Journal of Agriculture and Rural Development in the Tropics and Subtropics

Supplement 87

Study on Chicken Meat Production for Small-Scale Farmers in Northeast Thailand

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Publisher of the supplement
German Institute for Tropical and Subtropical Agriculture (DITSL,GmbH), Witzenhausen
Association for Sustainable Development (GNE mbH), Witzenhausen
Institute for tropical Agriculture e.V., Leipzig
University of Kassel, Faculty of Organic Agricultural Sciences, Witzenhausen
Association of Agronomists in the Tropics and Subtropics Witzenhausen, e. V., (VTW), Witzenhausen

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To be quoted as
Theerachai Haitook, 2006: Study on Chicken Meat Production for Small-Scale Farmers in Northeast Thailand, Beiheft Nr. 87 zu Journal of Agriculture and Rural Development in the Tropics and Subtropics, kassel university press GmbH

Bibliographic information published by die Deutsche Nationalbibliothek
Die Deutsche Nationalbibliothek lists this publication in the Deutsche Nationabibliografie; detailed bibliographic data is available in the Internet at http://dnb.ddb.de

Publishing House
kassel university press
www.upress.uni-kassel.de

Zugl.: Witzenhausen, Univ.Diss..2006

ISSN: 1613 - 8422
ISBN-10: 3-89958-238-1
ISBN-13: 978-3-89958-238-3
URN: urn:nbn:de:0002-2386

Dissertation (Dr. agr.) in the Department of International Animal Husbandry, Faculty of Ecological Agricultural Sciences, University of Kassel, Germany

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Disputation	3 July, 2006

Cover layout: Jochen Roth, Melchior v. Wallenberg, Kassel
Printed by: Unidruckerei der Universität Kassel

August 2006

PREFACE

Thailand is one of the world's leading countries in poultry egg and meat production. Poultry meat is produced mainly from broilers (86.4%), indigenous chickens (13.0%) and hybrid indigenous (0.6%) birds. Poultry meat is produced in the eastern, central, northern and northeastern province with 40%, 35%, 12% and 13%, respectively. The Saraburi and Nakhon Ratchasima Provinces are the main production areas in northeastern Thailand. The consumption of poultry eggs in the country has increased from 100 eggs/capita/year in 1990 to 160-185 eggs/capita/year (9.9 kg/capita/year) in the last few years. The consumption rate of poultry meat is 13.5 kg/caput/year (FAO 2002).

However, the growth of the poultry production business in Thailand is with large-scale producers and their contract farmers. Some farmers cannot survive financially due to the high cost production inputs, like feed, medicine and the marketing control by companies. Small-scale farmers engaged in poultry enterprises have to invest for housing and husbandry devices. Farmers earning their income from individual broilers by weight depend on the agreement with the company. This might be a high risk potential for them.

In rural areas, indigenous poultry plays a major role as a protein source in human consumption. Almost all households (80% in rural) raise indigenous chickens. The purpose is mainly for home consumption but also for sale and pets animal competition. It is estimated that there are 90-120 million indigenous chickens produced yearly, over 45% of total indigenous chickens raised in the country is from the northeast region. Currently, most farmers are raising poultry semi-intensively. Poultry flock characteristics consist of mixed species, ages and mixed flocks. They are allowed to scavenge in the day-time and are confined at night or freely occupy around or under the house or are provided with simple housing. Farmers supplement them with local available feed (i.e. rice, rice by-products, fruit, kitchen leftovers, vegetables, grasses, weed-seeds and some protein sources, e.g. insects, termites, earthworms, aquatic snails, crabs and small fish, etc). Indigenous chickens adapt well to the rural environment and poor-resource based farmers. It is considered that indigenous chickens have a high potential for being raised in rural areas with small-scale farmers, landless people, and ethnic groups who live in the mountainous areas, especially in the area where intensive annual cropping with large land areas and lots of crop by-products are available, e.g. grain and bran.

The demand for indigenous chickens is currently high but supply is limited because the current raising system is problematic.

This study aimed at identifying suitable feeding regimes for native chickens that reduce dependence on commercial feeds and make better use of on-farm feed resources. For this, the growth performance of different breeds of chickens was studied under different feeding regimes and with an emphasis on typical on-farm feed resources. Also, the effect of the feeding regimes on carcass quality was investigated.

Mr. Haitook started his study with chickens in May 2002 and finished with his thesis in July 2006.

Prof. Dr. Ezzat S. Tawfik, Dr. Michael A. Zöbisch

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to my supervisors, Prof. Dr. Ezzat S. Tawfik and Assoc. Prof. Dr. Michael A. Zoebisch for their continuous and constructive guidance and advice, and for their support and encouragement. I am also grateful for the research grant and scholarship which they provided for my research work, both in Thailand and Germany.

I am grateful to Prof. Dr. Günter Biedermann for his advice and guidance throughout the research. I also thank to Dr. Wattanaporn Mesakulthavorn and Dr. S.L. Ranamukaarachchi for their generous support and advice during my trials at the Agricultural Systems Research Farm of the Asian Institute of Technology (AIT), Thailand.

I would like to express my sincerely appreciation to my colleagues Dr. Khin Mar Cho, Dr. Satiraporn Sirisampan, Khun Duangkamol and all the field workers of Agriculture Systems Research Farm for their assistance. I would also like to thank Dr. Amrit Bart and his team for their encouragement and support during my thesis writing and working in the Post-Tsunami Sustainable Coastal Livelihood Program. Thanks to Khun Sumon Sangkaew and Khun Jatuporn Bundit for their assistant during the study.

Finally, I would like to give special recognition to my wife, Sakuntala, my daughter, Suranee, my twin sons, Patipat and Patipan, and my parents and cousins in Surin Province for their moral support throughout my studies.

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1 INTRODUCTION

1.1 General background

Over the last three decades, poultry production technology in Asia has been increasingly improved. Egg production, for example, has increased six times and now has a share of over nearly 60 percent of the total world production. Over the same period, chicken meat supply has increased 13 times. Recently, Brazil has been the world's largest chicken meat producer (6.22 million tons in 2001) and exporter (FAO, 2002a).

Thailand is one of the world's leading poultry meat and egg producing countries. In 2001, 1.26 million tons of poultry meat was produced, making it the fifth largest export country (DLD, 2000), with 249,755 tons exported (FAO, 2002). With 22.7 million eggs per day (Choprakarn *et al*., 2000), Thailand ranks number 16 of the world's largest egg producers. Poultry meat was produced mainly from broilers (86.4%), indigenous chicken (13.0%) and hybrid indigenous chicken (0.6%) (Choprakarn *et al.*, 2000). In Thailand, poultry production is concentrated in the Eastern Region (40%), Central Region (35%), Northern Region (12%) and Northeastern Region (13%). In the Northeastern Region, Saraburi and Nakhon Ratchasima Provinces are the main production areas.

In spite of country's success in poultry export, the consumption of poultry products is still low. Egg consumption in Thailand has increased gradually from 100 eggs per caput in 1990 (FAO, 2002a) to 150 eggs per caput per year in 2001 and has been declining to remain only 100 eggs per caput per year in 2004 (predicting) due to the effected from bird flu disease outbreak (Animal feed Business, 2005). However, the annual consumption in 2005 was 135-140 eggs per person. It is estimated that consumption rate in 2006 will increase up to 145 eggs per year (Asian Poultry Magazine, 2006). Poultry meat consumption rate had increased very slow during 1990-2003, from 9.9 kg (FAO 2002a) to 13.7 kg per caput per year, respectively. In 2004, the consumption dropped down to remain only 7.5 kg per caput per year and increased to 10 kg per caput per year in 2005 (Animal Feed Business, 2006).

Large shares of the production of poultry in Thailand were produced by large multinational companies, which dominate the industry. Approximately 10 to 12 companies control about 80% of the broiler production. The dominance of these companies led to a decline of independent growers, mainly due to the lower per-unit return that large commercial growers can tolerate. Many independent growers entered into price-guaranteed contracts between chicken growers, hatcheries and feed companies. Parent and grandparent stock have to be imported decreasing the production cost of day-old chicks. Feed represents about 70 to 75% of the total production costs, especially because some supplements used in the industry need to be imported. The presence of Newcastle disease has been a problem for the exporters because most importers require the product to be free from of this disease (FAO, 2002b). Another increasingly important issue affecting the poultry industry is animal welfare. Especially European countries require high animal welfare standards for the production associated with maintenance of good health (EU Commission, 2000).

Small-scale farmers usually keep small flocks of native breeds, generally fewer than 100 birds, in a 'backyard' system (FAO, 2002b). Choprakarn *et al.* (2000) estimated that 90-120 million indigenous chicken were produced annually, with a value of approximately 5.4 to 7.2 billion Baht (48 Baht= 1 €). Over 45% of the indigenous chicken raised in the country are raised in the Northeast Region. Kajarern *et al.* (1989) reported that almost all rural households (80% in Northeastern Thailand) raise indigenous poultry, mainly chicken. The purpose is mainly for home consumption but also for sale. Some chickens are also raised as pets and fighting cocks (Choprakarn *et al*., 2000; FAO, 2002b).

1.2 Status and roles of local chickens in Thailand

The small-scale farming areas of Thailand are generally poor. Northeastern Thailand is the poorest region of the country with an average GDP per person per year of 20,235 Baht (about 420 €). In this region, about 21 percent of the income is from agriculture (FAO 2002b). The agricultural production in the region is affected by generally low soil fertility, erratic rainfall and no investment into soil-fertility improvement and conservation practices. These conditions facilitate soil degradation and, hence, the loss of soil, soil fertility and soil productivity. Therefore, crop yields are generally low and fluctuating. The main sources of the income of the farmers in the region are arable crops, i.e. cassava (44%), rice (27%), maize (8%), sugar cane (8%), kenaf (5%) and other crops (8%) (Na nagara and Panichkul, 2000).

Native chickens have played an important role in the nutrition and protein supply of the people in the region, especially for pregnant women, babies and children (Hutanuwat, 1988; Kajarern *et al*., 1989; Polpak *et al*., 1992; Thitisak *et al*., 1992). Native chicken also play an important role as a food reserve for the households, they serve as an important source of protein while other sources of natural food are declining, such as wild birds, rats, crabs, fish, bamboo shoots, mushrooms, wild vegetables, etc. Native chickens can also generate supplementary cash income or be used in exchange with other kinds of goods that are necessary for living (Udomsieng, 1985). Also, chickens are widely considered as a sign of family wealth among villagers. Chickens are offered for important occasions and to visitors. Over 50% of the farm households consume chicken only for particular occasion, about 3-4 times a months, or approximately 600 g of meat per person per month. Native chickens are usually raised in extensive systems, often with supplementary feeding of rice by-products of low quality. An important part of the feed and vitamin supply is obtained from scavenging natural food, i.e. weed seeds, grass, insects (adults and larvae) termites, earthworms, small reptiles (lizards), etc. (RDI/KKU, 1989). The major feed resource for native poultry kept on small farms is rice, i.e. rice bran, broken rice and paddy. Feeding is generally done by broadcasting on the ground (Kajarern *et. al,* 1989).

The numbers of indigenous chickens kept by the households vary significantly, depending on the farmers' flock management and feeding resources.
According to Hutanuwat (1988), there is a need to increase the number of chicken per family to ensure adequate nutrition, especially of the children. A possible strategy could be improving of the native breed from a meat type to both meat and eggs type of chicken. Raising of native chickens needs a simple technique. Women often practice chicken raising, because chickens are small and easy to handle and they can be kept near the house. The consumers are mainly the men with little interest in the nutritional aspects of poultry keeping. Polpak *et al.*, (1992) found that women were more concerned and eager to improve chicken keeping than men, despite of their generally poorer education.

1.3 Problem statement

In Thailand, a large proportion of the poor people are small farmers. The alleviation of poverty of resource-poor farmers is a multi-facetted task. A better integration and improvement of livestock production into the small-farm enterprise could contribute significantly to the improvement of the livelihoods of small farmers (Davendra and Thomas, 2002). Small-scale livestock development, particularly native chicken raising, is normally considered as the most feasible option for poor small farmers (Palarak, 1985; RDI/KKU, 1989). But native chicken development has been neglected by the government (Ratanawaraha, 1988). With increasing need to concentrate on economic crops and livestock, native chickens are given the least of importance by farmers (Ratanawaraha, 1988). Therefore, most farmers do not want to invest money in their chickens, especially for better feed (Kajarern *et al.,* 1989).

The market demand for indigenous chickens is relatively high but the supply is rather limited because the current raising system is problematic. Over the past twenty years, several projects tried to improve indigenous chicken production, e.g. by promoting farmers to use vaccines to prevent disease outbreaks, improving feed quality in order to improve growth and carcass quality, etc. (Kajarern *et al.,* 1989). Ratanawaraha (1988) recommended to look at native chicken development in the context of home consumption and supplementary income, and not to focus on commercial-scale production for small farmers.

Sheldon (2000) recommended that an improving of local chicken production should be based on two principles. First, on the selection of genotypes better suited to the specific environments of small farms. The choice of genotypes could range from local indigenous breeds to crossbreeds of various types, but not exotic commercial types. Second, on better exploitation of low-cost feed and feed supplementation based on the locally grown crops and their by-products, which are not in competition with human nutrition. However, to facilitate these developments, there is also need for an enabling socioeconomic and institutional environment destined to assist resource-poor farming communities to coexist with purely commercialized livestock enterprises.

Currently, the available hybrid meat-types of chicken in the markets are from large-scale companies, which completely control the production and the market.High performance hybrid broilers have been well established and adopted by producers, with intensive management and the support of the feed industry.
Thai native chickens and their crossbreeds have also been well adapted in an attempt to improve the supply of farm-chicken meat to the market. However, the adoption by small-scale farmers remained a constraint. Ratanawaraha (1988) pointed out that besides biophysical factors and conditions such as disease outbreak, slow growth and low and erratic egg production, the socioeconomic factors play an important role in the low productivity of native chicken. Important factors may be the lack of extension and basic training on native chicken raising. Because of their relatively poor genetic potential, improving the productivity traits of native chicken is necessary. Crossbreeds of Thai native chicken with exotic breeds were introduced and tested for their suitability for the environments of small farms. Ratanpanya *et al*. (1989) reported that the crossbreeds of Thai native chicken (50%) were not suitable for the village condition due to poor diseases resistance, high mortality, poor hatchability – because of incubation neglect behavior–, high mortality of chicks due to poor brooding and chick rearing characteristics and a lack of scavenging behavior. For these reasons, crossbreeds face a lot of constraints for the typical small-farm environment. However, a definite advantage of crossbreeds is their higher egg-laying performance and their faster growth.

1.4 Objectives of the study

Overall objective

The aim of the study is –in the general context of the study area– to identify feeding regimes for chicken –especially native chicken- that are suitable for small-scale farms, and which reduce the dependence on commercial feeds thus making better use of on-farm feed resources.

