeds and agro-industrial by-products (brewery and alcohol residues, soybean residues, molasses, shells, etc) (Roberts, 2000). The quantity of available SFR has been determined by a number of methods: direct measurements with sacrificed birds, or calculated on the basis of metabolisable energy (ME) requirements for a certain level of performance (Roberts, 1992) and prediction, using prediction equations to estimate SFR on a range without supplementation (Olukosi & Sonaiya, 2003). According to Kitalyi (1998b), a number of studies on the qualitative and quantitative characteristics of SFR have been carried out in Asia (Ravindran & Rajaguru, 1985; Roberts, 1992; Gunaratne *et al.,* 1993; Ravindran & Blair, 1993). The scavenging feed resource base (SFRB) is not constant, and the proportion that comes as a supplement and from the environment varies with activities such as season, land preparation and sowing, harvesting, and grain availability in the household, and the life cycle of insects and other invertebrates (Dessie, 1996). Soil fertility, water availability for irrigation, and rainfall are other factors that determine the SFR (Cumming, 1992). The composition of SFR is illustrated by findings from the few studies and surveys conducted in developing countries using crop content analysis. The conclusion of these studies is that the nutritional status of scavenging chickens in rural environments was below the nutrient requirements of local and crossbred growers and layers for optimum performance, and varies with season and the type of bird. The SFR are sometimes deficient in protein rather than energy, and therefore, protein supplementation was considered to be more important than energy in the scavenging poultry production systems in Bangladesh (Rashid, 2003). Roberts (1992) introduced the concept of the scavenging feed resource base (SFRB) and calculated this is varied from 200 to 400 kg for each household annually in Sri Lanka. In another study carried out in Sri Lanka the SFRB was estimated to be 203 kg dry weight per family per year, including 23 kg protein and 609 Mcal of ME (Roberts & Gunaratne, 1992).

Another study in Southeast Asia reported an SFRB yield of 390 kg per family in Thailand (Janviriyasopak *et al.,* 1990).

Energy requirement of scavenging chickens: Metabolisable energy (ME) values are expressed either as apparent (AME) or true (TME) metabolisable energy. AME is the gross energy of the food minus the energy lost as faeces, urine and combustible gases when that food is eaten (Harris, 1966). However, as gaseous losses from poultry are very small they are always ignored, thus AME is calculated as ingested feed energy (IE) minus the sum of energy in faeces (FE) and urine (UE). ME = IE- (FE + UE), and ME is considered as "apparent" (McNab, 1999). TME was calculated by including the corrections for endogenous energy losses (EEL) by Harris (1966): thus, TME= IE - (FE + UE - EEL). According to Sibbald (1976), the energy status of both diets and feedingstuffs should be expressed in terms of their true metabolisable energy. ME has become accepted almost universally as the preferred measure of the energy contents of poultry diets (McNab, 1999). Animals have precise nutritional requirements, but under natural conditions are faced with a wide variety of foods to choose from, some of which are nutritionally inadequate (McDonald *et al.*, 1995). Therefore, as scavenging birds require ME in varying amounts for all metabolic purposes, including scavenging activities, then a deficiency of energy affects most aspects of their productive performance. Use of published equations to predict the apparent metabolisable energy needs of scavenging hens are inappropriate because they are based on caged, high-producing birds (Farrell, 2000). ME intakes from scavenging feed resources were reported to be below the requirements of growers and layers for optimum performance, and vary depending on season and type of bird (Dessie, 1996; Mwalusanya *et al,* 2002b; Rashid, 2003; Rashid *et al.,* 2005). Energy was found to be limiting during the rainy season in Ethiopia (Dessie, 1996). Therefore, energy supplementation is usually also considered necessary for scavenging chickens for optimum performance. Energy feeds in Vietnam are defined as products with less than 20 % CP and less than 18 % CF, such as grains (maize, paddy rice etc), mill by-products, roots and tubers, and these can all be used to supplement scavenging poultry (Tien *et al.,* 2001).

Protein and amino acid requirement of scavenging chickens: Proteins are made up of amino acids. The amino acids are classified as 'indispensable' or 'essential', and 'dispensable' or 'non-essential' amino acids. Essential amino acids are defined as those amino acids in which animals are unable to synthesize the corresponding carbon skeleton or keto acid. Non-ruminants must receive these amino acids via the diet. Non-essential amino acids are defined as those amino acids which animals are able to synthesize by themselves (D'Mello, 2003). However, from the biochemical point of view and thus in terms of the consequences for nutrition, amino acids are classified into three groups: Essential, semi-essential and non-essential amino acids (Larbier & Leclercq, 1994). The semi-essential amino acids may be synthesised from essential amino acids. For example, cystine and tyrosine are synthesized from methionine and phenylalanine, respectively (Sturkie, 1986; Larbier & Leclercq, 1994). Glycine (or serine) as well as proline are considered essential for optimum growth of young chickens (Sturkie, 1986). The concept of essentiality of amino acids underlies all protein quality evaluation measurements. There are 22 amino acids in body protein, and all are physiologically essential. Of these, however, 10 amino acids cannot be synthesized by poultry and must be supplied in the diet: lysine, methionine, tryptophan, threonine, arginine, isoleucine, leucine, histidine, phenylananine and valine. The basic function of dietary protein is to supply adequate amounts of required amino acids. Thus, the quality of a feed protein depends not only its nitrogen content, but also on its constituent amino acids, their digestibility, and physiological utilization of specific amino acids after digestion (Ravindran & Bryden., 1999). Protein and amino acids are the most expensive components of chicken diets. However, the amounts of protein and amino acids that should be supplied in supplements for scavenging birds are different from those needed for confined birds, because scavenging birds can get part of their requirements for protein and amino acids from scavenging feed resources (SFR) such as grains, insects and worms etc. Therefore, estimation of protein and amino acid contents of SFR should be the basis for more efficient nutrient supplementation of scavenging chickens. The dietary status of scavenging birds varies with season, climate, production type and age of birds. The amino acid profiles of the crop contents will give information on the intake of these nutrients, which is the basis for supplement policy of scavenging chickens (Mwalusanya *et al.,* 2002b). The protein and amino acids that must be provided in a supplement for scavenging birds depends also on breed type and level of production. The protein from the SFR was reported to be below the requirements of growers and layers for optimum performance in Bangladesh (Rashid *et al.,* 2005), and was critical, particularly during the drier months, in Ethiopia (Dessie, 1996). The SFR are often, but not always, deficient in protein rather than energy, and it was concluded that protein supplementation is usually more important than energy supplements in scavenging poultry production systems in Bangladesh (Huque, 1999; Rashid, 2003). The protein required in supplements for scavenging chickens depends on the quantity and balance of available amino acids, and for poultry, evaluation of protein sources is based upon the amounts of the three major limiting amino acids, lysine, methionine and tryptophan (McDonald *et al.,* 2002), and especially methionine is necessary for chicks. Protein feeds in Vietnam are defined as products containing 20 % or more of crude protein (DM basis), such as the by-product meals of animal origin as well as algae, oil meals, gluten and foliages etc (Tien *et al.,* 2001).

Factors which influence the feed intake of scavenging chickens: Feeding is a complex activity which includes actions such as searching for food, recognition of food and movement towards it, sensory appraisal of food, and the initiation of eating and ingestion (McDonald *et al.,* 2002). The feeding activity of scavenging birds, however, is influenced more by environmental conditions such as temperature, rainfall, season, agricultural farming systems, social habits and the economic situation of households. Nutrient intake is the major determinant of nutritional status and production performance in farm livestock. For most free-ranging domestic livestock, the feed intake is fairly low and therefore the quality of the SFR, such as amino acid balance, and energy content are important (Robert & Hugh, 2000). Stress factors such as extremes of temperature, stocking density and presence of disease or parasites also affect the intake of scavenging birds. The theory that poultry have a control system that allows them to choose suitable amounts of different foods to satisfy their nutritional requirements is regarded as being too simplistic, and other factors such as the physical form of ingredients, composition of the food, trough position and previous experience are also thought to be involved (McDonald *et al.,* 2002).