Specific objectives

To describe and analyze chicken production in the study area with a focus on chicken meat.

To investigate the growth performance of different breeds of chickens – including native types- under different feeding regimes and with an emphasis on typical on-farm feed resources.

To assess the carcass qualities of the different types of chicken and feeding regimes.

1.5 Rationale of the study

The study originates in the concept of improving the livelihoods of small farmers through better integration of livestock –in this case chicken– into the current farming system. Profitable niche opportunities could be developed for small farmers based on indigenous types of chicken, which are assumed to be better suited to the tropical climate and to the conditions on smallholder farms than high-performance hybrids. Also, the use of on-farm feed resources, which are often not utilized efficiently, could be improved. The chickens would be raised under largely natural conditions and in an animal-friendly way. Such a system would make best use of already available resources, with an absolute minimum of external input and with no negative environmental impacts that are often the effect of large-scale high-tech chicken-production systems.

2 REVIEW OF THE LITERATURE

2.1 General background

The demand for meat in the developing world has been increasing annually due to growing populations, rising incomes and urbanization. Delego *et al.* (2001), cited by de Haan (2003), estimated that this demand would grow from 111 million tons in 1997 to 213 million tons in 2020. The major share of this need will come from intensive – largely industrial – pig and poultry production units located in the developing world. Such developments will be further accelerated by international trends and the changing roles of the public and private sectors. In this context, there is an increasing international focus on poverty reduction, food security, food safety and the environment, with animal welfare as an emerging concern. Livestock development – as a component of rural development – is linked closely with poverty reduction strategies. This creates development opportunities but also generates potential threats for the environment and human health. For most of the world's livestock production systems, technologies for sustainable livestock production are available. However, the conglomerate livestock industry, which targets urban markets in particular, might crowd out small livestock holders. This would have a highly negative impact on the 600 million-plus rural poor who keep livestock as one of the few alternatives to escaping from the poverty trap. This 'crowding out' already occurs in many middle-income countries, with a strong concentration of production and processing activities (de Haan, 2003).

Over the past decade, livestock production in the developing world has been growing rapidly. Poultry production is growing faster (+12.1%) than other livestock enterprises, i.e., ruminant meat (+4.3%), pork (+8.5%), milk (+3.4%) and eggs (+9.4%). In developed countries, livestock production has been decreasing gradually for all livestock products (-1.2 – 2.0%), with the exception of poultry which has been rising (+1.9%) (FAO, 2000a). In Thailand, livestock and livestock products have an important share in national agricultural revenue. The total value of livestock products increased from US$1.560 billion in 1984 to US$1.774 billion in 1988, contributing 18.7% of the value of total products (US$9.49 billion) (National Statistics Office, 2002).

Statistics from the Department of Livestock (Table 2.1) illustrate that the numbers of some ruminant species, e.g. buffaloes and sheep, have decreased significantly between 1993 and 2005; buffaloes by 66 % and sheep by 54 %. The deceasing number of buffalos was related to the introduction of farm machinery for rice cultivation; the declining of number of sheep was related to changes in the consumer market. The number of cattle (beef and diary cattle) decreased from 7.47 million heads in 1993 to 4.91 million heads in 1999, i.e. by 34.2%. However, it has been increasing since then to 8.8 million heads by the year 2005, i.e. approximately by 40.5%. The increase of cattle was related to the promotion of beef cattle raising within the village revolving fund development in about 70, 000 villages all over the country. The number of pigs rose from 6.99 to 8.70

million heads between 1993 and 2005. With between 21 million and 22 million birds, the number of ducks has been relatively stable since 2000. There was a significant drop in 2004 due to the outbreak of avian flue. But numbers are recovering since then. The numbers of chickens has been increasing between 1993 and 2003 from 138.8 million birds to 252.7 million birds (82 %). This is due to the rapid development of the chicken-production industry in the country. However, the effect from the avian flu outbreak in 2004 caused a drop in the number of chickens in the country to about 179 million birds due to the bird destruction programme in the affected areas. However –due to successful disease control measures, in 2005, the number of chickens has increased to the level of 2003.

Table 2.2 illustrates that in 2005, a largest proportion of chickens (53 %) are raise in the Central Region of the country. The Northeast Region is also a major area of chicken production (24.6%). Smaller numbers of chickens are produced in southern Thailand (6 %) and northern Thailand (17%). Table 2.3 shows the proportion of the different types of poultry produced in the country between 2000 and 2005. Broilers are the largest group (58%) among the different types of chickens produced in the country. Native chicken, ducks and layer hens represent 25%, 8% and 16%, respectively. The largest number of chickens is produced in intensive systems by large producers or by contract farmers. About a third of the chickens are the native types. These are kept by most farmers as 'backyard' chickens, and their productivity is low. The avian flue outbreak in 2004 has been a major backdrop to the entire chicken industry. Nevertheless, chicken still are the major source of meat in the country.

Table 2.1 Numbers of livestock (heads) in Thailand -1993 to 2005

Year	Horse (heads)	Cattle (heads)	Buffalo (heads)	Pig (heads)	Goat (heads)	Sheep (heads)	Duck (birds)	Chicken (birds)
1993	18,047	7,472,573	4,804,146	8,569,126	151,860	110,465	21,778,395	138,832,027
1994	14,032	7,637,350	4,224,791	8,479,400	141,076	90,508	21,811,815	129,997,098
1995	16,875	7,609,068	3,710,061	8,561,921	132,400	75,329	18,896,635	111,648,510
1996	12,003	6,225,221	2,711,737	8,707,887	118,829	40,900	21,400,375	144,579,428
1997	14,672	5,594,808	2,293,938	10,139,040	125,262	41,926	21,829,896	164,685,842
1998	11,322	4,863,373	1,951,068	8,772,275	130,904	40,404	19,748,077	155,324,646
1999	7,350	4,918,396	1,799,606	7,423,101	132,845	39,485	22,330,123	169,632,507
2000	8,596	5,208,541	1,702,223	7,761,056	144,227	37,312	27,884,041	189,341,110
2001	8,039	5,571,283	1,710,095	8,203,270	188,497	42,720	28,448,399	214,979,081
2002	8,103	5,908,625	1,617,358	6,989,152	177,944	39,326	25,034,011	228,760,326
2003	7,137	6,296,526	1,632,706	7,815,534	213,917	42,883	23,800,092	252,718,883
2004	3,148	7,076,682	1,494,238	6,285,603	250,076	47,811	15,648,538	179,738,810
2005	5,575	8,275,188	1,624,919	8,174,524	338,355	50,779	21,549,345	254,204,068
Percent of different in 1993 and 2005	- 69.1	+ 10.7	- 66.2	- 4.6	+ 122.8	- 54.0	- 1.1	+ 83.1

Source: Department of Livestock Development (2006)

Table 2.2 Numbers of chickens by region in Thailand -1993 to 2005

Year	Central Region (birds)	Northeastern Region (birds)	Northern Region (birds)	Southern Region (birds)	Total (birds)
1993	83,246,791	25,916,449	19,299,493	10,369,294	138,832,027
1994	72,163,615	24,348,503	21,603,271	11,881,709	129,997,098
1995	62,587,266	24,446,914	15,039,270	9,575,060	111,648,510
1996	69,963,645	37,506,727	23,028,677	14,080,379	144,579,428
1997	79,928,557	42,104,802	24,457,990	18,194,493	164,685,842
1998	77,224,601	38,176,754	23,841,418	16,081,873	155,324,646
1999	78,067,555	47,210,939	27,327,803	17,026,210	169,632,507
2000	98,968,145	44,958,278	27,906,485	17,508,202	189,341,110
2001	111,819,685	54,106,254	30,829,909	18,223,223	241,979,081
2002	127,411,495	56,429,660	28,677,030	16,242,141	228,760,326
2003	153,275,177	51,686,324	32,798,811	14,958,571	252,718,883
2004	89,684,664	49,542,774	28,070,941	12,440,431	179,738,810
2005	135,513,823	62,516,470	38,723,520	17,450,250	254,204,068
Percent of different in 1993 to 2005	+ 62.8	+141.2	+100.6	+68.3	+83.1

Source: Department of Livestock Development (2006)

Table 2.3 Numbers, changing in population of broilers, native chickens, and ducks and hen- layers in Thailand 2000 to 2005

Year	**Broiler (birds)**	**Native chicken (birds)**	**Duck (birds)**	**Hen-layer (birds)**
2000	112,154,877	71,598,637	27,884,041	40,972,716
2001	125,160,664	67,304,286	28,448,399	40,249,243
2002	132,359,494	62,192,742	25,034,011	40,681,152
2003	165,314,786	63,091,574	23,800,092	24,312,523
2004	102,680,366	56,194,171	15,648,538	20,864,273
2005	147,674,157	65,319,757	21,540,345	41,210,154
Percent of different during 2000-2005	+31.7	-8.7	-22.8	+0.6

Source: Department of Livestock Development (2006)

Within the next decade, chicken meat will rank first in meat consumption globally for two reasons: (i) There are no religious restrictions and (ii) the production cycle is short and production rates are high (Animal Feed Business, 2005). Poultry production systems in many developing countries can be classified either as intensive commercial systems or extensive scavenger systems. The commercial unit compares favorably with developed world production standards. It is characterized by environmentally controlled housing, automated feeding and utilization of strains selected for high production rates. However, in the developing world 'backyard' production systems still constitute the major supplier of chicken meat. The chickens in these 'backyard' or 'scavenger' systems are adapted native or crossbreed types and require minimum feed and housing inputs. According to Farrel (1992), 80% of the chickens in rural areas in China are local breeds. In southern Africa, native chickens are also associated with low-input systems and household food security (van Marle-Köster and Nel, 2000).

Thus they are efficient waste disposers, converting food leftovers into valuable animal protein. They do not require specialized housing and some roost outside. Almost every homestead has some chickens which supply the cheapest sources of animal protein in the form of eggs and meat (George, 2003). In Myanmar, 85% of the poultry are native chickens. Unlike other livestock, a small flock of chickens can be raised by any household at the village level (Lwin, 2003). In Nepal, poultry are a valuable source of protein and provide cash income as well as manure; the explosive growth of the human population and increasing tourism have accelerated the demand for poultry meat and eggs (Mishra, 2003). In Uganda, rural chickens comprise 80% of the total poultry population (approximately 20 million).

2.2 Significance of chicken meat

2.2.1 Global production and consumption of chicken meat

The global production of meat from broiler chickens in 2005 was estimated to be 57.342 million tons; this is an increase of 3.82% compared to 2004 (55.233 million tons) (Figure A-1). The world's largest producers are the USA, China, Brazil, the EU (25 countries) and Mexico. The production trend in these countries has increased significantly. For 2005, it was estimated that they produced 15.8, 9.99, 8.62, 7.74 and 2.52 million tons, respectively (Figure A-2). The total amount of poultry meat exported in the world market rose from 2000 to 2003, but decreased in 2004 due to the outbreak of avian influenza in the main Asian producer countries, i.e., Thailand and China. However, exports increased again in 2005. The global export volume was 6.225 million tons, an increase of 7.36% from 2004. Brazil, USA, EU, China and Thailand are the largest exporters of poultry meat in the world, sharing the market at the proportions of 39.84, 33.53, 12.45, 4.82 and 4.82%, respectively (Figure A-3). However, the import trend of the major importing countries has been on the decline since 2001; the highest decrease was observed in 2004 (-11.75% from 2003) in the major importing countries, i.e., Russia, Japan and China/Hong Kong (Figure A-4).

Global chicken meat consumption in 2005 was estimated to be 54.99 million tons, with a rising trend of 3.57% over consumption in 2004 (53.10 million tons). The world's leading countries in poultry meat consumption were USA, China, EU, Brazil and Mexico at rates of 13.35, 9.99, 7.27, 6.14 and 2.88 million tons (Figure A-5). The consumption per capita was highest in the USA, Brazil, Canada and Mexico, with per-capita rates of 46.49, 33.34, 30.11 and 27.15 kg, respectively. Poultry meat consumption in the EU (25 countries) was practically stagnant, with fluctuations of between 14.8 and 15.63 kg per capita between 2000 and 2005 (Figure A-6) (Animal Feed Business, 2005).

2.2.2 Production and consumption of chicken meat in Thailand

Thailand is one of world's largest chicken meat producers (ranked 7 in 2003 with production of 1.351 million tons). Production has been on the increase since production of 1.022 million tons in 2000. In 2003, most of the production was for consumption (86%), the remainder being for export (14%). Of the countries that export chicken meat, Thailand was ranked 4 in 2003 (545,978 tons, worth Bt[1]46,701 million).

In 2004 outbreaks of avian influenza nationwide dealt a serious blow to the poultry industry. Production of chicken meat declined by 27% and exports plummeted by 63% compared with 2003. Thailand could not export frozen chicken meat in 2004 – only cooked chicken meat could be exported to selected countries. Approximately 200,000 tons of chicken products could be exported, worth Bt22,500 million. Japan, EU, UK and the Netherlands are the major importing countries of processed chicken meat (Figure A-8). At the same time, the poultry industry improved its productivity. National consumption increased (Figure A-7) gradually from 11.3 kg/capita/year in 2000 to 13.3 kg/capita/year in 2003; it then dwindled to only 8.1 kg/capita/year in 2004 due to avian influenza outbreaks. However, the situation in 2005 seems to be better; it has been forecast that consumption of chicken meat will increase to 10.1 kg/capita/year (Figure A-6). This is rather low compared to the high-consumption countries, but within the range of the EU (15.48 kg), China (7.65 kg), Russia (11.07 kg) and Japan (13.03 kg) (Animal Feed Business, 2005).

2.3 Major types of chickens in Thailand

Chicken raising in Thailand has been promoted since 1903 when King Rama V introduced new breeds, such as the Rhode Island Red, White Leghorn and Barred Plymouth Rock into the country (Thummabood, 1988). More exotic breeds were introduced during 1963 and 1964 by private enterprises, which led to the development of the chicken industry in the country (Choprakarn *et al.,* 2000). Larger-scale chicken meat production began during 1973 and 1974 (Thammabood, 1988); 163 tons of meat was the first significant export (Choprakarn, 2000). In 1979, the fifth national socioeconomic development council started to address the raising of native chickens on a larger scale

[1] Bt = Thai baht. Approximately US$1.00 = Bt38.00 (April 2006).

nationally. A study conducted in northeast Thailand found that the native chicken growth rate was only 9 g/bird/day. In 1983, the Northeast Office of Agriculture held a seminar on native chickens in the country (Choprakarn *et al.,* 2000) and in 1997 the Native Chicken Conservation and Development Association was established. Both pure breeds and crossbreeds are being conserved and further developed.

2.3.1 Pure breeds

A. Native chickens

The Thai native chicken is one of the oldest known breeds of domestic fowl. There are two main types of native chicken. *Shamos* chickens of Malayan (sic) origin, have been widely used and bred for cock fighting. During the 19th century, they were exported to the USA for cock fighting. It is a rugged fowl, very tall, standing up to 30 inches high; the cock weighs approximately 5 kg, the cockerel about 4.1 kg, the hen 3.2 kg and the pullet 2.5 kg (Stromberg, 1996). The *Batong* is a native chicken in the southern parts of Thailand. Its ancestry is associated with the *Langshan* breed and it was introduced to the area by Chinese migrants (Chanlula, 1998).

Native chickens predominate in villages. Chantalakhana and Skunmun (2002) classified native chickens into two strains: (i) *Ooh* chickens are a heavy strain with a large body. They are more of a meat type, and more important economically than other strains. The female is generally black. The male *Ooh* chicken is large and makes a good fighting cock. Their feathers are orange-red mixed with green, black, white or grey feathers. Their mature weight (3 years) averages 2-3 kg for the female and 3-5 kg for the male. About 93% of village chickens are reported to be of the *Ooh* strain; (ii) The *Chae* chicken is smaller and lighter in weight. These chickens are raised mainly as pets and are insignificant economically. Both sexes have similar characteristics. The features and coloring resemble the male *Ooh* chicken; there is also a pure white strain. The mature weight is about 1-2 kg. About 9% of village chickens belong to the *Chae* strain. Typically, native chickens are the ‘meat’ type. The *Ooh* strain is well adapted to the rural environment, and can survive on poor quality food (e.g. rice byproducts) while still maintaining a satisfactory growth of 7-8 g/bird/day (Phalarak, 1985; Thammabood and Choprakarn, 1982).

B. The Rhode Island Red

The Rhode Island Red is a dual purpose breed (meat and egg type). It is characterized by its red-brown feathers, yellow skin, single comb and rose comb and brown egg shell. Egg laying starts at the age of 5.5-6 months. Mature males and females weigh 3.1-4.0 kg and 2.2-4.0 kg, respectively (Laohakaset, 2001; Chinrasri, 2004). Laying reaches up to 280-300 eggs per year. Rhode Island Red development began in 1854 with a crossbreeding of *Malay* or *Chittagong* cocks with ordinary farm hens. They were also crossed with dark *Brahmas*. They were considered to have better meat and to be better layers. Since then, the breed has been constantly improving (Stromberg, 1996).

C. The Barred Plymouth Rock

The Barred Plymouth Rock is a dual breed (meat and egg type) characterized by black and white band feathers, a single comb and yellow skin. They start laying eggs at the age of 5.5-6.0 months. They lay brown eggs, and are distinguished by their excellent meat. In Thailand, the Barred Plymouth Rock is a basic breed for hybrid production (Laohakaset, 2001; Chinrasri, 2004).

D. The Shanghai

Shanghai chickens were introduced into Thailand from China in 1981. Morphologically, they are similar to the Rhode Island Red, but they are slightly bigger. A typical weight is 4 kg for the male and 3.1 kg for the female. Egg laying starts at the age of about 190 days; they produce around 180 eggs/year (DLD, 2003). Prachyalak *et al*. (1994) reported that *Shanghai* chickens had relatively good growth; the chickens reached a body weight of 1.5 kg at the age of 10 weeks. When crossed with Thai native chickens, the crossbreed grew faster than the Thai native chicken.

2.3.2 Crossbreeds

A. Commercial hybrids

In Thailand, commercial hybrids are usually bred for meat production. Meat chickens – broilers – are bred for rapid growth; they will typically reach an average weight of 2 kg at the age of 8 weeks. Broiler strains are based on crosses between the Cornish White, the New Hampshire and the White Plymouth Rock. Broiler chickens consume only 2 kg of commercial feed for each kilogram of live weight (Smith, 1990). In Thailand, parent stock is normally imported. More recently, greater emphasis has been placed on feed efficiency and composition of the growing birds. For breeding companies, the reproductive performance of the breeders is also very important (Pym, 1997) because an acceptable laying capacity is needed to guarantee enough day-old chicks for the market. Important commercial hybrid chickens (meat type) in Thailand are *Arber Acor*, *Hubbard*, *Hybro*, *Ross I*, *Anak*, *Avian* and *Cobb* (Chinrasri, 2004).

B. Crossbreeding of exotic breeds with Thai native chickens

Crossbreeding improves the genetic structure of the local breed, increases genetic variation in the population and encourages hybrid vigor. One way to increase the productivity of local stock is the crossbreeding of native poultry with exotic birds because native birds tend to have low productivity. Intense selection is applied in the male strains for meat quality, food conversion and food efficiency. Such selection is less intense in this context for females. The use of crossbred females ensures hybrid vigor, maximum egg production, viability and hatchability (Smith, 1990). Growth is controlled by genetic disposition (about 78%) and the environment (about 22%) – for example, climate, food, water and quality of animal husbandry (Thammabood *et al.,* 1983 cited by Boonlua, 1989).

Native crossbreeding is usually conducted with exotic breeds noted for their egg-laying capacity, such as the Rhode Island Red and the Barred Plymouth Rock. The crossbred chickens:

- are similar in general physical appearance to the native chickens (i.e., with black feathers)
- are compatible with market prices
- are easier to raise than pure exotic breeds
- are able to utilize local feed resources
- grow more rapidly than native chickens
- have higher egg yields.

Normally, crossbreeding is done with at least two different breeds. The Department of Livestock Development (DLD) introduced crossbred chickens in 1979. Initially, the basic breeds used were the Rhode Island Red and the Barred Plymouth Rock. The policy was to distribute these crossbreeds to small farmers (Punyavee and Morathop, 1996). Currently, there are two- to five-line crossbreeds on the market.

Two-line crossbreeds: The 2-line crossbreeds are crossings between Thai native chickens and *inter alia* exotic breeds like the Rhode Island Red, the Barred Plymouth Rock and the White Leghorn. The main purpose is to improve the general performance of Thai native chickens apropos egg production and meat quality, to improve the acceptance of local feed and to improve resistance to diseases and parasites. The blood level of the crossbreeds is 50:50 from each breed. Crossbreeding is also practiced among exotic breeds in order to produce better parent stock (Figure 2.1).

Three-line crossbreeds: 3-line crossbreeds are popular among farmers. Commonly, these native crossbreeds contain native chickens (50%), Rhode Island Red (25%) and Barred Plymouth Rock (25%) (Figure 2.2). Crossings among two lines of crossbreeds (female) as the parent stock are then crossbred with cocks of native chickens (male). Presently, 3-line crossbreeds are produced in Thailand by: (i) The DLD, (ii) Suwan-6 (Kasetsart University), (iii) Kaset Farm (a private breeder), (iv) Chai-ari Farm (a private breeder) and (v) Tanaosri (a private breeder). The private breeders have developed their own parent stocks for mass production in their own hatcheries.

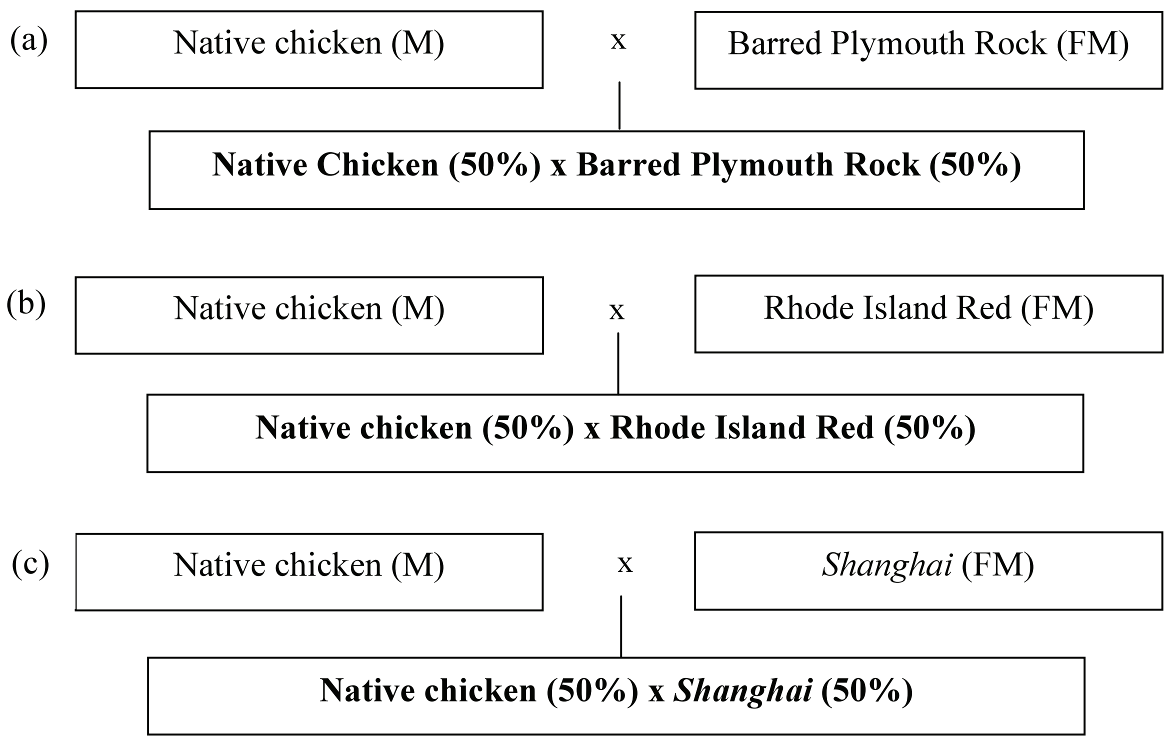


Figure 2.1 Common crossbreeding of 2-line native crossbreeds: (a) native chickens and Barred Plymouth Rock, (b) native chickens and Rhode Island Red; (c) native chickens and Shanghai

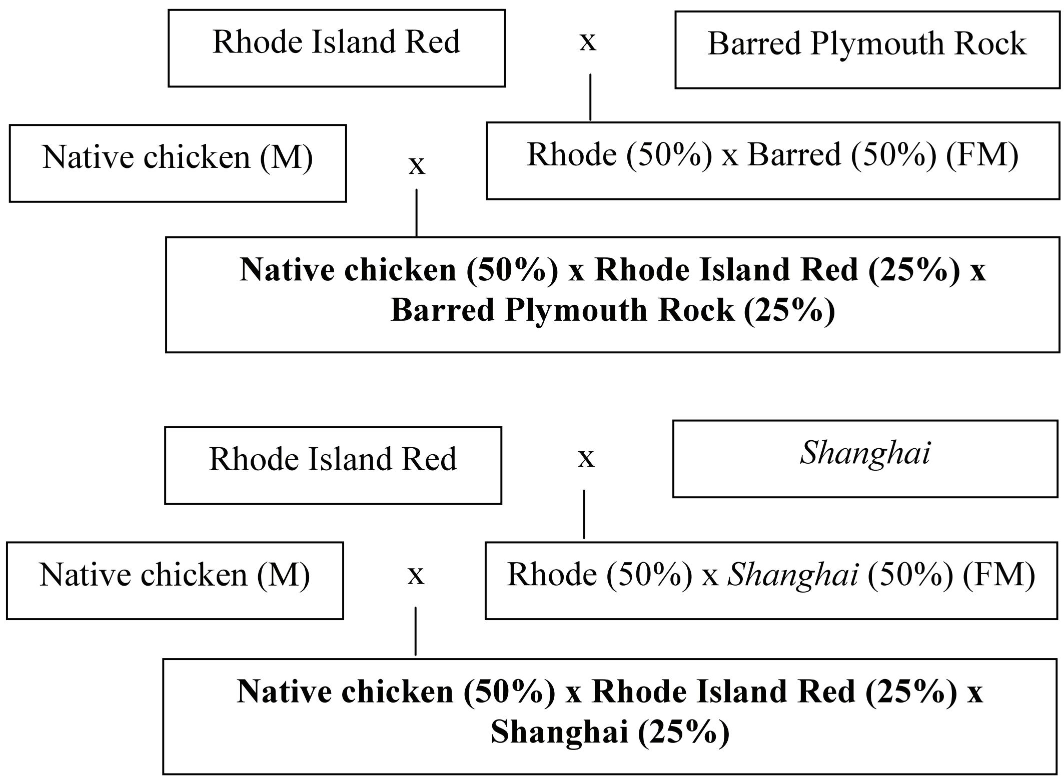


Figure 2.2 Common crossbreeding programs to produce 3-line native crossbreeds

Four-line crossbreeds: Private breeders have produced 4-line crossbreeds by introducing *Shanghai* blood lines into the 3-line crossbreeds. Two types of 4-line crossbreeds are common in Thailand. For Type 1, the parent stock has 3 blood lines which commonly consist of Rhode Island Red (25%), Barred Plymouth Rock (25%) and *Shanghai* (50%) (Figure 2.3). For Type 2, the parent stock consists of Rhode Island Red (12.5%), Barred Plymouth Rock (12.5%) and *Shanghai* (75%) (Figure 2.4). The hens of each type are then crossed with Thai native cocks.

The final 4-line crossbreeds of Type 1 consist of Rhode Island Red (12.5%), Barred Plymouth Rock (12.5%), *Shanghai* (25%) and Thai native chickens (50%). Type 2 comprises Rhode Island Red (6.25%), Barred Plymouth Rock (6.25%), *Shanghai* (37.5%) and Thai native chickens (50%). However, for Type 1 the size of the chickens is not uniform. Type 2 crossbreeds grow faster and have better feed utilization than Type 1. Type 1 crossbreeds reach marketable size of 1.1 kg/bird at 90 days, while Type 2 reaches the same size within 70 to 80 days. The morphology of both types is similar. However, Type 2 hens lay fewer eggs than Type 1 hens; this has been a constraint to chick production (Promchaiwattana, 2003).