Sustainable rural poultry production in Vietnam and other developing countries

Sustainable livestock development leads to increased food security, and is based on locally available natural resources, with low inputs, and should also lead to improved environmental protection. Rural poultry or household poultry production is considered as tool in poverty alleviation, food security and the promotion of gender equality in rural Africa, Bangladesh and India (Gueye, 2000; Dolberg, 2003). In 2004, the world's total poultry population was estimated to be 16 billion chickens, and the chicken population in developing countries still accounts for 71.6 % of the total world population (Gueye, 2005). Family poultry production constitutes an important component of the agricultural and household economy in the low income countries, and also provides employment and income generation for resource-poor farmers (Gueye, 2003, FAOSTAT, 2005). In Vietnam, about 61 million people live in rural areas (FAOSTAT, 2005) and almost all of rural families keep poultry. Therefore, improvement of the incomes and nutrient status of these rural households by the development of sustainable poultry production will contribute to sustainable rural development in Vietnam.

Advantages of scavenging chicken systems: Capital, labour, and technology inputs are extremely low, and the genetic resources that scavenging chickens represent consist of mainly indigenous breeds, with low productivity. However, scavenging chickens can use locally available, inexpensive feed resources and can reproduce and survive under very harsh conditions. Also the costs of production per egg or per kg of meat is lower compared to intensive chicken systems, because scavenging birds do not need commercial feeds, which are very expensive for farmers in rural areas in Vietnam. Scavenging birds can convert left-over grains, human food wastes, and insects etc into valuable protein for sale or consumption by the family. In addition the meat and egg quality and taste are better than for commercial chickens, and market prices are often 1.5 to 2 times higher compared to commercial chickens in Vietnam. Scavenging poultry are easy to integrate with other systems, such as VAC (garden- fish pond- animal) systems in Vietnam, and improve soil fertility, and control insects and weeds. They adapt well to widely different ecological conditions. Scavenging chickens can improve food security and are not in competition with human food needs, and because of the low inputs, it is possible to get high economic efficiency compared to systems that use commercial feeds. For example, a small flock of twenty layers kept intensively could consume more than 700 kg of food per year, which is enough for 2 adult human beings (Smith, 2001). The genetic resources in scavenging poultry systems are mainly indigenous breeds with low productivity. However, they are suitable for the poor feeding and management conditions common in the rural tropical areas, and can be easily improved by crossing with exotic breeds. Village chicken production using mainly crossbreds of indigenous chickens in many situations is the most suitable system for rural households (Ramlah, 1998).

Disadvantages of scavenging chicken systems: The most important disadvantages are low productivity and survival rate and poor disease and parasite control. In Vietnam at the moment, Avian Influenza and Newcastle disease are the major constraints of poultry production. Scavenging birds have been identified as reservoir hosts for pathogenic organisms, and it is more difficult to control infection and to apply vaccination programmes compared to confined birds (Sonaiya *et al.,* 1999). Chick mortality is considered to be a major problem facing rural chicken producers. Survival rate of chicks without disease outbreaks ranges from 60-70 % in South East Asia, and only 60 % of chicks survive after 10 weeks of age in Tanzania (Aini, 1999; Mwalusanya *et al.,* 2002a). Mortality was reported to be 47 % for young birds in traditional scavenging systems without vaccination in Vietnam (Vang & Son, 2000). Predators and theft also are constraints. Smaller flock size and longer life cycles of scavenging birds compared to commercial birds means that it is difficult for government to apply industrialization and modernization in poultry production in Vietnam.

Improving rural poultry production by making better use of locally available feed resources: Due to high population pressure, the average area of arable land per capita in Vietnam is low (0.1 ha), so there should be put a high priority on the development of a more sustainable and productive agriculture (Ly, 2002). Sustainable rural development is one of the priority policies of the Vietnamese government, especially in agriculture. Sustainable livestock development in general, and poultry development in particular, by making better use of locally available feed resources is widely practiced in Vietnam, the main objective being to develop livestock production for small scale farmers. This involves the use of cassava, legume trees, aquatic plants and agro-industrial by-products as sources of feed for livestock within integrated farming systems. Clearly all of the feed resources are not available in every environment, and the lack of high quality protein is a common constraint. Therefore improving the diets of rural poultry should focus on improving the supply of protein feeds. The characteristics of locally available feed resources as alternative sources of energy and protein were summarized by Rodriguez & Preston (1997): high productivity and efficiency in use of natural resources (eg: land, water and solar energy); relatively low inputs for cultivation; low nutrient density and low digestibility in the case of tree leaves; limited shelf life in the fresh state (eg: sugar cane juice and palm sugar). According to Ravindran (1993) attempts to expand the animal industries in the developing nations of the tropics have long been hampered by the ever-rising cost and chronic shortages of traditional feed resources. Seasonal and unreliable rainfall, marginal soil fertility and subsistence farming leave these nations with an erratic supply of locally grown cereals and protein feeds. Annual imports of feed alone in developing countries represent several billions of dollars. There is a need, therefore to develop alternative feeding systems based on roots and tubers, by-products, etc and supplemented with locally grown soybean, aquatic plants and fodder tree leaves (Sansoucy, 1995). Cassava foliage is considered a potentially valuable and cheap protein supplement feed. When cassava foliage was cut at root harvesting, the protein yield amounted to 122 kg ha^{-1} (Khang, 2004).

Gueye (2003) recommended a policy to identify and use locally available feed resources to formulate diets that are as balanced as possible. Both conventional and alternative feed resources that are readily available to smallholder farmers should be identified. Shrub leaves (*Leucaena sp., Calliandra sp., Sesbania sp., etc*), aquatic plants (*Azolla sp., Water hyacinth, etc),* insects (eg. termites), fruits (eg. palm oil fruit, papaya, guava, etc) and small animals (e.g snails, earthworms, etc) can all be used as poultry feed.

Summary of materials and methods

Study sites

The experiments were carried at the Goat and Rabbit Research Centre (GRRC) of the National Institute of Animal Husbandry (NIAH), and small farms around GRRC in Bavi district, Hatay province in Northern Vietnam (Experiments in Paper I, II and IV). The GRRC is located 65 km to the North West of Hanoi. In 2002- 2004, total rainfall ranged from 1300 mm to 2400 mm, most of which fell in the short rainy and rainy seasons (from February to October), with only 123 mm in the dry season (from November to January) in 2004. The mean daily temperature ranged from 17.2^0 C to 29.5^0 C during the experiments. The experiment reported in Paper III was carried out in villages in Tuyenquang Province in the

Northern mountainous area of Vietnam, 165 km to the North of Hanoi. Total rainfall was 1627 mm, and annual daily mean temperature ranged from 22^0 C to 30^0 C during the experiment.

Experimental design (Paper I, II, III and IV)

The experimental design in Paper I and II was a completely random factorial design. In Paper I, breed, season and location were factors (2*2*2), with four replicates in each factor. In Paper II the experiment had a completely randomised factorial design (2*2) with management system as one factor, and supplementation as the other factor, with four replicates.

In Paper III, the experiment had a completely randomised block design, with family as a block, and with four dietary treatments and four replicates per treatment. In Paper IV, experimental design was completely randomised with four dietary treatments and four replicates.

Birds and dietary treatments (Paper I, II, III and IV)

Paper I: A total of 192 Ri (local) and 192 Luongphuong (improved) birds at 20 weeks of age were purchased and slaughtered for physical and chemical analysis of crop contents in two seasons and at two locations, with four replicates (12 birds /replicate).

Paper II: A total of 192 Luongphuong dual-purpose birds at 4 weeks of age were allocated to four dietary treatments and four replicates with 12 birds/replicate (6 males and 6 females/replicate). The dietary treatments were: CF(+), confinement and supplementing the basal diet with lysine and methionine; CF(-), confinement and the basal diet, but without supplementation of lysine and methionine; Sca(+), scavenging and supplementing the basal diet with lysine and methionine; Sca(-), scavenging and the basal diet, but without supplementation of lysine and methionine.

Paper III: A total of 96 Tamhoang (an improved breed) and 64 Ri (local breed) hens at 23 weeks of age were allocated randomly to eight farms, with each farm as a block (20 birds/ farm), and with four dietary treatments and four replicates (3 Tamhoang and 2 Ri birds/replicate). The dietary treatments were: CMF, confined (C), with a mixed feed (MF) (75% maize meal and 25 % soybean meal) *ad libitum*; ScM, scavenging (Sc), with a supplement of 60 g/bird per day of maize meal (M); ScS, scavenging, with a supplement of 25 g/bird per day of soybean meal (S); ScMF, scavenging, with a supplement 60 g/bird per day of the mixed feed (MF). A mineral and vitamin premix was supplied separately *ad libitum* to all groups.

Paper IV: A total of 128 Luongphuong pullets (an improved breed) at 4 weeks and 96 Luongphuong laying hens at 23 weeks of age were allocated to four treatments and with four replicates per treatment (8 pullets and 6 laying hens/replicate, respectively). The treatments were: Ctrl, scavenging but with access to a balanced concentrate at night; CF, confined and given the Ctrl diet *ad libitum*; CLM, scavenging and supplemented at night with the Ctrl feed, but with soybean meal (SBM) replaced by cassava leaf meal (CLM); SBM, scavenging and supplemented at night with the Ctrl feed, but with fish meal replaced by SBM.

Housing and management (Paper I, II, III and IV)

The birds were vaccinated against Newcastle, Marek's and Gumboro disease (Paper I, II, III and IV). For the scavenging treatments (Paper II, III and IV), the birds were first trained to scavenge and to find their respective pens and were sexed and leg banded for identification. The non-confined groups were allowed to scavenge freely for about eight hours (from 8:00 to 16:00 h) per day on about 10,000 m^2 of pasture, under *Acacia mangium* and *Leucaena leucocephala* trees, on rice, maize and sugar-cane fields and home gardens (Paper I, II and IV). However, in Paper III, daily scavenging time on the smallholdings was about ten hours (from 07:30 to 17:30 h) on 2,000 to 3,000 m^2 of rice field, and natural pasture or in nearby gardens around each farm. The experimental pens were open throughout the day, but the feeders were raised during the day to prevent access, and lowered in the evening to give the birds access to the feeds throughout the night. Clean water was available the whole day. During the night all birds were confined in pens, with an average density of about 4-5 birds per m^2 (Paper II, III and IV). Rice husks on packed-earth floors were used for bedding, and artificial light (electric bulbs) used at night, throughout the experimental period. Automatic feeders and drinkers were placed in each pen, and were cleaned and refilled daily in the morning. Fresh feed was added and residues weighed twice daily, in the early morning and late afternoon.

Paper I. Two batches of birds at 20 weeks of age were purchased (one batch in the dry season and one batch in the rainy season) and slaughtered for collection of crop contents. The birds were confined at night in each farm with no supplement provided and then released at 08:00 h and slaughtered at 16:00 h on four consecutive days in each season.

Feeds and diets (Paper II, III and IV)

Paper II. The birds in the supplemented groups [CF(+) & Sca(+)] were fed the basal diet, with a CP content of 175 g/kg DM, ME content of 12.7 MJ /kg DM, lysine content of 9.9 g /kg DM and methionine content of 4.2 g /kg DM. The birds in the un-supplemented groups [CF(-) & Sca(-)] were given only the basal diet, with a CP content of 176 g/kg DM, ME content of 12.8 MJ/kg DM, lysine content of 6.9 g/kg DM, and methionine content of 2.7 g/kg DM.

Paper III. The birds in the control (ScMF) and confined groups (CMF) were given a mixed feed (MF) (75 % maize meal + 25 % soybean meal) with a CP content of 188 g/kg DM and ME content of 15.9 MJ/kg DM. The birds in ScM and ScS treatments were offered, respectively, maize meal with a CP content of 107 g/kg DM and ME content of 16.1 MJ /kg DM or soybean meal with a CP content of 431 g/kg DM and ME content of 15.5 MJ/kg DM.

Paper IV. In Experiment 1, the pullets in the control (Ctrl) and confined (CF) groups from 4 to 12 weeks of age were fed a basal diet with a CP content of 156 g/kg DM and ME content of 12.4 MJ/kg DM. The experimental diet with soybean meal (SBM) replaced by cassava leaf meal (CLM) had a CP content of 153 g/kg DM and ME content of 11.5 MJ/kg DM, and the diet with fish meal replaced by SBM had a CP content of 154 g/kg DM and ME content of 12.5 MJ/kg DM. The pullets in the control and confined groups from 12 to 20 weeks of age were fed a basal diet with CP content of 145 g /kg DM and ME content of 12.2 MJ/kg DM. The experimental CLM diet had a CP content of 144 g/kg DM and ME content of 11.6 MJ/kg DM; and the SBM diet had a CP content of 143 g/kg DM and ME content of 12.4 MJ/kg DM.
In Experiment 2, the laying hens in the control and confined groups were fed a basal diet with a CP content of 165 g/ kg DM and ME content of 12 MJ/kg DM; the CLM diet had a CP content of 163 g/kg DM and ME content of 11.3 MJ/kg DM; the SBM diet had a CP content of 164 g/kg DM and ME content of 12.2 MJ/kg DM.

Sample analyses and calculations (Paper I, II, III and IV)

Chemical analyses of samples were performed according to AOAC (1990). The dry matter (DM) was determined by drying at 105^0 C for 16 hours to a constant weight. Crude protein (CP), as nitrogen (N) x 6.25, was analysed by the Kjedahl method using copper as catalyst. Ether extract (EE) was determined by solvent extraction in a Soxhlet apparatus. Crude fibre (CF) was determined by the ceramic fibre filter method (AOAC, 1990). Ash was determined by sample burning at 525^o C in an oven (AOAC, 1990). Calcium was determined by atomic absorption spectrometry (AAS-300 system), (CAS- 7440-70-2, AOAC, 1990), and phosphorus by the Alkalimetric Ammonium Molybdophosphate method (CAS- 7723- 14-0, AOAC, 1990). Nitrogen Free Extract (NFE) was calculated following the formula NFE (%) = 100 % DM – (CP + EE + CF + Ash). Amino acids were determined according to Spackman *et al.,* (1958) using an ion-exchange column in a high performance liquid chromatographic system (HPLC). The metabolisable energy (ME) of the crop contents (Paper I) was calculated by an indirect method for estimating true metabolisable energy (TME), using the equation of Wiseman (1987):

TME (Kcal/kg DM) = 3951 + 54.4 EE – 88.7 CF– 40.8 Ash

In which: EE= % Ether extract, CF= % Crude fibre, Ash= % Ash,

ME (Paper I) was then determined on the basis of TME by assuming that TME is 8 % higher than ME (Rashid, *et al.,* 2005). Hydrogen cyanide (HCN) was determined by spectrophotometer using barbituric acid pyridine reagent at a wavelength of 620 nm (O' Brien *et al,* 1991), and by titration with alkaline silver nitrate (0.1 N $AgNO_3$) (AOAC, 1990). ME content (Paper II, III, IV) was calculated from chemical analysis data using the formula of Nehring and Haenlein (1973):

ME (Kcal/kg) = 4.26 X1 + 9.5 X2 + 4.23 X3 + 4.20 X4

Where X1 through X4 are digestible crude protein, digestible fat, digestible crude fibre and digestible nitrogen-free extract. Digestibility coefficients for each feedstuff were estimated according to NIAH for poultry (NIAH, 2001). The diets were formulated by Uneform Software (Thomson, 1997) using Microsoft Excel for Windows 2000.

Statistical analysis

The data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of MINITAB Reference Manual Release 13.31 for Windows 2000. Pair-wise comparisons of means were made using the Tukey test.

Summary of results

Effect of season, location and breed on intake of scavenging feed resources

Paper I. The results show that the mean weights of crop contents were about 50 % higher for the rainy season compared to the dry season, and significantly lower for the local breed compared to the improved breed ($P< 0.001$). However, there was no significant difference between the lowland and highland villages ($P>0.05$).

Grains and green materials were the main components of the crop contents and varied according to season, breed and location ($P<0.05$). The proportions of insects and worms, food waste and "other" components were significantly higher in rainy season ($P<0.05$), but not significantly different between breeds and locations ($P>0.05$).