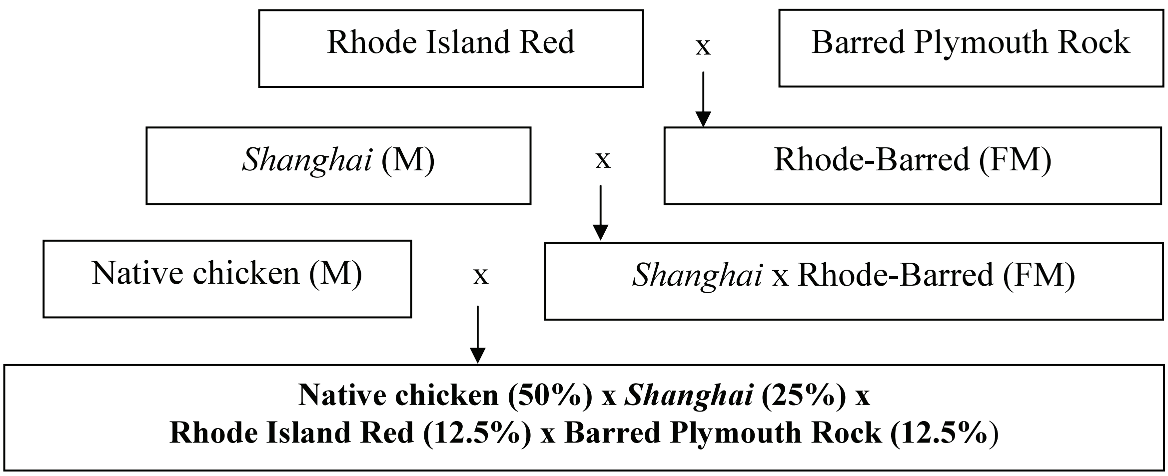


Figure 2.3 Type 1 crossbreeding for 4-line native crossbreeds

Five-line crossbreeds: For 5-line crossbreeds (Figure 2. 5), the parent stock consists of Rhode Island Red (12.5%), Barred Plymouth Rock (12.5%), *Shanghai* (25%) and hybrids (meat-type chickens, 50%). The parent stock is crossed with Thai native cocks. The final crossbreed composition is thus Rhode Island Red (6.25%), Barred Plymouth Rock (6.25%), *Shanghai* (12.5%), hybrid (meat type, 25%) and Thai native chickens (50%). The purpose of 5-line crossbreeding is to upgrade the meat of the hybrid chickens with the meat quality (flavor, firmness, low fat) found in native chickens. Five-line crossbreeds can reach marketable size in 60 to 90 days, depending on the desired final weight. The hen (4-line crossbred chicken) can lay 240 eggs/year. Five-line crossbreeds have higher food conversion efficiency than pure breeds, and can generally grow well with lower quality feed than broilers. Five-line crossbreeds lay 100 to 130 eggs/year (Thammabood, 2000).

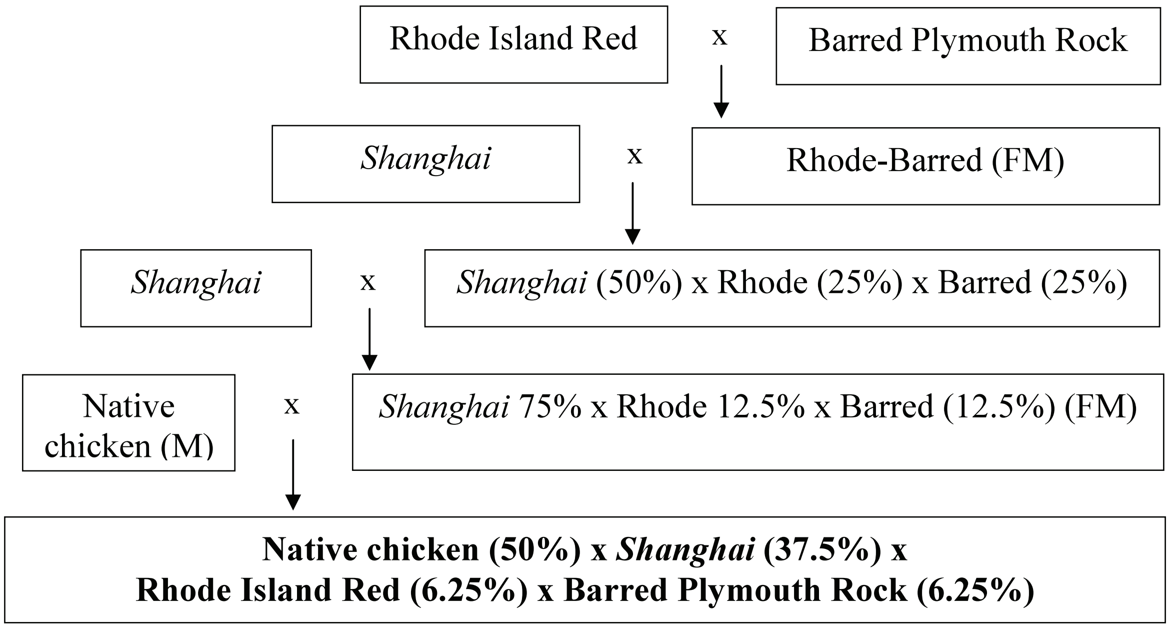


Figure 2.4 Type 2 crossbreeding for 4-line crossbreeds

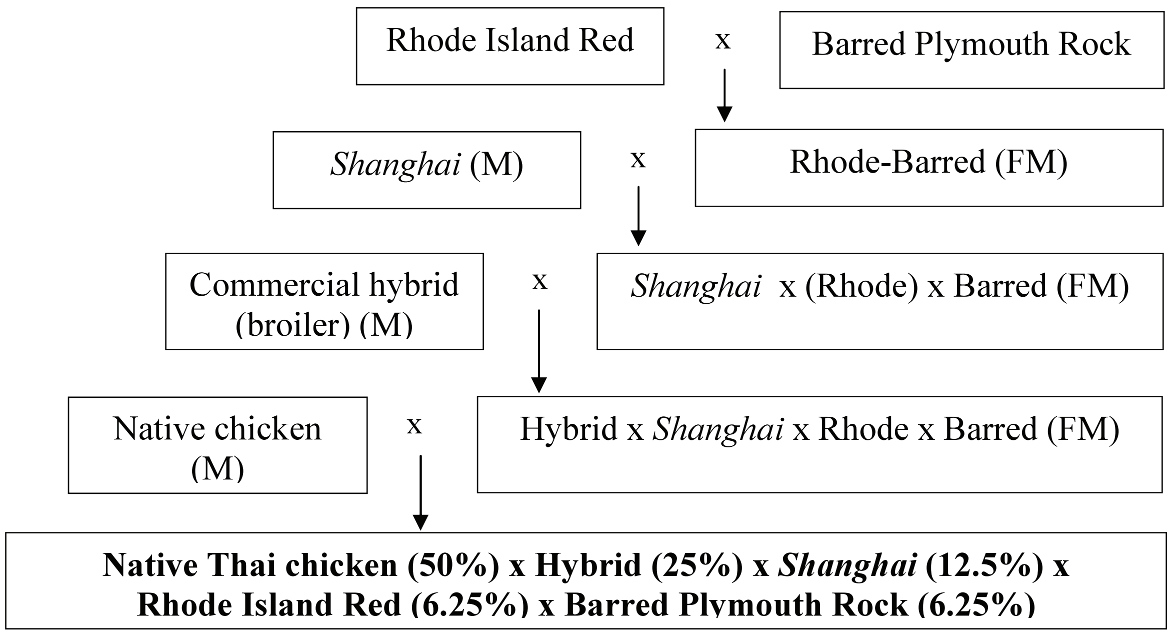


Figure 2.5 Crossbreeding for 5-line native crossbreeds

2.4 Nutrient requirements

The nutrient requirement is the minimum amount of nutrients needed by animals to: (1) maintain their activities (Chinrasri, 2004); (2) maximize growth, feed utilization efficiency, laying capacity and hatchability (Laohakaset, 1997); and (3) optimize fat accumulation (Chinrasri, 2004). Advances in feeding techniques are key factors for successful poultry production. Modern feeding techniques have developed from the extensive feeding systems practiced on small farms, which are based on local feed resources and scavenging. Commercial poultry production focuses on maximum production, economic return, etc. Feed cost is the major production cost in poultry production; it accounts for 60-70% of the total production cost (Kajarern, 1990; Laohakaset, 1997; Chinrasri, 2004)

2.4.1 Protein and energy requirements

Energy in poultry feed is normally expressed in units of metabolizable energy (ME) per unit weight e.g. kJ/g and the requirements of poultry are expressed in terms of ME per day (kJ/d) (Smith, 1990). Energy in the diet largely comprises carbohydrates, but some comes from fat and amino acids. Poultry usually consume just enough food to meet their energy requirements, which are also dependent on the daily ambient temperature (Laohakaset, 1997). The control of feed intake is based primarily on the amount of energy in the diet. Thus, increasing the dietary energy concentration leads to a decrease in feed intake and vice versa. This is valid as long as the diet is adequate apropos all of the other essential nutrients, and that bulkiness, texture, accessibility and palatability do not limit intake (Smith, 1990).

The protein requirement of a bird is defined as the requirement for a supply of the essential amino acids together with a sufficient supply of suitable nitrogenous compounds from which non-essential amino acids can be synthesized. Protein requirement should not be specified as a single figure because the amount of protein which must be supplied depends upon the yield of amino acids obtained by the bird when that protein is digested. Amino acid profiles that meet the needs of one bird will not necessarily meet the needs of another. Thus it is clear that the quality of protein can only be usefully described in terms of the amino acids that it supplies to the bird. However, it is still useful to specify the total requirements for crude protein in addition to specifying the requirements for each essential amino acid as this ensures that the diet supplies sufficient precursors for the non-essential amino acids (Smith, 1990).

2.4.2 Vitamin and mineral requirements

Vitamins are often involved in enzyme systems. They are required by the bird in small quantities. The actual amount required depends on the diet, the rate of growth or egg production, the size of the bird and possibly the climate. An imbalance of vitamins can lead to serious disorders. All vitamins are available commercially in a synthetic form and so their provision to poultry is a simple operation in developed countries. However these synthetic vitamins may not be available in tropical countries. Mineral requirements are defined in terms of mineral elements; they are almost always added to diets in compound form. Calcium (Ca) and phosphorus (P) are the key elements in production and maintenance of the skeleton. The skeleton accounts for about 99% of the Ca and 80% of the P in the body. The two minerals interact with each other both before and after their absorption from the digestive tract. Poultry requirements for Ca and P are influenced by the amount of vitamin D in the diet. In general, the need for Ca and P increases as the level of vitamin D decreases and vice versa (Smith, 1990).

2.4.3 Water requirements

Water is normally provided *ad libitum* for poultry (Smith, 1990). Bird body water is approximately 60% while eggs contain approximately 65%. The presence of water is essential if nutrients are to be absorbed and toxic materials removed from the body. Water is essential for the control of body temperature, especially in hot environments. Panting is an essential heat loss mechanism under these conditions and lack of water quickly leads to death by hyperthermia. Birds consume considerably more water at high ambient temperatures than at low ambient temperatures. Other factors which influence water intake include diet, rate of egg-laying and the size of the bird. Insufficient water can seriously retard growth and impair egg production. This is particularly true in tropical countries where deprivation of water can lead to death within 24 hours. Even a 10% restriction of the amount of water can significantly reduce growth rate and food conversion efficiency. A rise in protein levels increases water consumption. Correspondingly, sodium chloride in the diet increases water intake (potassium and magnesium salts can have a similar effect).

2.5 Effects of the environment on poultry production in tropical regions

The effect of environmental conditions on animal production is well recognized. Most environmental conditions in tropical are less favorable for animal production compared with temperate zones. These environmental conditions or variables include the climate (e.g. air temperature, humidity, air movement, rainfall and light), as well as soil quality and water resources. The major factor that significantly inhibits efficient animal production in tropical is high ambient temperature, both directly and indirectly (Chantalakhana and Skunmun, 2002).

The genetic disposition of poultry cannot be utilized fully if there are environmental constraints. Improvement in production and its efficiency generally depends on the quality of environmental management. Heat stress has a marked effect on behavior, food and water consumption, blood composition, cardio-respiratory behavior, heat production and body temperature of poultry. When the animal is exposed to heat stress, regulatory mechanisms are involved both in specific and non-specific actions. The specific actions dealing with homeostasis include heat loss and cardio-respiratory adjustments. Non-specific actions are dependent on integrative capacities of the nervous and endocrine systems. In the absence of responses, the bird becomes fatigued and dies. Temperature, humidity and air velocity are primary environmental factors which require the bird's ability to adapt to extensive changes in temperature. Stability of body temperature is an essential factor in production efficiency. Broilers have a thermo neutral zone of 32°C to 35°C. The upper critical temperature for broilers is between 36°C and 37°C (Van der Hel *et al.*, 1991). The chicken is comfortable when the ambient temperature is in the thermo neutral zone (18°C to 36°C). Thus health, weight gain, productivity and feed efficiency are maximized and stress is minimized at these temperatures. Poultry body-heat gain is generated by chemical, mechanical and thermal sources. Chemical sources of body heat involve metabolism (e.g., digestion of feed). Mechanical sources are related to physical activities. Body-heat gain is derived from a thermal source if the ambient temperature is greater than the body temperature. The effects of heat stress include decreased voluntary feed intake, growth rate, feed efficiency and ME intake; lower egg production, including degradation of egg-shell quality in the summer season; increased breathing rate (panting); increased susceptibility to disease and finally death. During heat stress, the blood electrolyte balance is altered, blood potassium can be depressed and immune functions can be affected (Chaiyabutr, 2004).

2.6 How chickens adapt to heat stress

Naturally birds try to adjust during high ambient temperatures to maintain routines and for their survival. Chaiyabutr (2004) stated that chickens will relief through:

1) Panting, which helps to cool body temperature in two ways. First, it increases saliva secretion, which can increase evaporative cooling. Second, heavier breathing increases evaporative cooling through the respiratory tract with a subsequent cooling effect.
2) Standing and lying down more frequently during temperatures higher than 36°C.
3) Burrowing into the litter and dispersing their body heat through conductivity.
4) Increasing blood plasma; this helps the bird to tolerate heat as the high specific heat of water decelerates rising body temperature.
5) Increasing the turnover of water and electrolytes as much as possible via the kidneys. Water loss is mainly attributable to an increase in urine production and free water clearance is independent of water consumption. An increment of total urinary K^+, P^-, Na^+, Mg^+, and Ca^{++} excretion has been reported with heat-stressed broilers (Barley and Teeter, 1993 cited by Chaiyabutr, 2004).
6) Higher water consumption due to the loss of water and minerals in order to support evaporative cooling; increasing the sodium re-absorption rate helps heat-acclimated broilers to reduce metabolic heat loading.

2.7 Ways to reduce heat stress in chickens in the tropics

Proper management can minimize the adverse affects of heat stress in poultry. Successful poultry management should take into the account the status of the flock, anticipating heat stress and responding by modifying the environment. To reduce the effects of heat stress in poultry, Chaiyabutr (2004) recommended:

1) Providing adequate access to cool, clean water. During heat stress, drinking is a critical consideration to reduce body temperature.
2) Restricting feed or short-term feed withdrawal during heat stress to reduce mortality. Adjustments to increase the dietary fat level during heat stress may reduce the heat increment of the diet which will lower body temperature (Fuller and Rendom, 1977 cited by Chaiyabutr, 2004).
3) Acclimating poultry to heat. Heat stress acclimation is the physiological response of the poultry (to counter the high ambient temperature) by repeated, short, daily exposure to a hot, humid climate. In this way, poultry can survive a short period of acute heat exposure with a lower body temperature. Heat acclimation of chickens will increase their heat resistance.
4) Supplementing drinking water with minerals (salt) can increase the tolerance of broilers to acute heat stress. Body weight gain and water consumption is influenced by electrolytes with NaCl supplements in the drinking water.
5) Allowing the birds to burrow into the litter and diffuse their body heat through conductivity.
6) Providing ascorbic acid supplements. A study by Gross (1988, cited by Chaiyabutr, 2004) showed that mortality could reduced from 40 to 0% when ascorbic acid was included at 0-330 ppm in the diet one day before heat exposure.
7) Improving the quality of poultry housing, especially with respect to air humidity and ventilation. Many different systems are used to reduce heat stress in poultry, such as fans, evaporative cooling systems, water spraying, sprinkling, dripping and light adjustments.