Almost all analysed chemical and amino acid contents were significantly higher in the rainy season ($P<0.01$). The CP, Ash, Ca, calculated ME and total essential amino acids of crop contents were significantly higher for the improved compared to the local breed ($P< 0.05$). However, DM, CP, EE and NFE contents were not significantly different between breeds (P>0.05). The CF, Ash, Ca, P, NFE contents were significantly higher for the highland compared to the lowland areas (P< 0.05). However, the DM, CP and total analysed amino acids were not significantly different between locations (P> 0.05).

Effect of scavenging and supplementing lysine and methionine on feed intake, performance and carcass quality of scavenging chickens

Paper II. The results show that DM, CP, ME and other supplement nutrient intakes were about 12 % higher for the confined groups compared to the corresponding scavenging treatments (P< 0.001), and around 6 % higher for the diets without supplementation of lysine and methionine compared to the supplemented diets (P< 0.001). DM and nutrient intakes were about 24 % higher for the males compared to the females (P< 0.001).

Average daily weight gain (ADG) was significantly higher for the diets supplemented with lysine and methionine compared to the non-supplemented diets, in both confined and scavenging systems. ADG was significantly higher for males compared to females (P< 0.001). Supplement feed conversion ratios (FCR) and feed cost/kg gain (FCS) were about 16 and 28 % higher for the confined groups compared to the corresponding scavenging groups, with and without supplementation of lysine and methionine, respectively (P< 0.001). The supplement FCR and FCS were about 12 % and 23 % lower for the supplemented diets with lysine and methionine compared to the un- supplemented diets (P< 0.001). However, the supplement FCR and FCS were not significantly different between males and females (P>0.05).

Carcass, breast and thigh proportion was significantly higher for the scavenging birds compared to the confined birds without supplementation of lysine and methionine (P< 0.05). However, the carcass, abdominal fat and thigh proportions were not significantly different in scavenging groups with or without supplementation of lysine and methionine (P>0.05). Abdominal fat proportion was significantly higher for the un-supplemented diets compared to the lysine and methionine supplemented diets in confined birds (P<0.001). DM and CP contents of breast muscle were significantly higher for the supplemented diets compared to the un-supplemented diets (P<0.001). Mortality was 4.2 % for the non-supplemented and confined treatment, and zero in the other treatments.

Effect of scavenging and supplementing energy and protein on feed intake, performance and economic efficiency of scavenging hens.

Paper III. The supplement DM and nutrient intakes were about 31 % lower for the scavenging and supplemented groups (ScMF) compared to the confined and supplemented groups given the mixed feed (CMF) ($P<0.01$). The DM and nutrient intakes were significantly lower for the Ri hens (local breed) compared to the Tamhoang hens (improved breed). The CP intakes of the scavenging groups were about 40 % lower for the diets with energy supplementation (ScM) compared to the diets with mixed feed supplementation (ScMF), and ME intakes were 55 % lower for the diets with protein supplementation (ScS) compared to the mixed feed ($P<0.01$).

The hen-day and hen-housed production after 14 weeks in lay were not significantly different for the scavenging groups compared to the confined groups given the mixed feed, and between energy supplementation compared to the mixed feed supplementation in the scavenging groups ($P>0.05$). However, hen-day and hen-housed production of the scavenging birds was significantly lower for the birds supplemented with protein compared to those given the energy supplement and the mixed feed ($P<0.05$). The egg weight of the scavenging groups was significantly higher for the group given the protein supplement compared to the energy supplement ($P<0.05$). Egg production was significantly lower for the local breed (Ri) compared to the improved breed (Tamhoang) ($P<0.001$). Mortality was significantly higher for the scavenging birds compared to confined birds and higher for protein supplementation compared to the energy supplementation. However, mortality was not significantly different between local and improved breeds.

Supplement FCR and FCS per kg eggs were about 36 % lower for the scavenging groups compared to the confined groups with supplementation of the mixed feed ($P<0.001$). The supplement FCS of the scavenging groups was significantly lower for the diets with supplementation of energy compared to the diets with supplementation of protein and the mixed feed ($P<0.05$). The supplement FCR and FCS were significantly lower for the improved breed compared to the local breed ($P<0.05$).

Effect of scavenging and supplementing different protein sources on feed intake, performance and economic efficiency of scavenging chickens

Paper IV. The results show that DM, CP and ME intakes of the Luongphuong pullets were about 28 % higher for the confined group compared to the corresponding scavenging group ($P<0.001$), but were not significantly different among scavenging groups with replacement of soybean meal (SBM) by cassava leaf meal (CLM), and fish meal (FM) by SBM ($P>0.05$) (Experiment 1). However, the DM, CP and ME intakes of the Luongphuong hens were about 22 % higher for the confined group compared to the corresponding scavenging group in Experiment 2. The DM, CP and ME intakes of the scavenging Luongphuong laying hens were significantly higher for the diets with SBM replaced by CLM and FM replaced by SBM compared to the scavenging and control (Ctrl) diet ($P<0.001$).

In Experiment 1, average daily weight gains (ADG) and supplement FCR of the Luongphuong pullets were not significantly different for the scavenging groups compared to the confined groups or among scavenging groups ($P>0.05$). However, the supplement FCR was about 18 % higher for the confined group compared to the corresponding scavenging group with supplementation of the Ctrl diet. Supplement FCS was about 25 % higher for the confined compared to the scavenging group with supplementation of the Ctrl diet. However, there were no significant differences among scavenging groups when SBM was replaced by CLM, and FM by SBM ($P>0.05$).

In Experiment 2, the hen-day production was significantly lower for the confined group compared to the corresponding scavenging group ($P<0.001$). However, there were no significant differences among scavenging groups when SBM was replaced by CLM and FM by SBM ($P>0.05$). The supplement FCR and FCS were about 32 % higher for the confined group compared to the corresponding scavenging (Ctrl) group. The supplement FCR and FCS were significantly higher for the SBM diet compared to the Ctrl diet ($P<0.001$).

Egg weight, shell thickness and shape index were not significantly different for the confined groups compared to the scavenging groups, and among the scavenging groups. However, yolk weight was significantly lower for the confined groups compared to the scavenging groups ($P<0.001$), although there were no significant differences among scavenging groups ($P>0.05$).

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General discussion

Effect of season, location and breed on feed and nutrient intake from scavenging feed resources (SFR)

The results from the physical and chemical analysis of crop contents in Paper I show that the quantity and quality of scavenging feed resources (SFR) were significantly different between seasons, breeds and locations. This confirms that the availability of SFR is not only dependent on the natural environment, season, climate and insect cycles but also dependent on household activities and farming systems and social habits in different locations. Our findings compare fairly well to studies in other developing countries such as Sri Lanka (Gunaratne *et al.,* 1993), Ethiopia (Dessie, 1996), Bangladesh (Huque, 1999; Rashid *et al.,* 2005), Tanzania (Mwalusanya *et al.,* 2002b) and Nigeria (Olukosi & Sonaiya, 2003). In these studies it was found that the feed intakes of scavenging birds are not constant, and vary according to season and climate, type of bird and their nutrient requirements. For example, tropical environments are often characterized by a wet and dry season and thus the availability of SFR, including vegetation, insects and grains are clearly dependent on season and climate. The feed and nutrient intakes of scavenging birds from SFR were estimated by two different methods: crop content analysis (Paper I) and feeding trials (Paper II, III and IV). The results show that mean DM weight of the crop contents of Luongphuong hens (Paper I) was 11.6 g DM. According to Feltwell & Fox (1978) birds fill their crop in four-hour cycles of eating, although some feeds may completely bypass the crop depending on the type of feed (Ajuyah, 1999). Thus, as they had been scavenging for about eight hours in our study (from 8:00 h to 16:00 h), their intake would have been around 11.6 x 2 times = 23.2 g DM per bird per day. This would account for around 30 % of the 77.5 g DM of the total daily feed intake of the confined Luongphuong hens at 20 weeks of age in the feeding trial (Paper IV), which was found to be 28 % lower for the scavenging birds compared to the confined birds (Paper IV). Therefore the estimated DM intake from crop content analysis was only very slightly higher compared to the intake estimated by the feeding trial method. This is possibly because scavenging birds require additional energy for scavenging activities. The studies confirmed that daily feed intake from scavenging can be estimated from both feeding trials and crop content analysis.

ME and nutrient intakes of scavenging local and improved hens from SFR were about 50 % higher for the rainy compared to the dry season (Paper I), and therefore supplementation for scavenging birds should be given more attention during the dry season. However, the proportion of ME and nutrient intake from SFR also depended on breed, and was about 29 % higher for the local compared to the improved hens (Paper III). An explanation can be that local breeds are better adapted to the scavenging conditions in Vietnam. The difference also would have been due to the higher productivity of the improved breed, resulting in increased maintenance and production requirements and thus a lower proportion from scavenging (Smith, 2001). Light intensity, day-length, humidity, wind speed, rainfall and flock density also have a specific effects on feed intake and productivity of scavenging chickens, but these factors were not determined in these studies.

It can be concluded that the nutritional status of scavenging chickens probably corresponds mainly with differences in availability of feeds in the surroundings, which vary with season and location.

Effect of scavenging and supplementing of energy, protein and amino acids on feed intake, performance, carcass quality and economic efficiency of scavenging chickens

Improvement of the productivity of scavenging chickens should also lead to higher profitability, although improving the nutritional balance of supplementary diets is difficult because it is not known what feeds they are scavenging and what birds are actually eating (Smith, 2001). In our studies, the CP and ME intakes of scavenging hens were estimated at about 30 % of the intake of confined hens by crop content analysis (Paper I). These values are very similar to the 31 % of the CP and ME requirements supplied from scavenging, as estimated from the feeding trials (Paper III). This indicates that supplementation of both energy and protein is necessary to improve the productivity of scavenging local and improved hens in the study areas in Northern Vietnam. However, energy supply from SFR was found to be more limiting than protein supply in village chickens when different supplements were provided (Paper III). This in agreement with Sonaiya (1995) who found that most of the materials available for scavenging have a relatively low concentration of ME, since they contain high levels of crude fibre. Feed intake for poultry is determined mainly by their energy requirement, and the major dietary factor that affects feed intake thus is the concentration of energy in the diets (Smith, 2001). Scavenging birds in different environments select both energy and protein sources. When offered a choice the birds are allowed to balance the energy: protein ratio of their overall diet (McDonald, *et al.,* 2002). This ratio was 1041 KJ: 12.7 g and 723 KJ: 8.8 g, respectively, for the confined and scavenging treatments, respectively, (Paper III) and similar for confined and scavenging treatments. Under free-choice feeding, birds are usually offered a choice between three types of feedstuff: an energy source, a protein source, and in the case of laying hens, a calcium source (Emmans, 1991; Pousga *et al.,* 2005). Selection shows considerable variation between different production types, because of different requirements for energy and protein among laying hens, pullets and growing chickens. The most important factors affecting energy and protein intake are thus the characteristics of the birds (body weight, live weight gain, output of eggs, and nutritional deficiencies). Intake from SFR also depends on age and breed and production type, and was about 31 % of total nutrient intake of Ri (local) and Tamhoang (improved) hens (Paper III), and 22 to 28 % for Luongphuong (improved) laying hens and pullets, respectively (Paper IV), and only 12 % for the Luongphuong (improved) growing chickens at 12 weeks of age (Paper II). The intake proportion from SFR would be higher in other systems with lower supplementation, because the amounts of supplements provided in our studies were quite high, automatically reducing the proportion of the total feed that came from scavenging.

The results in Paper II show that lysine and methionine supplementation to diets of improved growing birds that were sub-optimal in terms of protein and essential amino acids, improved performance and carcass quality and reduced feed cost. The available amino acids in the SFR accounted for about 20 % of requirements of the improved breed, according to NRC recommendations (Paper I). This is in agreement with other studies showed that high concentrations of dietary amino acids are needed to support the Luongphuong breed that is a dual-purpose breed developed for eggs and meat (Dat *et al.,* 2001). Thus adequate amino acid nutrition is vital to successful feeding programs for this type of chicken (NRC, 1994). For chicks the 'first limiting' amino acid is most commonly methionine, although lysine and perhaps arginine may also be deficient (McDonald *et al.,* 2002). Therefore, amino acid supplementation of scavenging chickens should focus on lysine and methionine concentration, especially in low protein diets. However, scavenging birds can also get amino acids from the environment, and these vary according to season and were significantly higher for the rainy season compared to the dry season (Paper I).

The carcass and egg quality of scavenging birds was improved by scavenging, and there were higher proportions of breast and thigh meat and lower proportions of abdominal fat, and higher yolk weight for the scavenging birds compared to the confined birds (Paper II & IV). This is in agreement with the studies of Castellini *et al.,*(2002) and Wattanachant *et al.,* (2004) to compare the effects of organic production system, stocking density and diet on the carcass quality of broiler and Thai indigenous chickens. It was found that the increased activity in low stocking-density systems reduced fatness and favoured the development of the muscle mass. However, this also depends on breed and other environmental factors, and despite a restricted diet, the birds increased fat accretion in relation to protein accretion to build energy reserves for the colder nights in the experiments of Bassler (2005) carried out in Sweden.

The major limitation of scavenging is generally the low productivity, especially under smallholder conditions and remote areas (paper III), and mainly as a result of low intake of nutrients and un-balanced nutrient diets, however, supplementation of energy, protein and amino acids improved performance and reduced production costs (Paper II & III). The ADG and egg production were not significantly different for the scavenging birds compared to the confined birds when given the mixed feed with supplementation of energy and protein, and lysine and methionine (Paper II & III). This confirms that scavenging systems need not be inferior in terms of performance, provided that well-balanced supplements are provided. The supplement FCR and FCS per kg weight gain and eggs were significantly reduced, from 12 to 23 % for meat production (Paper II), and from 16 to 36 % for egg production (Paper III and IV). It was also concluded that net profit not only depends on productivity, but also on the relationship between inputs and outputs, although mortality is usually higher for scavenging compared to confined birds. However, mortality rates in our experiments were much lower than is normal for scavenging village flocks, probably because all chicken were vaccinated against major diseases and were given sufficient amounts of supplementary feed, and improved housing and management.

Effect of scavenging and supplementing different protein sources on feed intake, performance and economic efficiency of scavenging chickens

The results in Paper IV show that replacing the soybean meal (SBM) with cassava leaf meal (CLM), and the fish meal (FM) with SBM did not affect the production performance of scavenging pullets and laying hens, and increased net economic benefit. This can be explained by the fact that scavenging hens can get at least 20-30 % of their protein requirement from SFR (Paper I, III and IV), and much of this is well balanced animal protein, such as insects, earthworms, snails, frogs and human food leftovers (Paper I). As a result, completely replacing the SBM with CLM (20 % of total diet) did not affect the production performance of the scavenging pullets and laying hens, although feed intake increased about 10 % compared to the control diet (Paper IV), possibly caused by higher fibre in the CLM diet. However, the level of CLM in practical poultry diets will also depend on the type of ingredients that are being replaced, and CLM was included in layer diets up to 25 %, without adverse effects on egg production, egg quality and feed efficiency, and supplementary methionine improved the gains of broilers given a diet containing 20 % CLM (Ravindran *et al.,* 1986; Ravindran, 1990). It is therefore possible to replace a high quality protein with lower quality plant proteins, such as CLM, in the diets of scavenging birds. SBM and FM are reasonably good protein sources in poultry diets. However, the human demand for both soybeans and fish is increasing in Vietnam, and therefore, cheap, locally available protein sources such as cassava leaf and other leaf meals should be considered as replacements. Protein feeds are always scarce and are one of the most important constraints for poultry production in developing countries, especially for rural poultry production. Unlike the tubers, cassava leaves are rich in protein, minerals and vitamins (Oomen & Grubben, 1978). If the cassava foliage yield is around 0.9 tonnes DM ha^{-1} (Gomez & Valdivieso, 1984) at root harvesting, foliage production from cultivated areas in Vietnam can amount to about 330,000 tonnes DM of cassava foliage, equivalent to about 45,000 tonnes of protein per year (Khang, 2004).