2.8 Growth of chickens

2.8.1 Commercial hybrid broilers

The protein and energy requirements of commercial hybrid broilers have been investigated by several researchers from different agencies within Thailand. The hybrid broiler sector is continuing to undergo rapid growth so these investigations are ongoing; they are juxtaposed by the development of breeds, feed resources and feeding technology, as well as the improvement of environmental conditions. Commercial hybrid broilers respond to a higher ME diet. Sukhupanyaruk (1977) discovered that commercial hybrid broilers had low growth when they were fed with a diet that contained 2,500 kcal ME/kg at the age of 0-4 weeks, and 2,700 kcal ME/kg at the age of 4-8 weeks. Growth increased when they were fed with higher dietary energy. Growth increased when they were fed with a diet containing 3,100 kcal ME/kg and 20% dietary protein at the age of 0-4 weeks. At the age of 4-8 weeks, broilers required 3,100 kcal ME/kg and 18% dietary protein. Nevertheless, Saichou (1994) reported that a different level of dietary protein had no effect on the growth of a broiler ($P<0.05$). However, the commercial hybrid broilers responded to higher dietary energy because average body weight gain and feed intake was higher when they were fed with higher energy (3,400 and 3,420 kcal/kg) than lower energy (3,280 kcal/kg) ($P<0.05$) at between 0-3 weeks; however there was no significant ($P<0.05$) interaction on energy levels and protein levels on growth at 3-8 weeks. Energy of 3,250 kcal/kg with 18.50% dietary protein achieved better average body weight gain and feed conversion ($P<0.05$) from 0-6 weeks compared to 6-8 weeks. Therefore, Sae-tang (1998) recommended that commercial hybrid broilers at ages of 0-3 and 3-7 weeks should be fed with 3,050 and 3,100 kcal ME/kg. Energy and protein ratios (E/P ratio) at 0-3, 3-6 and 6-7 weeks were 145:1, 163:1 and 179:1, respectively. The feed efficiency of broilers at different energy levels was not significant ($P<0.05$). The feed conversion ratio for 1-49 days varied between 2.11 and 2.14. In addition, there was an attempt to reduce dietary protein with supplements of amino acid in order to maximize return of investment from commercial broiler husbandry. Weight gains were significantly different between treatments. Broilers fed with a diet that contained metionine amino acid (0.6% of diet) and a diet with metionine amino acid (0.5%) + cystein (20%) as recommended by the NRC (1994) had higher weight gains than those fed with the 17% dietary protein as the control treatment (Priem-Ngu-luam, 2000).

2.8.2 Native chickens

Native chickens exhibited slow growth. Investigations revealed that native chickens responded significantly to different feed qualities and husbandry environments. The growth rate heritability in chickens is very high, especially in an unselected population. It was estimated that the h^2 of growth rate could be between 40 and 80%. Continued selection for growth rate results in a reduction of genetic variation and trait heritability may become very low (Smith, 1990). Native chicken h^2 at the age of 8 weeks was 0.78 which was similar to exotic breeds such as the New Hampshire, White Leghorn and Rhode Island Red (only at the measurement period) (Thamabood *et al.*, 1982 cited by Choprakarn *et al.*, 2000).

Thamabood and Choprakarn (1982) studied the response of native chickens to supplement feeding with 7, 10, 12 and 14% dietary protein twice a day (in the morning and evening) besides their natural scavenging. They found that the growth rates of native chickens less than 4 months old were 8.9, 10.6, 8.5 and 8.7 g/bird/day, respectively. It was quite remarkable that the chickens which were fed with the 10% dietary protein supplement had the highest growth rate. Nevertheless, the growth rate of native chickens could be higher at a rate of 13 g/bird/day when fed with 12-18% dietary protein (Choprakarn *et al.*, 1985). Thus, growth was greater with a better diet as reported by Rotjanasatid *et al.* (1983) who found that the weight gain of native chickens was 15 g/bird/day when fed with a commercial broiler diet. The response of native chickens to high feed quality in terms of a protein and energy combination was also investigated. RDI/KKU (1988) found that the average body weight gain of native chickens receiving 21-18% and 19-16% dietary protein was similar (1,327.6 g and 1,302.5 g) but greater than those receiving 17-14 % of dietary protein (1,251.3 g) ($P<0.01$). The average body weight gain of chickens receiving 3,000 and 2,800 kcal ME/kg was not significantly different (1,258.1 g and 1,271.3 g) but higher than those receiving 2,600 kcal ME/kg (1,251.3 g) (P<0.01). For the age range of 8-16 weeks, chickens receiving 18% and 16% of dietary protein had a greater growth rate than those receiving 14% dietary protein. It was clear that at the age range of 0-8 weeks, the growth of native chickens fed with 19% and 18% dietary protein was not significantly different but the growth trend of chickens fed with 19% protein was higher. However, at the same level of protein intake, native chickens receiving the lower energy level exhibited better growth than those receiving the higher energy level in the diet. These facts conflicted with Teerapantuwat *et al.* (1988) who found that weight gains of native chickens at the end of week 20 for chickens receiving the different dietary protein levels, i.e. 17, 16, 15 and 14% were 1,749, 1,803, 1,765 and 1,658 g/bird, respectively which was not significant for body weight gain. The study found that daily weight gains during weeks 12-16 were highest (17 g) and decreased during weeks 16-20 to 15 g/bird/day. Choprakarn *et al.* (2000) reviewed the requirements of native chickens from several studies conducted in Thailand. They found that native chickens required at least 8% dietary protein and 2,600 Kcal ME/kg diet. So natural food, such as insects, is a good source and supply of protein.

2.8.3 Crossbred native chickens

In Thailand, crossbred native chickens have been developed by the DLD since 1979. The growth of crossbred native chickens is faster than native chickens in the semi-intensive system. However, crossbreeding had been attempted among native chickens with several exotic breeds i.e., Rhode Island Red, Barred and White Plymouth Rock and *Shanghai*. The thrust was mainly for growth improvement, increased egg yield and carcass quality improvement. Consequently, husbandry management should be upgraded from the backyard system to the more intensive system with a commercial focus (Panja, 2000).

Mayawes (1985) found that the trend of weight gain of a 2-line crossbreed (native chicken and Rhode Island Red [NR]) increased with an increase of dietary protein (i.e. in the range of 8-20% dietary protein). The most suitable protein levels for the age range of 2-6 weeks, 6-14 weeks and 14-26 weeks were 18, 14 and 10%, respectively. The average body weight gains per bird that received this diet were 239 g in week 6 and 1,048 g in week 16. The cumulated feed intake per bird during the periods of 2-6 weeks and 6-14 weeks were 651 and 2,124 g, respectively. Prachyaluk *et al.* (1994) reported that a 2-line crossbreed (native chicken x *Shanghai* [NH]) receiving a diet containing 20-18% dietary protein and 2,800 Kcal/kg ME had the best body weight and growth rate, being 1,470 and 17.2 g/day, respectively.

Leotaragul and Pimkamlai (1999) reported that the growth of a 2-line crossbreed (native chicken and NR) was significantly different when they received different feed types in the feedlot system. The body weights at 12 weeks were 1,470.14, 1,395.70, 1,270.22 and 585.75 g; their average daily weight gains were 17.12, 16.23, 13.99 and 6.59 g when they received a commercial broiler diet, a commercial layer diet, a commercial broiler diet mixed (50:50) with fine rice bran and a corn gluten meal mixed (50:50) with a fine rice bran, respectively. Thus the 2-line crossbred native chicken had a better performance when it received a good quality diet. The 2-line crossbred native chickens can be raised in both semi-intensive and backyard systems because they exhibited the same growth. Intarachote *et al*. (1996a) studied the growth of different types of 2-line crossbred native chickens raised in both house management and backyard systems. The treatment received the same feed throughout the experiment. There was no significant difference among the types of crossbred native chickens within and between husbandry systems. The body weights at 12 weeks for native chickens and NR, native chickens and NH, native chicken 75% and *Shanghai* (NNH) from the house management and backyard systems were 1,088.7, 1,327.3, 1,202.1 g and 1,262.1, 1,323.5, 1,244.6 g, respectively. However, the growth of a 2-line crossbreed raised in farm conditions was better than that raised on-station.

Intarachote *et al*. (1991) reported on a difference in weight gain between chickens (native chicken and NR) raised under research station and farm conditions. At 12 weeks, the averages of individual weights were 1,189 g on-station and 1,251 g on-farm; at 16 weeks, the average weights were 1,761 g on-station and 1,836.6 g on-farm. Chaiyanukulkitti *et al*. (1990) reported that a 2-line crossbreed (native chicken and NR) fed with a mixed diet containing 15% CP (including 5% leucaena leaf meal) – at 117 days – had an average weight (both sexes) of 1,235 g . The feed conversion ratio (FCR) (2-16 weeks) was 5.71. Chickens fed with the same level of protein but mixed with 5% lucern leaf meal – at 115 days – had an average weight of 1,235 g with an FCR during 2-16 weeks of 5.12.

Loupaibol *et al.* (1999) investigated the production of a 3-line crossbreed (native chicken and Rhode Island Red and Barred Plymouth Rock [NRB]) raised in a research station (Treatment 1: T1) compared with husbandry in two different villages (Treatment 2: T2 and Treatment 3: T3) in the northeast of Thailand. The body weights at 10 weeks of T1, T2 and T3 were 1,084.0, 995.0 and 953.0 g/bird; Average Daily Gain (ADG) was 14.91, 13.58 and 12.99 g/day, respectively. The growth of chickens raised by farmers was lower than chickens reared in the research station because farmers often changed the diet of the chickens. Farmers fed their chickens with a commercial pig diet or a commercial layer diet instead of commercial broiler diet. They also mixed in local feed resources such as broken rice, fine rice bran at a ratio of 1: 1: 1 by weight. The growth rate of the 3-line crossbred native chicken in the research station was higher than in the villages. This was due to the better feed composition in the research station.

Panja (2000) conducted a study on the growth and carcass quality of a pure-bred Thai native chicken (supplier: DLD) with three lots of different 3-line crossbred native chickens (suppliers: (1) Chai-ari Farm, (2) Tanaosri Farm and (3) DLD). The chickens were fed with 18% dietary protein and 2,700 kcal ME/kg for four months. The results showed that the native chicken had the lowest final weight (1,525 g/bird). The 3-line crossbreeds from Chai-ari farm had the highest final weight (2,100 g/bird), while those from Tanaosri farm showed the best result for the FCR (2.69). Purintrapiban *et al.* (2004) reported that the growth of a 3-line crossbreed (NRB) was higher when they received the 16% dietary protein (2,600-2,800 Kcal ME /kg) from palm kernel cake as protein at the level of 10-30% in the diet formula. Body weight and daily gain at the age of 16 weeks were 2,672.5-2,745.0 g and 22.68-23.30 g per bird per day, respectively.

Jeendoung *et al*. (2001) studied the growth of a 2-line crossbreed (NR) and a 3-line crossbreed (NRB) fed with commercial layer diet (19-15-13 % dietary protein). Body weights at birth of NR were lower ($P<0.05$) than NRB. The body weights at 4, 8 and 12 weeks for NR and NRB did not differ ($P>0.05$), but at 16 weeks the weight of NR was higher ($P<0.05$) than NRB. Daily weight gains for NR and NRB from 0-4, 0-8 and 0-12 weeks were not significantly different, but NR was better ($P<0.05$) than NRB at 0-16 weeks. Body length, shank length and thigh length at 4, 8, 12 and 16 weeks for NR (1,810.00 g) were greater ($P<0.05$) than NRB (1,593.33 g). Whereas ADGs during 0-16 weeks were 15.82 and 13.88 g/bird/day for NR and NRB.

Intarachote *et al*. (1996a) compared the growth of a 2-line crossbreed (75% native chicken and *Shanghai* [NNS]), a 3-line crossbreed (native chicken and *Shanghai* and Barred Plymouth Rock [NSB]) and a 4-line crossbreed (native chicken and *Shanghai* and Rhode Island Red and Barred Plymouth Rock [NSRB]). These chickens received the same diet with *ad libitum* feeding. The body weights at hatching for NNS, NSB and NSRB were 35.19, 36.08 and 34.39 g/bird, respectively. Body weights at 12 weeks were 1,228.02, 1,009.89 and 1,146.20 g/bird, respectively. Body weights at 16 weeks were 1,665.45, 1,459.77 and 1,603.72 g/bird. Body weights at 20 weeks were 1,938.17, 2,016.62 and 1,806.44 g/bird, respectively. The growth rate of native chickens was higher during 8-16 weeks and decreased during 16-20 weeks. The average daily weight gains during 0-12 weeks were 14.20, 11.59 and 13.24 g; during 0-16 weeks they were 14.56, 12.71 and 14.01 g; and during 0-20 weeks they were 13.59, 14.47 and 12.66 g, respectively.

Chomchai *et al.* (1998a) studied the effects of dietary protein and energy levels on the growth of a 4-line crossbreed (NSRB). The chicks were fed *ad libitum* with four dietary protein levels (12.13, 13.19, 17.36 and 19.82%) and three dietary energy levels (2,207, 2,609 and 3,010 kcal ME/kg) throughout the rearing period of 14 weeks. The final body weights at 14 weeks were 1,059.91, 1,317.80, 1,427.7 and 1,486.4 g; average daily weight gains were 10.45, 13.09, 14.21 and 14.81 g/day, respectively. FCRs were 4.25, 3.87, 3.49 and 3.45; intake was 46.16, 51.04, 52.02 and 52.28 g/bird, respectively. The results indicated that increasing dietary protein levels could improve body weight and growth rate, FCR and carcass traits ($p<0.05$). There were no statistically significant differences in body weight and growth rate due to dietary energy levels but the FCR could be significantly ($P<0.05$) improved at higher energy levels. The level of ME between 2,207 and 3,010 Kcal/kg was sufficient for NSRB. Chickens which received the low level of energy (2,207 Kcal ME/kg) would adjust by increasing intake until they received a sufficient daily energy requirement. So their growth rates were slightly similar to other chickens. Feeding NSRB chicks with a diet containing 17.36% protein and 3,010 kcal ME/kg produced a good performance and had the lowest feed cost per gain. The growth curve of the NSRB chicks was fitted in cubic terms. The guidelines for improved feed efficiency should be adjusted to feed concentrations given to the chicks at 0-2, 2-11 and 11-14 weeks of age.