It is concluded that scavenging is an economical and sustainable system, and locally available plant protein feeds can be used to replace expensive purchased protein sources without any effects on the production performance.

Conclusions

- Estimation of daily feed intake from scavenging by crop content analysis (30 % of total DM intake) gave a similar result to the estimate obtained by comparing the supplement intake of scavenging and confined hens (28 % of total DM intake).
- Local (Ri) and improved (Tamhoang & Luongphuong) scavenging chickens were probably getting between 12 and 31 % of their total feed intakes from scavenging, resulting in reductions in supplement feed conversion ratios and feed cost per kg gain of from 12 to 23 %, respectively, for scavenging growing chickens, and from 16 to 36 %, respectively, per kg eggs, for the scavenging laying hens, compared to the confined chickens. However, the proportion of the total intake from scavenging varied considerably, and was influenced by season, breed and location.
- Supplementation of energy, protein and lysine and methionine is necessary if scavenging chickens are to achieve optimum performance. Energy supplementation was found to be more important than protein, especially for egg production. The calculated metabolisable energy and crude protein intakes from the supplements were 29 and 34 % higher, for the improved breed compared to the local breed, respectively. However, the improved breed was able to scavenge as effectively as the local breed with appropriate supplementation.
- The amino acids supplied by scavenging feed resources are not sufficient for optimum performance, especially lysine and methionine. Supplementation of lysine and methionine of growing improved chickens reduced supplement feed conversion ratios and feed cost per kg gain by 12 and 16 %, respectively, compared to non-supplemented diets. Also, the growth performance, carcass quality and economic efficiency of the growing chickens were improved.
- Using cassava leaf meal to replace soybean meal, and soybean meal to replace fish meal in the supplementary diets for scavenging pullets and laying hens did not affect the production performance, but resulted in improved economic benefits.

Implications

The scavenging chicken system is a traditional production system, with low productivity. However, inputs are also low and the system is suitable for rural areas in developing countries. The productivity and profitability of scavenging systems can be improved with appropriate supplementation of energy, protein and essential amino acids. Scavenging chicken development, by making better use of locally available feed resources, such as cassava leaf meal, will contribute to improve sustainable rural poultry development and human food security.

Future research

Studies on scavenging chicken systems should be continued to determine the proportion of minerals and vitamins coming from scavenging for different classes and flock densities of both growing chickens and laying hens. Other locally available and unconventional feed resources, such as earthworms, termites and foliages, should be evaluated in on-station and on-farm research.

References

Aini. I. 1990. Indigenous chicken production in South East Asia. *World Poultry Science Journal, 46,* 51- 56.

Aini. I. 1999. Diseases in rural family chickens in South East Asia. In: *The first International Network for Family Poultry Development (INFPD)- Electronic Conferences on the Scope and Effect of Family Poultry Research and Development,* FAO, Rome, Italy.

Ajuyah, A.O. 1999. Novel pairing technique for estimating feed intake and nutrient digestibility by scavenging village chickens. In: *The first INFPD/FAO-Electronic Conference on Family Poultry,* FAO, Rome, Italy.

Ali, M.S. 2002. *Study on the effect of feed supplementation to laying hens under rural conditions of Bangladesh.* MSc thesis of the Royal Veterinary and Agricultural University, Denmark.

AOAC, 1990. *Official Methods of Analysis.* 15th edition., Association of Official Analytical Chemists , Washington, DC. 1, 69-90.

Bassler, A. W. 2005. *Organic Broilers in Floorless Pens on Pasture*. PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden. ISSN 1652-6880, ISBN 91- 576- 6966- x.

Bessei. W, 1990. *Experiences with rural poultry development projects*. In: Proceedings of CTA seminar on smallholder rural poultry production, Thessaloniki, Greece, 9-13th October. Vol. 1, pp. 53- 60.

Castellini, C., Mugnai, C. & Dal Bosco, A. 2002. Effect of organic production systems on broiler carcass and meat quality. *Meat Sciences,* 60, 219-225.

Cumming, R.B. 1992. *The advantages of free choice feeding for village chickens.* In: Proceeding 19th World Poultry Congress, Amsterdam, Vol. 3, pp. 627-630.

D' Mello, J.P.F. 1995. Leguminous leaf meals in non-ruminant nutrition. In: *Tropical Legumes in Animal Nutrition.* D' Mello, J.P.F & Devendra. P (Ed.). Biddles, Guildford, London, 247-281 pp.

D'Mello. J.P.F. 2003. Responses of growing poultry to amino acids. In: *Amino Acids in Animal Nutrition*, Second Edition CABI Publishing, Cambridge, USA, 237- 263 pp.

Daghir, N.J. 1995. *Poultry Production in Hot Climates.* CAB International, Wallingford, UK.

Dat, N.H., Dong, N.T., An., L.T., Tung, H.X. & Huong, P.B. 2001. A study on the biological characteristics and production performance of Luongphuong chickens of M1 and M2 strains at Lien Ninh station. *Annual Scientific Report of the National Institute of Animal Husbandry, Hanoi, Vietnam.*

Dat, N.H., Dong, N.T., Tung, H.X. & Huong, P.B. 2001. Study on crossing between Luongphuong and Ri breeds to produce "Garden chickens" for smallholder farming systems. *Annual Scientific Report of the National Institute of Animal Husbandry, Hanoi, Vietnam.*

Dessie, T. 1996. *Studies on village poultry production systems in Central highlands of Ethiopia.* MSc thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Dolberg F. 2003. Review of Household Poultry Production as a Tool in Poverty Reduction with Focus on Bangladesh and India. *Pro-Poor Livestock Policy Initiative,* Working Paper No. 6. FAO, Rome, Italy.

Emmans, G.C. 1991. Diet selection by animals: Theory and experimental design. In: *Proceeding of the Nutrition Society,* pp 59- 64.

FAO. 2002. Village poultry production in Vietnam. International Network for Family Poultry Development (INFPD), e-conferences, FAO (*Food and Agriculture Organization of the United Nations)*, Rome, Italy.

FAOSTAT. 2002. Statistical database. Food Nutrition and Food Security, FAO (*Food and Agriculture Organization of the United Nations)*, Rome, Italy.

FAOSTAT. 2004. FAOSTAT- Agriculture. FAO, Rome, Italy.

FAOSTAT. 2005. FAOSTAT- Agriculture. Total/Rural/Urban Population, FAO, Rome, Italy.

Farrell, D. J. 2000. The energy and protein needs of scavenging hens. *Livestock Research for Rural Development, 12 (4).*

Feltwell, R. & Fox, R. 1978. *Practical Poultry Feeding.* Faber, Boston, London. 5th Edn. Longman Scientific & Technical, Harlow, Essex, England.

Giang, V.D., Chinh, B.V., Huyen, D.V. & Ha, N.N. 2001. Potential and characteristics of animal feeds in Vietnam. *Composition and Nutritive Values of Animal Feeds in Vietnam*. Agricultural Publishing House, Hanoi, Vietnam, pp. 22- 36.

Gomez, G. & Valdivieso, M. 1984. Cassava for animal feeding: effect of variety and plant age on production of leaves and roots. *Animal Feed Science and Technology*. 11, 49-55.

Gueye, E.F. 2000. The role of family poultry in poverty alleviation, food security and the promotion of gender equality in rural Africa. In: *Outlook on Agriculture, Vol.29* (2), pp. 129- 136.

Gueye, E.F. 2003. Information dissemination for family poultry research and development. *Livestock Research for Rural Development 15* (2).
http/www.cipav.org.co/lrrd/Lrrd15/2/guey 152.htm.

Gueye, E.F. 2005. Family poultry must no longer be a "Hidden Harvest", In: *International Network for Family Poultry Development (INFPD), FAO, No. 1, (15) January- June, 2005.*

Gunaratne, S.P., Charndrasiri, A.D.N., Mangalika Hemalatha, W.A.P. & Roberts.J.A 1993. Feed resource base for scavenging village chickens in Sri Lanka. *Tropical Animal Health and Production,* 25: 249-257.