Chomchai *et al.* (1998b) rearing the NSRB crossbreed, fed them *ad libitum*, with three dietary protein levels: 1) 18% from 2-16 weeks of age, 2) 11% from 2-16 weeks of age and 3) 18% from 2-8 weeks and 11% from 8-16 weeks of age. The chickens were reared in two housing systems: 1) a litter floor system (5 birds/m^2) and 2) a poultry run (1.7 birds/m^2). Native chicks fed with 11% dietary protein and reared in a poultry run were used as a control in this experiment. The result indicated that at the age of 16 weeks, NSRB chicks had a better performance than native chicks ($P<0.05$) such as growth (body weight: 1,388.16 vs. 769.33 g; ADG 13.01 vs. 6.97 g/day), feed consumption (54.97 vs. 35.26 g/day), FCR (4.35 vs. 5.06), carcass traits (dressed: 62.25 vs. 59.16%) and meat quality. Different levels of dietary protein affected the performance of NSRB. It appeared that feeding with 18%, 18-11% and 11% dietary protein throughout 16 weeks improved growth rate (body weight: 1,736.87, 1,378.45, 1,049.17 g; ADG: 16.58, 12.91, 8.73 g/day), feed consumption (60.80, 57.29, 46.84 g/day), FCR: 3.67, 4.44, 4.93, carcass traits (dressed: 64.7, 62.26, 59.8%) and meat quality of NSRB chicks, respectively. NSRB exhibited the best growth when receiving 18% dietary protein. Thus, there were no significant different effects among the husbandry systems in terms of body weight (1,433.79 and 1,342.54 g), ADG (13.46 and 12.56), feed consumption (57.10 and 52.84 g/day), FCR: 4.37 and 4.32, carcass traits (dressed: 62.7 and 61.8%), respectively. The NSRB chicks fed with 18% dietary protein and kept in the litter floor system did well and had the lowest feed cost per gain.

2.9 Feed utilization efficiency

Feed utilization efficiency is the total efficiency with which all the nutrients are utilized. When expressed in its usual form as the FCR, it is a gross measure of efficiency and selection for this trait places emphasis on the efficient use of food for both maintenance and growth. Breeders of commercial broilers began to select for feed efficiency during the 1980s, and some quite remarkable responses have been achieved. It is now common for commercial broilers to achieve an FCR of less than 1.7 at an average live weight of 1.8 kg, and even better than 1.5 for certain selected lines raised under excellent conditions (Pym, 1997).

The level of feed consumption is a basic and important factor that determines the rate of growth and body composition achieved by animals throughout their lifecycle. The coordinated regulation of feed intake and energy balance involves integration of environmental conditions (i.e. feed, availability, day length and temperature) and internal physiological signals (i.e. hormone levels, metabolite levels and energy store). The central nervous system, brainstem and hypothalamus play a critical role in the regulation of feed intake and energy balance. The regulation of feed intake includes a central system that serves as the controller of feed intake. This central system comprises specific neural sites and circuits in the brainstem and hypothalamic regions that receive inputs from two major peripheral systems. A short-term system, also referred to as the peripheral satiety system, transmits meal-related signals (e.g., the presence of feed of specific nutrients) primarily from the gastrointestinal tract satiety centers located in the brainstem (Jensen, 2001). Satiety signals originating from the gut are relayed from the brainstem to the hypothalamus to activate neural pathways that modulate feed intake in the short-term (i.e., on a meal-to-meal basis). A long-term system provides information to the hypothalamus on the amount of energy stores e.g., adipose tissue mass). Long-term regulation of energy balances occurs via neural and neuroendocrine pathways activated in the hypothalamus in response to specific signaling molecules from the peripheral pathways that are also integrated with satiety signaling pathways originating in the brainstem. The net result is a system that cumulatively regulates meal-to-meal feed intake along with long-term maintenance of energy (fat) storage to achieve energy homeostasis and, ultimately, to promote stability in body weight (Richards, 2003).

A bird reacts to high temperature by reducing its food intake. However, the food efficiency of poultry can be improved be keeping them at temperatures higher than those normally found in temperate regions in winter. In particular, food intake by laying birds declines exponentially as environmental temperature is increased. Consequently production of eggs is reduced as well; lower feed intake (20%) was the indirect effect on the reduction of egg production in high ambient temperature, which was the major effect (80%). If water intake by the bird is doubled (250 to 500 g/day) in a short period (24 hours) then the feed intake will be reduced to the level that it was consuming prior to the increase of ambient temperature. Daylight also affects feed intake – only during the last three hours of daylight do birds quickly learn to eat all their food as they would if food were available during the whole day. By reducing day-time heat production by 16% and increasing night time heat production, growth and food intake decrease 0.12% for each degree of temperature increase above 21°C. Feed conversion efficiency is maximum between 21 and 26°C. At high ambient temperature any method of feeding that lowers the heat increment would be advantageous. Thus feeding with a higher fat diet should be advantageous because fat affords a lower level of heat increment than other energy food. The decreases of intake affect the uptake of amino acid in the diet; this should be increased and balanced. At 21°C and humidity of 48-90% there is no effect on growth and the FCR but at 29°C and 30-70% humidity the growth rate of broilers slows down (Smith, 1990).

Hartman (1981) reported on broilers fed with mash and a pelleted diet and fed with different diet per cubic foot. Broilers fed with the pelleted diet grew faster and reached 1,750 g about three days earlier than those fed with the mash diet. For both the mash and pelleted diets, growth was slower than on the less dense feeds. Intake of pelleted diet can be up to 8% greater than the intake of the same food presented as meal due to partial cooking and convenience. It is high in young birds as it promotes growth rate, but in adults this can lead to increased fat deposition and obesity (Smith, 1990). Thus, bulk density of the diet may also limit the quantity of nutrients that can be ingested per day. Pelleting of a bulky diet will increase the nutrient density per unit volume of diet and enable the consumption of more nutrients. The addition of fat to a diet increases the energy concentration and decreases the bulk density of the feed. Ambient temperature has a marked influence on energy requirement and hence on feed intake. Chickens exhibit lower feed consumption in higher ambient temperatures – feed consumption will decrease by about 1.5% for each rise of 1ºC above the thermo neutral zone. On the other hand, a cooler ambient temperature causes an increase in feed consumption (NRC, 1984).

The most important factors affecting food intake are the characteristics of the bird (body weight, rate of live weight gain and output of eggs), quality of food and the environment. Heavy birds consume more food than lighter birds. The control of food intake of light-bodied laying hens is very precise and they adjust to considerable variation in the energy level in their diets and maintain their daily intake of energy at a constant level. Heavy birds, on the other hand, will consume more energy on a high energy diet than a low energy one and become fat. Birds that grow faster than average, normally consume more food than the average. Faster growth means better food conversion, because a greater proportion of the food is used for production. It was found that 1% increases in egg production were associated with a 2% increase in food intake. Thus food intake is greater (20%) when active egg formation is taking place than days when eggs are not formed. The concentration of energy in diet is a major factor affecting food intake. An increase in dietary energy results in a decrease in food intake. If the diet is deficient in one or more essential nutrients, appetite is depressed; this is associated with a decline in growth or reproductive performance. Hens and chicks will sometimes consume extra food to restore their intake of limited amino acids to an adequate level, in the case of some amino acid deficiency (Smith, 1990).

Appetite or voluntary food intake is the amount of food that a bird consumes when it has unlimited access to a diet. Reduction of food intake is a useful warning of error in management or outbreak of diseases. It is suggested that heat produced after food is consumed raises the temperature of the blood and hypothalamus, so the desire to eat is lessened. Light intensity and day length have some effect on voluntary food intake. For chicks, lighting has a more direct effect upon food intake by regulating behavior patterns and extending food activity. Maximum food intake and growth rate are obtained when chicks are reared in continuous light. Broilers with too much light may increase activity and therefore reduce efficiency of food utilization. Various methods of restriction of food intake can be used. These include skip-a-day feeding, low protein diets, high fiber diets and low lysine diets. Skip-a-day feeding is a technique to ensure that every bird, including those low down in the pecking order will achieve 100% of their desired consumption, whereas birds further down the pecking order may consume less than 50%. For broiler strains, severer levels of restriction (less than 50% of appetite) are applied, particularly in the rearing phase. Birds are given food in a restricted way and water is provided *ad libitum*. Wet litter may result in the humid rainy season; this problem can be overcome by restricting the water intake of the bird as well. Food containing high levels of protein is expensive to purchase, and so a diet which is too high in protein is unnecessarily expensive. The excess protein is broken down and used as an energy source and the excess nitrogen is excreted as uric acid (Smith, 1990).

Bonnet *et al.* (1997) explained that a reduction in feed efficiency might also be due to primarily lower feed digestibility, the first step of feed utilization. Such inconsistency of energy uptake might be attributed to various factors, *inter alia*, feed intake, age, genotypes, sex and type of diet. A reduction in feed digestibility might contribute to a decrease in the amounts of nutrients available for growth. For birds that were fed a corn-soybean meal diet, energy digestibility did not significantly change when birds were exposed to high temperature. Lipid digestibility appeared to decrease which could be related to an increase of the saturated to unsaturated fatty acid ratio. The decrease was probably related to insufficient secretion of bilitary salts. The reduction of feed intake decreased total mineral retention. Chronic heat exposure significantly decreased protein digestion, probably due to protein quality such as rapeseed meal and digestibility was poorer than soybean meal; meat meal is known to be less well-digested than soybean protein sources, which can decrease the overall protein digestibility by 0.6%. The use of high protein digestible materials may attenuate the effect of high temperature on protein digestibility. ME, decreased at high temperature, was only partly explained by decreased protein and fat digestibility. Starch digestibility was also reduced in heat-exposed chickens. This depended on the origin of the starch. At thermo neutrality, feed restriction tended to improve protein, fat and starch digestibility, irrespective of the diet. The use of a feed formulation adapted for a warm period of the year was recommended. The decrease of feed digestibility explains in part the decreased growth of broilers exposed to high temperature. Water consumption dramatically increased at 32°C; this can enhance the feed passage rate. Chronic heat exposure has also been shown to reduce the size of the gastrointestinal tract – the lower proventiculus – and gizzard weight, which could explain part of the reduction in protein digestibility (Savory, 1986 cited by Bonnet, 1997). The decrease in intestinal villosity surface that further reduces absorption in alanine absorption capacity by enterocytes is probably related to delayed cell maturation. Change in vascular characteristics might also contribute to reduced digestibility capacity, thus blood flow is reduced in the upper gastrointestinal tract after chronic heat exposure.

2.9.1 Feed utilization efficiency of hybrid broilers

Broilers are usually allowed to feed on an *ad libitum* basis to ensure rapid development to market size, although some interest has been expressed in controlling feed intake in an attempt to minimize the development of excessive carcass fat. It is difficult to establish a single set of requirements that is appropriate for all types of broiler production. Therefore, nutrient requirement may vary according to the criterion of adequacy. In the instance of essential amino acids, greater dietary concentration may be required to optimize efficiency of feed utilization than would be needed to maximize weight gain (NRC, 1994). Any expression of nutrient requirement can only be a guideline representing a consensus of research reports. These guidelines must be adjusted as necessary to fit the wide variety of age, sex and strains of broiler chickens. Mayawes (1985) referred to the report of Jacson *et al.* (1982) as they found that the level of dietary protein affects feed intake and protein utilization in broilers; feed intake increases when broilers receive dietary protein from 16 to 24% but the rate of feed intake declined when broilers received dietary protein over 24% (72.4, 74.4 and 72.3 g/bird/day for dietary protein of 16, 24 and 36%, respectively). The protein (% dietary) and energy (kcal ME/kg) requirements of broilers recommended by the NRC (1994) at 0-3, 3-6 and 6-8 weeks of age were 23:3,200, 20:3,200 and 18:3,200, respectively. The average feed consumption and feed conversion efficiency for seven weeks overall were 94.97 g/bird/day and 1.97, respectively. In Nigeria, Olomu and Offiong (1980) studied broilers fed with different protein and energy levels in the hot climate of the country. Broilers were fed with a diet that contained four levels of dietary protein (17, 20, 23 and 26%) and three levels of energy (2,800, 3,000 and 3,200 kcal ME/kg). They found that the best growth at the age of 0-5 weeks occurred in broilers that had been fed with 23% dietary protein and 2,800 kcal ME/kg. Energy content in the diet did not have a significant effect in terms of weight gain and feed intake, but feed efficiency was higher with the diet that contained higher energy. During 6-9 weeks, the broilers could be fed with any level of protein content tested because the level of protein contained in the diet had no significant effect on the weight gain and feed utilization efficiency. The most suitable diet was the one that contained 20% dietary protein and 3,000 kcal ME/kg.

The National Research Council (NRC, 1984) published a table of growth and feed requirements of broilers (Table 2.4) as a guideline for feed management. Over nine weeks, the weights of male and female broilers were 2,925 g and 2,350 g, with an FCR for the whole period of 2.27 and 2.35, respectively.

2.9.2 Feed utilization efficiency of native chickens

Native chickens raised in rural areas are part of the scavenging or extensive system. They consume natural food such as insects and worms or agricultural byproducts such as rice grains, kitchen waste and vegetable waste. Villagers let their chickens scavenge for food all day long. Popular feeding places are cattle or pig pens. So feed costs for native chicken rearing are very low, almost nil when compared to commercial rearing which is a completely different activity. Rearing native chickens at the village level has no production costs and is low risk. Introducing commercial feed and feeding is neither appropriate nor practical. Moreover genetic performance is lower than commercial breeding, thus nutrient requirements are lower. Commercial breeding is not appropriate for farmers and rural conditions, especially the investment in feed and feeding. Any proposed feeding activity for native chicken rearing at the village level should be based on the lowest possible cash expense (Rattanawaraha, 1988).

Table 2.4 Body weight and feed requirements of male and female broiler chickens

Age	Body weight (g)		Weekly feed consumption (g)		Cumulative feed consumption (g)	
Week	**M**	**F**	**M**	**F**	**M**	**F**
1	130	120	120	110	120	110
2	320	300	260	240	380	350
3	560	515	390	355	770	705
4	860	790	535	500	1,305	1,205
5	1,250	1,110	740	645	2,045	1,805
6	1,690	1,430	980	800	3,025	2,650
7	2,100	1,745	1,095	910	4,120	3,560
8	2,520	2,060	1,210	970	5,330	4,530
9	2,925	2,350	1,320	1,010	6,650	5,540

Source: National Research Council (NRC, 1984);

Researchers have investigated the nutrient requirements of native chickens as well as improving diet by utilizing local feed resources. Banasithi *et al.* (1988) recommended that the level of protein (% dietary) and energy (Kcal/kg) required by native chickens at different ages were: 19%: 2,800; 15%: 2,200 and 13%: 2,600 for starters, growers and layers, respectively. Panja (2000) investigated the performance of native chickens reared commercially. Native chickens produced by the DLD were fed with 18% dietary protein and 2,700 kcal ME/kg for 16 weeks. The feed intake and feed utilization of native chickens were 50.70 g/bird/day and 3.78, respectively. Teerapantuwat *et al.* (1988) reported that protein efficiency was higher in younger native chickens, decreasing as age increased (i.e. 2.66 at 4 weeks, 1.66 at 16 weeks and 1.12 at 20 weeks). FCRs between 0-12 weeks ranged between 2.45 and 2.94, and increased to 3.98 and 5.8 at 16 and 20 weeks, respectively. It was clear that feed efficiency decreased from week 16 onwards. In this study, the feed efficiency of chickens fed with 14% dietary protein was lowest but not significantly different from the higher percentage of dietary protein. Boonjue (2004) found that the feed intake of native chickens varied with the stage of productivity rather than the level of dietary protein. The response of native chickens to five different levels of dietary protein (12.00, 13.50, 15.00, 16.50 and 18.00%) was investigated. At 16 weeks, feed intake was 92.77, 90.24, 103.12, 94.53 and 101.56 g/bird/day, respectively. Feed intakes during the laying period according to different protein levels were 89.77, 87.26, 103.30, 105.75 and 104.95 g/bird/day, respectively. Feed intake decreased during the incubating period: 65.77, 68.11, 67.63, 69.08 and 69.12 g/bird/day, respectively. Thus, the results showed that protein level did not affect body weight at first egg laid, weight of first eggs laid, body weight before and after the hatching period and feed intake during egg hatching (15% dietary protein since the onset of lay).

2.9.3 Feed utilization efficiency of crossbreed native chickens

Exotic breeds generally require higher levels of nutrition and management which cannot be met under village conditions (Chantalakhana and Skunmun, 2002). Improving the breed of native chickens by crossbreeding with exotic breeds would improve growth, feed utilization efficiency and quality of carcass. Such improvement targets the needs of farmers and consumers.

Crossbred native chicken require and respond to better diet quality compared to native chickens, however, this depends on the number of breed lines: a 2-line crossbreed (native chicken and Rhode Island Red) responded to a better diet because they were fed with a commercial broiler diet, a commercial layer diet, a commercial broiler diet mixed with rice bran and rice bran mixed with maize (Leotaragul *et al.*, 1999). Prachyalak *et al.* (1994) reported that a 2-line crossbreed (NH)) fed with 20-18% dietary protein and 2,800 kcal ME/kg demonstrated the best feed utilization efficiency (2.98); thus feed cost per gain was lowest (Bt17.42/kg) when fed with 16-14% dietary protein and 2,800 kcal ME/kg. Nasakul (1992) concluded that suitable levels of protein content for a 2-line crossbreed (NR) at 0-6 weeks and 6-16 weeks were 18% and 14%, respectively. A decrease of protein level from 20-18% to 18-14% had no effect on feed intake at 0-6 weeks. However, there was a significant difference at 7-16 weeks; feed intakes were 8,352 g for the native chicken and 7,660 g for the Rhode Island Red. Intarachote *et al.* (1996a) compared the growth of a 2-line crossbreed (75% NNS), 3-line crossbreed (NSB) and a 4-line crossbred (NSRB). These chickens received the same diet with *ad libitum* feeding. Feed utilization efficiency of NNS, NSB and NSRB for the overall growth stage of 0-12, 0-16 and 0-20 weeks was 2.52, 3.26 and 2.49; 2.96, 4.06, 2.72 and 3.54, 3.79 and 3.31, respectively. The study recommended that NNS and NSRB could be slaughtered at 16 weeks because growth and feed utilization efficiency declined after 20 weeks, whereas NSB could be slaughtered at 20 weeks because it still exhibited better growth and feed utilization efficiency.

A comparison of the feed utilization of native crossbreeds at the village level and on-station was conducted by Loupaibol *et al.* (1999). They reported that a 3-line crossbred native chicken (NRB) exhibited a better performance when raised on-station because its feed conversion efficiency and quantity of feed intake was lower than chicks raised at the village level (chicks raised at the village level received lower quality of feed). The cumulative quantity of feed intake (0-10 weeks) was 2,992.72, 3,293.50 and 3,427.72 g/bird for the chicks raised in village 1, village 2 and on-station, respectively. FCRs were 2.76, 3.42 and 3.43, respectively. In addition Panja (2000) compared feed intake and feed utilization of a 3-line crossbreed produced by three suppliers (commercially): (1) Chai-aree Farm, (2) Tanaosri Farm and (3) the DLD. The chickens were fed with a diet containing 18% CP and 2,700 kcal/kg for four months. Feed intake and feed utilization were 54.82, 53.18 and 50.34 g/bird/day; 2.77, 2.69 and 3.11, respectively. The 3-line crossbred strains from Chai-aree Farm had the highest final weight (2,100 gm/bird), while those from Tanaosri Farm had the best FCR (2.69). Similarly Purintrapiban *et al.* (2004) reported that feed intake and feed utilization of a 3-line crossbreed (NRB) could be improved when supplemented by soybean meal with palm kernel cake for protein at a rate of 10-30%. All diets were nutritionally balanced to the same level of dietary protein (16%) and energy (2,800-3,000 Kcal ME/kg). The chickens were raised for 98 days. Feed intake and feed utilization efficiency between soybean meal and palm kernel cake at rates of 10, 20 and 30% were 80.81, 80.90, 78.06 and 81.40g/day; 3.52, 3.48, 3.50 and 3.59, respectively.

Chomchai *et al.* (1998a) reported that a 4-line crossbreed (NSRB) that received lower dietary protein (12.3%) had the lowest average daily feed intake (46.16 g/day), significantly different to the feed intake of chicks which received 13.91, 17.36 and 19.82% dietary protein – their feed intakes were 51.04, 52.02, 52.28 g/day ($P>0.05$), respectively. Contrariwise, the feed conversion efficiency of chicks receiving high dietary protein (17.36% and 19.82%) were 3.49 and 3.45, respectively which was better than 4.25 and 3.87 of those receiving the lower level of dietary protein 13.91% and 12.13%, respectively. Similarly, the level of energy in diet affected average feed intake because chicks receiving lower dietary energy (2,207 Kcal ME/kg) had the highest average feed intake (56.97 g/day) compared to highest energy (3,010 Kcal/kg) which had the lowest feed intake (45.85 g/day) – because they adjusted by increasing their feed intake to meet their energy requirement. Levels of energy in the diet affected feed conversion efficiency. Feed conversion efficiency was not significantly different among chicks which received 2,609 and 3,010 Kcal ME/kg (FCR: 3.65 vs. 3.44), however it was better than chicks receiving 2,207 Kcal Me/kg (FCR: 4.21) – significantly different at $P<0.05$.

Chomchai *et al.* (1998b) compared the performance of a 4-line crossbreed (NSRB) with native chickens. Chicks received different levels of dietary protein of 18, 18-11 and 11%, and were reared in two different housing conditions (litter floor system and poultry run system). The NSRB had better feed utilization efficiency than the native chickens (2-16 weeks) because their feed intake (54.97 vs. 35.26 g/day) was higher with lower feed conversion efficiency (4.35 vs. 5.06) compared to native chickens. Feed intake of chicks receiving higher dietary protein (18% and 18-11%) was higher than chicks which received lower dietary protein (11%). The growth stages of starters and growers require higher dietary protein for building up body tissue and organs so low-protein chicks grew slowly and were stunted. Chicks that received lower dietary protein (11%) after 8 weeks still exhibited normal growth and feed intake because they received sufficient protein during early stage (2-8 weeks). Feed conversion efficiency of chicks receiving 18% dietary protein throughout 2-16 weeks was 3.67 which was better than 4.44 for the chicks which received 18% and 11% dietary protein during 2-8 and 8-16 weeks, respectively. Feed consumption of chicks raised in the litter floor system (57.10) was significantly different ($P<0.05$) to those raised in the poultry run system (52.84) because chicks raised in the poultry run system received natural food found on the ground. Feed conversion efficiency between the litter floor system (4.37) and poultry run system (4.32) was not significantly different. However, the run system reduced incidences of cannibalism.

2.10 Housing floor and stocking density

Hartman (1992) found that mixed-sex day-old broiler chicks were allotted 54, 75, 97 and 118 square inches of floor space per bird (29, 21, 16 and 13 birds/m^2, respectively). The three lower stocking densities were significantly higher at 7-week body weight and carcass weight than densities of 29 birds/m^2. However, at six weeks of age, the best feed conversion occurred in broiler stocking density of 29 birds/m^2 whereas the poorest FCR was found in the lowest stocking density (13 birds/m^2). The abdominal fat pad in the lowest stocking density (13 birds/m^2) was significantly larger than that either 29 or 21 birds/m^2. Mortality of chicks in the lowest and highest stocking densities was not significantly different. In addition, the highest stocking density demonstrated breast blisters and ammonia burns. Nevertheless, the highest stocking density gave the highest profit per unit of floor.

Veldkamp and Middlekoop (1997) evaluated a new floor constructed with slats about 8 inches (20 cm) above the original floor; these were covered with an air-permeable cloth and 1.5 to 2.5 inches (4-6 cm) of wood-shaving litter were applied on the surface. Fans were installed into the ventilated floor to circulate air through the litter and maintain moisture below 25%. Stocking density was 22 birds/m^2 at placement and chickens were raised to 42 days of age. There was an overall improvement of 3.3% in weight gain, 1% in feed efficiency and 10% mortality for the ventilated system compared to the regular litter floor. Thus the drier litter over the ventilated floor resulted in improved broiler health and carcass quality. The ventilated flooring concept is an environmentally friendly housing system that improves the performance of broilers, especially in summer and at high stocking densities. Economically, however, the system increased broiler production cost by 3%. However, stocking density could be changed according to the floor type and housing characteristics. The stocking density of broilers could be higher in the early stage and decreased subsequently as recommended by Oluyemi and Robert (1981) cited by Laohakaset (1997) who indicated that the stocking density of broilers for each growing stage of 1, 2, 3, 4, 5, 6 and 7 weeks was 50, 40, 35, 28, 23, 20 and 18 birds/m^2.

The more intensive raising of crossbred native chickens, i.e. number of chicks per unit area was considered in order to improve growth and feed utilization. However high stocking density leads to the problem of cannibalism. Crossbred native chickens raised on a grass floor at the rate of 1 birds/3 m^2 (0.33 bird/m^2)

and 3 birds/m^2 on a concrete floor was the most suitable stocking density as there were no significant differences among the crossbred chickens and rearing systems (Intarachote *et al*., 1996b). Chomchai *et al.* (1998b) raised 4-line crossbred chickens at a density of 1.7 birds/m^2 in a poultry run system (with additional space) and a density of 5 birds/m^2 in a litter system; there were no significant differences in growth and feed utilization. Raising 4-line crossbreeds by providing additional space in the pen had advantages in terms of healthier chickens and reduced cannibalism generated by space competition. Similarly, Chomchai *et al.* (1998a) stocked 4-line crossbred chicks at a density of 2.8 birds/m^2 and this was a suitable density on a litter floor. Loupaibol *et al.* (1999) stocked 3-line crossbred chicks at a density of 8 birds/m^2 with *ad libitum* feeding using a rice-husk floor system at the village level and on-station. There were no significant differences in growth.

There is constant economic pressure on poultry producers to reduce the cost of rearing poultry. One method is to rear broilers in cages rather than on the floor. Suggested cost reduction factors associated with raising broilers in cages include eliminating litter cost, reducing the cost of medication, improving the FCR, reducing housing cost by increasing bird density, controlling disease problems, reducing labor cost, decreasing incidence of bruising and reducing the cost of moving broilers to the processing plant (Reece *et al.*, 1971). However the cage floor system has problems, i.e. breast blisters and leg weakness (Koonze *et al.* 1963), leg abnormality, broken wings and bones.

Akpobome and Fanguy (1992) evaluated the cage floor system for production of commercial broilers. The floor system consisted of three types of mesh (wire, steel and plastic), three types of perforated floor (wood, Styrofoam, and plastic) and three types of dowelling (rigid, rotating and padded). A solid wood floor with wood-shaving litter served as the control. Birds reared on wire-mesh floors experienced a significant reduction in live body weight at 6 and 8 weeks when compared with all other floor types tested. The remaining experimental floor types were comparable to the litter floor control group using body weight as the performance criterion. The mesh floor experienced the highest incidence of breast blisters. The incidence of wing breakage was significantly greater than leg breakage for all floor systems tested. Mortality was only a problem with birds reared on wire-mesh floors. The study suggested that a padded dowel floor system can be used to produce cage broilers of about 2,500 g in weight without leg or breast damage and that these birds will be equivalent to those currently produced by the industry on a litter floor system.

2.11 Factors affecting the mortality of chickens

Mortality of broilers in the tropics is higher due to heat stress from many factors, especially ambient temperature (Chaiyabutr, 2004). Ouart *et al.*(1990) reported that during heat stress and unrestricted feeding, the mortality of broilers was as high as 41%; similarly May *et al.* (1978) cited by Chaiyabutr (2004) found that for broilers exposed to 41°C for 4 hours, mortality could be as high as 60%.

Whereas in the rural areas of tropical countries, native or indigenous chickens mostly tolerate heat stress and have good adaptability to ambient temperature. Production could be upgraded by mating them with productive exotic stock that have possibly one or two major genes for heat tolerance (Gowe and Fairfull, 1995). Genetic selection for increased growth rate and other growth-related traits leads to rapid increase in body weight, especially body fat at later ages. The modern diet may be the contributing factor to the increased incidence of late mortality in the modern strain, i.e. the cause of ascites-related mortality in modern fast growing broiler strains. This may associated with a decrease of the percentage of heart and lung size relative to body size. Thus, the increased levels of total body fat and fat around the heart may be factors that contribute to the higher death rate of modern broilers. Mortality and fat levels were also higher in birds on higher energy modern diets compared to old diets. Birds with high abdominal fat levels were observed to have a lot of fat throughout the visceral mesentery, around the heart (Harvenstein *et al*., 2003).