Harris, L.E. 1966. Biological energy interrelationships and glossary of energy terms. *National Academy of Sciences, National Research Council (NRC).* Publication, 1411, Washington, D.C, pp. 35

Host, P. 1988. *Native fowls as reservoir for genomes and major genes with direct and indirect effects on production adaptability*. In: Proceeding 18th World Poultry Congress, Nagoya, Japan, 4-9th September, 1988, pp. 105.

Huque, Q.M.E. 1999. Nutritional status of family poultry in Bangladesh. *Livestock Research for Rural Development* 11 (3).

Janviriyasopak, O., Morris, R.S., Thitisak, W. & Leesirikul, N. 1990. *The organization of a basic poultry health service.* In: Proceeding of the International Seminar on Animal Health and Production Services for Village Livestock. Khon Kaen, Thailand, 2-9 th August, 1989, pp. 419- 422.

Khang, D.N. & Wiktorsson, H. 2000. Effects of cassava leaf meal on the rumen environment of local yellow cattle fed urea-treated paddy straw. *Asian-Australasian Journal of Animal Sciences, 13 (8)*, 1102- 1108.

Khang, D.N. 2004. *Cassava foliage as a protein source for cattle in Vietnam.* PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden, ISSN 1401-6249, ISBN 91-576-6752-7.

Kitalyi, A.J, 1998a: Family poultry management systems in Africa. *First INFPD/FAO electronic conference on family poultry*, FAO, Rome, Italy.

Kitalyi, A.J. 1998b. Village chicken production systems in Africa: Household Food Security and Gender Issues. *Animal Production and Health paper 142*, FAO, Rome, Italy.

Larbier, M. & Leclercq, B. 1994. *Nutrition and feeding of poultry.* INRA, Nottingham University Press. British Library Cataloguing in Publication Data, ISBN 1- 897676- 52- 2.

Larbier, M. & Leclercq, B. 1994. Protein metabolism in: *Nutrition and feeding of poultry.* INRA, Nottingham University Press. British library Cataloguing in Publication Data, ISBN 1- 897676- 52- 2. 75- 100 pp.

Lung, B.D. & Man, L.H. 1999. Poultry feed and feeding. *Agricultural Publishing House, Hanoi, Vietnam,* pp. 211.

Ly, L.V. 2002. The Role of Animal Production in Farming Systems of Vietnam. *National Institute of Animal Husbandry, Hanoi, Vietnam.*

Man, L.H. & Son, N.T. 2001. Feeding and management of Ri and crossbred Ri breeds. *Scientific papers, Agricultural Publishing House, Hanoi, Vietnam.*

Man, N.V. & Wiktorsson, H. 2001. Cassava tops ensiled with or without molasses as additive: effects on quality, feed intake and digestibility by heifers. *Asian Australian Journal of Animal Sciences, 14* (5), 624- 630.

McDonald, P., Edwards, R.A., Greenhalgh, F.D. & Morgan, C.A. 1995: *Animal Nutrition.* Fifth Edition, Longman Scientific and Technical, Harlow, Essex, England.

McDonald, P., Edwards, R.A., Greenhalgh, F.D. & Morgan, C.A. 2002: *Animal Nutrition.* Sixth Edition, Pearson Education Limited, Edinburgh Gate, Harlow, Essex CM20 2JE, England.

McNab, J. M. 1999. Energy supply to poultry. *Journal of experimental zoology 283,* 377- 386.

Men, B.X. 2001. *Feeding and management systems for smallholder duck production in the Mekong Delta of Vietnam*. PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden, ISSN 1401- 6249, ISBN 91- 576- 589- 9.

Minitab Reference Manual 2000. *Release 13.31 for Windows 2000*. Minitab Inc., USA.
Mwalusanya, N.A., Katule, A.M., Mutayoba, S.K., Minga, U.M., Mtabo, M.M.A. Olsen, J.E.& Minga, U.M. 2002a. Productivity of Local Chickens under Village Management Conditions. *Tropical Animal Health and Production, 34*, 405-416.
Mwalusanya, N.A., Katule, A.M., Mutayoba, S.K., Minga, U.M., Mtabo, M.M.A. & Olsen, J.E. 2002b. Nutrient status of crop contents of rural scavenging local chickens in Tanzania. *British Poultry Sciences, 43*, 64-69.
National Institute of Animal Husbandry, 2001. *Composition and nutritive value of animal feeds in Vietnam.* Agricultural Publishing House, Hanoi, Vietnam.
Nehring K. & Haenlein G.F.W. 1973. Feed evaluation and ration calculation based on net energy. *Journal of Animal Sciences, 36* (5), 949- 964.
NRC (National Research Council). 1994. *Nutrient Requirements of Poultry.* 9th Revised Edition, National Academy Press, Washington, D.C.
O' Brien, G.M., Taylor, A.J. & Poulter, N.H. 1991. Improved enzyme assay for cyanogens in fresh and processed cassava. *Journal of the Sciences of Food and Agriculture,* 56, 277- 289.
Olukosi, O.A & Sonaiya, E.B. 2003. Determination of the quantity of scavengeable feed for family poultry on free range. *Livestock Research for Rural Development 15* (5)
Oomen, H.A.P.C & Grubben, G.J.H. 1978. *Tropical leaf vegetables in human nutrition.* Department of Agricultural Research, Royal Tropical Institute, Amsterdam, Netherlands, 69, 136 pp.
Permin, A. & Pedersen, G. 2000. *Problems related to poultry production at village level*. In: Proceeding of the Workshop on the Possibilities for Smallholder Poultry Projects in Eastern and Southern Africa, Morogoro, Tanzania, 22-2 th, May 2000.
Phuc, B.H.N. 2000. *Tropical Forages for Growing Pigs: Digestion and nutritive values.* PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden, ISSN 1401-6249, ISBN 91-576-5755-6.
Phuc, B.H.N., Ogle, B. & Lindberg, J.E. 2000. Effect of replacing soybean protein with cassava leaf protein in cassava root meal based diets for growing pigs on digestibility and N retention. *Animal Feed Sciences and Technology 83,* 223-235.
Pousga, S., Boly, H. & Ogle, B. 2005. Choice feeding of poultry: a review. *Livestock Research for Rural Development, 17(4),*
Pousga, S., Boly, H., Lindberg, J.E. & Ogle, B. 2005. Scavenging Chickens in Burkina Faso: Effect of season, region and breed on feed and nutrient intake. *Tropical Animal Health and Production.* 37 (2005), 1-12.
Ramlah, A.H. 1998. Production aspects of village chickens in South East Asian region. *First INFPD/FAO electronic conference on family poultry*, Vol. 7, December 1998 to 5th March, 1999. FAO, Rome, Italy.
Rashid, M. 2003. *Nutritional status of scavenging chickens with special emphasis on energy and protein supplementation under rural conditions in Bangladesh.* MSc thesis, the Royal Veterinary and Agricultural University, Denmark.
Rashid, M., Islam, M.N., Roy, B.C., Jakobsen, K. & Lauridsen, C. 2005. Nutrient concentrations of crop and gizzard contents of indigenous scavenging chickens under rural conditions in Bangladesh. *Livestock Research for Rural Development 17,* (2)
Rashid, M., Roy, B.C & Asaduzzaman. 2004. Chemical composition of crop contents of local scavenging chickens. *Pakistan Journal of Nutrition 3* (1), 26-28;
Ravindran, G. & Ravindran, V. 1988. Changes in the nutritional composition of cassava (*Manihot esculenta Crantz)* leaves during maturity. *Food Chemist 27,* 299-309.

Ravindran, V. & Blair, R. 1993. Feed resources for poultry production in Asia and Pacific. III. Animal protein sources. *World Poultry Sciences Journal 49,* 219-235.
Ravindran, V. & Bryden, W.L. 1999. Amino acid availability in poultry- *in vitro and in vivo* measurement. *Australian Journal of Agricultural Research 50*, 889-908.
Ravindran, V. & Rajaguru, A.S.B. 1985. Nutrient contents of some non-conventional poultry feeds. *Indian Journal of Animal Sciences 55,* 58-61.
Ravindran, V. 1990. Cassava leaf meal. In: *Non-traditional feed sources for use in swine production* (Eds. Thaker, P.A. & Kirkwood, R.N). Butterworths, Boston. 91- 101 pp.
Ravindran, V. 1993. Cassava leaves as animal feed: Potential and limitations. *Journal of the Science of Food and Agriculture 61,* 141-150.
Ravindran, V., Kornegay, E.T. & Rajaguru, A.S.B. 1987. Influence of processing methods and storage time on the cyanide potential of cassava leaf meal. *Animal Feed Science and Technology 17,* 227.
Ravindran, V., Kornegay, E.T., Rajaguru, A.S.B., potter, L.M & Cherry, J.A. 1986. Cassava leaf meal as a replacement for coconut oil meal in broiler diets. *Poultry Sciences, 65 (9),* 1720- 1727.
Robert, W. M. & Hugh. D. 2000. Measurement of dietary nutrient intake in free-ranging mammalian herbivores. *Nutrition Research Reviews 13,* 107- 138.
Roberts, J.A & Gunaratne, S.P. 1992. *The scavenging feed resource base for village chickens in a developing country.* In: Proceeding of the 19th World Poultry Congress, Amsterdam, The Netherlands, 1, pp. 822-825.
Roberts, J.A. 1992. *The scavenging feed resource base in assessments of the productivity of scavenging village chickens.* In: Newcastle Disease in Village Chickens. (Ed. P.B Spradbrow), Australian Centre for International Agricultural Research, Canberra, Australia, Proceeding 39, pp. 29- 32.
Roberts, J.A. 2000. Utilization of Poultry Feed Resources by Smallholders in the Villages of Developing Countries. In: Proceeding of a Workshop '*Poultry as a Tool in Poverty Eradication and Promotion of Gender Equality* '(Eds. Dolberg F. & Petersen, P.H). 22- 26th March, 1999, Tune Landboskole, Denmark.
Rodriguez, L.& Preston, T.R. 1997. Local feed resources and indigenous breeds: fundamental issues in integrated farming systems. *Livestock Research for Rural Development 9 (2),*
Sansoucy, R. 1995. Better feed for animals, more food for people. *Animal Production Service,* Animal Production and Health Division, FAO, Rome, Italy.
Sibbald, IR. 1976. A bioassay for true metabolisable energy in feedingstuffs. *Poultry Sciences, 55,* 303- 308.
Smith, A.J., 2001. *Poultry – Tropical Agriculturalist Series.* Revised edition, CTA, Macmillan Press Ltd., London.
Sonaiya, E.B. 1995. Feed resources for smallholder poultry in Nigeria. *World Animal Review.* FAO, 82 (1995/1). Pp. 255- 260
Sonaiya, E.B., Branckaert. R.D.S & Gueye, E.F. 1999. Research and Development Options for Family Poultry. In: *The first INFPD/FAO Electric Conference on Family Poultry,* FAO, Rome, Italy.
Spackman, D. H., Stein, W. H., Moore, S. 1958. Automatic recording apparatus for use in chromatography of amino acids. *Analytical Chemistry 30*, 1190-1206.
Statistical Yearbook, 2004. Statistical Publishing House, Hanoi, Vietnam
Stukie, P.D. 1986. *Avian Physiology.* Fourth Edition, Springer-Verlag, New York, Inc. USA, pp, 326- 344.
Thomson, E. 1997. Uneform software, University of New England, Armidale 2350 NSW, Australia.
Tien, H.V., Giang, V.D. & Chinh, B.V. 2001. Formulas used in estimation of energy values in animal feeds. *Composition and nutritive values of animal feeds in Vietnam.* Agricultural Publishing House, Hanoi, Vietnam, pp,17- 21.

Vang, N.D. & Son, N.T. 2000. Report on chicken sector in Vietnam, *National Institute of Animal Husbandry, Hanoi, Vietnam.*
Vang, N.D. & Ly, L.V. 2000. A review of poultry production in Vietnam, *National Institute of Animal Husbandry, Hanoi, Vietnam.*
Vang, N.D. 2003. Study on selection and pure-breeding to improve the performance and quality of some local and exotic chicken breeds and produce suitable crossbreds for household production systems. In: *proceeding of the third Vietnamese- Hungarian conference on domestic animal production and aquaculture-quality and rural development, Hanoi, 18- 19th October, 2003*.
Vang, N.D. 2004. Achievements of livestock production to contribute to the animal sciences and technology. *Scientific paper in National Workshop on Animal Sciences and Veterinary and Medicine, Hanoi, 8-9th December, 2004.*
Wattanachant, S., Benjakul, S. & Ledward, D.A. 2004. Composition, colour and texture of Thai indigenous and broiler chicken muscles. *Poultry Sciences*, 83,123-128.
Wiseman, J. 1987. *Feeding of Non-ruminant Livestock*, Butterworths, London, United Kingdom, pp. 9-13.

Acknowledgements

The studies were carried out at the Goat and Rabbit Research Centre (GRRC), National Institute of Animal Husbandry (NIAH), and on-farm in villages in Tuyenquang province in Northern Vietnam, with financial support from the Swedish International Development Cooperation Agency, Department for Research Cooperation (SIDA/SAREC). I am grateful to all these institutions for supporting to me.

I also would like to express my gratitude to:

My supervisor, Prof. Dr. Brian Ogle, for all his advice and useful guidance to me during my study, including English corrections. Thanks for all his support to me in research and social activities.

My co-supervisors, Prof. Dr. Jan Erik Lindberg and Prof. Dr. Le Viet Ly for their valuable advice, encouragement and enthusiasm during my study.

Prof. Dr. Inger Ledin, former Head of Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences (SLU) for kindly helping me throughout my study.

Assoc. Prof. Dr. Hans Petterson, Assoc. Prof. Dr. Peter Uden, Dr. Klas Elwinger and Mr. Börje Ericsson for help with the computer and analytical methods, Dr. Erling Burstedt (Head of Department of Animal Nutrition and Management), Prof. Hans Wiktorsson and staff at the Department of Animal Nutrition and Management of SLU for their help and encouragement during my time in Sweden.

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

Prof. Dr. Luu Trong Hieu, Dr. Ngo Van Man, Dr. Nguyen Van Cong and the members of the steering committee of the MEKARN, SAREC project for their help and encouragement during my study.

Assoc. Prof. Dr. Nguyen Dang Vang, Director of NIAH, Dr. Vu Chi Cuong, Vice Director of NIAH and the Directorate Board of NIAH, for giving me permission to study, support and encouragement throughout my study.

Assoc. Prof. Dr. Dinh Van Binh, Director of GRRC, MSc. Hoang The Nha, vice Director of GRRC and the staff at GRRC, Tuyenquang Women Union and the farms in Bavi district and Tuyenquang province for their facilitation and support to me during my experiments.

Prof. Dr. Le Van Lien, Dr. Nguyen Huu Tao, Dr. Tran Quoc Viet, Assoc. Prof. Dr. Le Duc Ngoan, Assoc. Prof. Dr. Nguyen Van Thu, Dr. Mai Van Sanh, Dr. Nguyen Thi Mui, Dr. Doan Thi Khang, Mr. Do Van Hien, Mr. Dao Hung Giang, Mr. Chu Manh Thang and Mr. Le Van Huyen, for their great help and encouragement during my study.

My colleagues:
Dr. Pham Cong Thieu, Dr. Le Hong Son and the staff at the Department of Animal Nutrition and Feed Processing, Department of Feed Analysis, and other departments of NIAH, for analysis work at the laboratory, their great support and encouragement to me during my study.

My colleagues and friends: Dr. An, Dr. Khang, Tong Anh, Dong, Len, Sen Hong, Van, Xuan, Nhat, Nguyet, Vo Lam, Thieu, Khai, Nghia, Quang, Kien, Malin, Borin, Nadir, Van Thong, Oudom, Salimata, Hadja, Alice, Salifou … for their friendship, helping, sharing and encouragement for me during my time away from home.

My colleagues and friends, who are not listed here, but I believe that I have known what you have been giving me.

My big family, mother, sisters, brothers and nephews for all their support and encouragement during these years. Thanks for believing in me.

All of my love to my wife, Do Thi Viet Hang, my son, Do Quoc Tri, and closest friends who understood my work, always gave their support, and shared the happiness and sadness with me.