The mortality rate of native chickens in Thailand was as high as 22.4% from day-old chicks to 4 months of age. The hatched out chicks during March to August had higher mortality than chicks that hatched during other months (Choprakarn, 1988). However, the survival rate of chicks without disease outbreak could be as high as 70-90%. The survival rate in the rainy season is generally lower because of high humidity, strong winds and fluctuating temperature which make chicks susceptible to respiratory disorders and other infectious diseases. In Thailand, outbreaks of Newcastle disease are more frequent in the rainy season than in other seasons. In contrast, outbreaks of fowl cholera, a disease that mainly affects mature birds, are most frequent in summer (Chantalakhana and Skunmun, 2002). The major factors causing high mortality of native chickens according to researchers were young age and seasonal change. In the transitional period from the summer to the rainy season, mortality was higher than the transition from the rainy season to winter and winter to the summer season. The main causes of mortality were disease outbreak, especially Chronic Respiratory Disease (the most difficult to prevent and treat), white feces (fowl cholera), external parasites, e.g. chicken body lice and mites, and internal parasites i.e. round worm (*Ascaridia galli*) and tape-worm (Kajarern *et al*., 1989). This corresponds with the study of Namdaeng (1990) who surveyed 17 provinces of northeastern Thailand. It was concluded that the major problems for raising native chickens were diseases and parasites which caused death among birds (about 65%) every year in almost every household. Moreover, 95% of the farmers had never treated or protected their native chickens from disease outbreak. The most vulnerable period of mortality was reported to be February to April, with a peak in March. The factors that appeared to affect the survival of the chickens during this period were (1) no vaccination, (2) no chicken housing and (3) inadequate provision of feed and water. Similarly, Loupaibol and Jitpraneechai (1999) indicated that all farmers reported high mortality of their chicks from diseases and parasite infection. However theft and dogs were other factors. The dead chickens were disposed of by either throwing the bodies into the jungle, by burying, burning or even eating. Most of the farmers had never received advice related to the prevention of infections or the proper disposal of animals that died from diseases from any agencies.

Chanthalakhana and Skunmun (2002) reported that Newcastle, fowl cholera and other diseases could wipe out the whole flock in a household in a short time. The study in northeast Thailand found that more than 96% of households had experienced the outbreak of an infectious disease; 89% of households reported outbreaks once or twice a year. During outbreaks, 93% of villages reported nearly total or total loss of chickens. The outbreaks could occur in any season, but most (63%) occurred during the summer (February to April), the rainy season (25%) and the cool season (12%). Most frequent outbreaks occurred in April (41%), May (15%) and March (11%) but outbreaks did occur all year round.

The survival of crossbred native chickens raised at the village level was poorer than native chickens. Choprakarn (2000) reported that in a semi-intensive system (vaccination, supplementary feeding and household husbandry), the mortality of crossbred native chickens (30-40%) was higher than native chickens (25-30%). Mortality of crossbred native chickens could remain at 5-15% when they were raised on-station with similar management to native chickens (10-15%). This indicates that the survival rate of crossbred native chickens could be improved with better management. This evidence was supported by the study of Punyavee and Morathop (1996). They investigated the mortality rate of 2- and 3-line crossbred native chickens on-station. The study found that overall mortality (0-12 weeks) of two types of 2-line crossbreeds (native chicken x Rhode Island Red and native chicken x Barred Plymouth Rock) was 6 and 6%, respectively. Whereas overall mortality (0-12 weeks) of 3-line crossbreeds (native chicken x Rhode Island Red x White Plymouth Rock) and (native chicken x Rhode Island Red x Barred Plymouth Rock) was 6% and 3%, respectively. The mortality of these crossbreeds was not significantly different ($P>0.05$). Intarachote *et al.* (1996b) found that cumulative mortality of 2-, 3- and 4-line crossbreeds during 0-12 weeks was 2.27, 20.83 and 7.40%, respectively. The period needing most attention was 0-4 weeks because it had the highest level of mortality for the three types of chicken. Two-line crossbreeds had lower mortality because of the higher blood level of native chickens (75%) so they were easier to manage and had high resistance to a poor environment. The survival rates of 3-line crossbreeds raised at the village level and on-station were not significantly different. The results indicated that 3-line crossbreeds had higher resistance to rearing conditions although feeding management at the village level was poorer than on-station (Loupaibol *et al*., 1999).

2.12 Disease prevention and vaccination constraints at the village level

The most important diseases in Thailand are Newcastle, fowl cholera and fowl pox. These diseases have caused death at rates of 68, 52 and 17 of flocks, respectively (Rattanasettakul *et al.*, 1984). Phalarak (1985) was satisfied with the performance of a 3-line crossbreed (native chicken x Rhode Island Red x Barred

Plymouth Rock) compared with native chickens because vaccination reduced the mortality. He found that the mortality rates of 3-line crossbreeds and native chickens raised at the village level (with vaccination) in the northeast of Thailand were 15 and 11.3%, respectively. The major causes of death were fowl cholera, fowl pox and accidents for native chickens, whereas Newcastle disease and respiratory system diseases caused higher mortality in crossbreeds (18.7%) than native chickens (11.3%). However unknown causes could account for 50% of total mortality. Mortality of crossbreeds (5.9%) due to louse and mite infection was higher than native chicken (0%). Vaccination was the key factor in chicken disease prevention in villages. Constraints were type of vaccines, farmers' status, number of chickens and management techniques.

Chantalakhana and Skunmun (2002) reported that 73% of households had never vaccinated chickens against disease. Villagers who vaccinated their chickens mostly obtained information from their neighbors (46%); only 27% received information from government agencies, and 18% from drugstores. No regular vaccination program was followed, and vaccination was generally done once a year. The major sources of vaccine were drugstores (73%) and government agencies (24%). About 64% of vaccines obtained from government agencies were bought by villagers, the remainder was obtained from government agencies free of charge. Government service for vaccination against infectious diseases appeared to be minimal, as indicated by the fact that among those who had ever used vaccines (27%), only 24% obtained the vaccines from a government agency (mostly through purchase).

Ratanasetakul *et al.* (1984) also agreed that vaccination is the best method of disease control at the village level. They recommended that it was possible to vaccine native chickens simply, by combining vaccination regimes. At 7 days, it is possible to use Newcastle (strain-F) vaccine and infectious bronchitis vaccine. At 2 months, it is possible to use Newcastle disease vaccine (strain-MP) with infectious bronchitis vaccine, or combine infectious bronchitis vaccine and fowl cholera vaccine. Thus, farmers can vaccinate chickens effectively against most diseases (all vaccines simultaneously). Phalarak (1985) suggested that promotion is needed for native chicken vaccination and is an important task for the government, especially among extensionists. It is necessary to research and analyse farmers' social problems for better understanding of their situations.

2.13 Chicken carcass quality and affecting factors

Carcass quality depends on consumer preferences (Smith, 1990). Poultry meat yield is an important economic consideration in production processing, further processing and marketing of poultry. Generally, yield is important to the producers and processors to maximize saleable return against production and processing expenses. Higher yields are invariably associated with improved efficiency and better profits. Early interest in poultry meat yields is associated with maximized production efficiency, improving carcass quality and maximizing processed yield. Factors affecting meat yield are genetics, diet, age and sex and management (Fletcher and Carpenter, 1993). Selection of meat-type chickens previously focused not only on increased growth but also on improved carcass quality. In particular, emphasis has been on body composition, with higher breast and leg meat yield and lower abdominal fat. This focus responds to consumer desire for healthier meat, and to the evolution of the market through a rising demand for portioned and processed products. Profitability in broiler production is therefore largely determined by the possibility of increasing the proportion of prime parts in the carcass, mainly breast meat, and by reducing fat. Body composition can be significantly improved by selection, as shown by the high level of the heritability of the amount of meat, ranging from 0.40 and 0.65 in the study of Le Bihand-Duval *et al.* (1998) (cited by Le Bihand-Duval *et al.*, 1999). For abdominal fat, the heritability range was between 0.50 and 0.80 (Chamber, 1990 cited by Le Bihand-Duval *et al.*, 1999).

Commercial selection of meat-type chickens has focused on increased growth rate and the percentage of prime parts in the carcass, with higher breast meat yields and lower fat (Tesseraud *et al.,* 2003). Broilers, which are regarded as having high quality meat in western countries, are regarded as tasteless and not 'chewy' enough in many African countries. Carcass quality is difficult to define objectively. However, if the birds are to be marketed in supermarkets, the breast muscles should be wide and deep. The fact that female and male carcasses are different in size (males grow faster than females and therefore their carcasses will be larger by the same age) is even an advantage because of consumer demand for a range of different carcasses and different weights (Smith, 1990). In addition to meat production industrially, uniformity is an important goal in the processing industry because it allows for more accurate food supply and cost prediction. Highly uniform flocks are managed efficiently due to the reduced range of nutrient requirements. Thus the processing of uniform flocks is more easily accommodated by automated processing equipment. High flock variability can lead not only to increased production cost but also to decreased market value (Vandegrift *et al*., 2003).

Bunndy and Diggins (1968) described broiler meat of either sex to be tender and pliable with a smooth-textured skin and flexible breastbone cartilage. Most consumers buy dressed fowl or ready-to-cook fowl. Dressed fowl refers to birds which have been slaughtered, bled and have had the feathers removed. Dressed birds are usually sold as fresh-slaughtered poultry. Ready-to-cook poultry refers to birds that have been slaughtered and bled, and the feathers, entrails, head, feet and shanks have been removed. The gizzard, liver, heart and neck are usually wrapped in waxed paper and placed inside the carcasses. The factors considered in determining the quality of an individual carcass are: (1) conformation, (2) flesh, (3) fat, (4) absence of pinfeathers, (5) degree of exposed flesh resulting from cuts, tears and broken bones, (6) absence of skin discoloration, flesh blemishes and bruises, and (7) lack of freezing defects. Depending on the assessment of these criteria, the chickens are usually classified into three quality grades, i.e. A or 1 (highest), B or 2 and C or 3.

Increase in carcass yield *per se* is clearly linked to improvement in overall growth and body weight primarily via additive genetic variation. The existence of significant average heterosis for abdominal fat pad weight in a di-allel is suggestive of general genetic principle, perhaps related to the improved feed efficiency of a hybrid. Male hybrids exhibited a 29% decrease in fat pad weight while female hybrids exhibited a 7% increase (Barbato, 1992). Harvenstein *et al.* (2003) studied the yield of carcass parts in 1957 using Athens-Canadian Randombred Control (ACRBC) and the Ross 308 commercial broiler, which were fed diets that were representative. The study found that the yield of broiler carcass parts had continued to increase over time and genetics had been the major contributor to the change of yield. Genetics contributed about 85 to 90% of the differences observed in carcass and part yields. Nutritional changes accounted for 10-15% of these differences.

Carcass quality is mostly affected by poor litter quality, especially for the areas of the body having the greatest contact with litter, i.e., foot pads and breast. Major characteristic symptoms are foot pad burns, lesions or dermatitis, and pododermatitis. Foot pad burns are higher in females than males. Foot pad lesions can provide an open channel for entry of pathogens into the bloodstream leading to leg disorders. Wet litter leads to the incidence of foot pad blisters that can increase dramatically in a few weeks. Foot pads that are softened by contact with moist litter may be more susceptible to ammonia burns and abrasion by coarse or splintery litter material, leading to a higher incidence of blister. Fresh litter, in some instances, may actually contribute to more foot pad lesions than used litter. Breast blister presents another important carcass quality parameter of substantial economic significance to the poultry industry. Factors that contribute to all increased incidence of breast blisters are: increasing bird weight and age, narrow breast angle, lack of breast feathering, coarse litter materials, ammonia; wet litter results from inadequate ventilation, high relative humidity, low litter depth and high stocking densities. Unlike foot pad blister, males have a higher incidence than females. Breast trims were found to be higher in winter than summer according to Bilgii (1993) cited by Malone (1997). Maintaining moisture content of less than 25% will help to reduce foot pad and breast blisters. Managing litter moisture rather than managing litter is more effective in this respect. Additionally, available water activities (Aw) of the litter surface is another factor recently identified as having major implications in broiler production. Litter Aw is a measurement that is related to the relative humidity of litter and is a key factor in bacterial multiplication (Malone, 1997).

Harvenstein *et al.* (2003) stated that the switch from the “normal” broiler strains that were being used in the late 1980s and early 1990s to the so-called meat-type or high yield broiler that is in current use resulted in a doubling of the percentage yield of breast meat. The total breast meat average at 43 days for the broiler strain in 1957 and 2001 was 11.6 and 20.0% live weight, respectively. Sae-tang (1998) reported that – for broilers and under tropical conditions – the portion of the carcass in relation to the live weight (around 81%) and the portion of abdominal fat (around 2.5%) did not differ with the dietary energy level of the feed. Edward *et al* (1973) reported an increase of fat when poultry increased in body weight. Meat of male poultry had higher protein content than females at 42 days. Male commercial broiler meat comprised total fat (17.9%) and protein (16.8%), whereas female broilers had total fat of 22.2% and protein at 16.3%. Priem-Ngu-luam (2000) determined the chemical composition of broiler carcasses at the age of 56 days. The contents of the main elements were moisture (61-62%), CP (16-17%) and crude lipid (16-17%). The breast meat of broilers contained moisture at 70-72%, protein at 24-26% and crude lipid at 0.92-0.96%. In broilers fed with supplements of methionine amino acid (single) and/or together with cystein amino acid, the protein content of the meat increased while the crude lipid content decreased, both in the whole carcass and the breast meat. In Africa, van Köster and Webb (2000) evaluated carcass characteristics of different types of native African chickens and commercial broilers (Cobb). The study found that the proportion of dressed carcasses of Cobb broilers was significantly higher ($P<0.05$) than native chickens. The carcass muscle content for most native lines was in the region of 55%. Native lines had low carcass yields mainly due to their slower growth; they had higher bone and lower fat contents than the commercial broilers. Native lines have not been selected for growth or carcass traits, but for household food security. The higher bone content in native chickens may be associated with adaptation to flight and scavenging. Thus the study concluded that some native breeds appeared to be the most suitable lines in terms of carcass characteristics, for low-input systems where poultry production is for household food security.

Native chicken meat had a better result because the proportions of total fat and protein were suitable. Loupaibol *et al.* (1983) reported that the dressed carcass of native chicken was 85.4% while Toomsen (1988) measured the carcass portion for 16-20-week-old birds as 76.83%. Teerapantuwat *et al.* (1988) reported that the dressed carcass (Thai style) of native chicken with a body weight of 1,200 g was 78.41% with a meat portion of 36.07%. Thus, they found that there were no significant differences for different levels of protein. The dressed carcasses of 8, 12, 16 and 20 week-old-chickens were 55.94, 62.70, 65.99 and 66.37%, respectively. The meat proportion of chicken increased according to the age of the chicken. For ages 4, 8, 12, 16 and 20 weeks the meat portions were16.46, 26.60, 29.50, 36.05 and 33.82%, respectively. The meat proportion was highest for 16-week-old chicken. Isriyodom *et al.* (1993) found that the proportion of the whole carcass of native chicken at 16 weeks was not significantly different from Rhode Island Red and Barred Plymouth Rock (88.5, 83.6 and 86.1% respectively). Intarachote *et al*. (1996b) found that the percentage of the total carcass was higher at 12 weeks than at 16 or 20 weeks. However, the portions of legs and drumsticks increased with age. Therefore, the carcass of a Thai native chicken was still higher than the Famiyo strain (85.2%) and White Leghorn (84.8%). Thus, Intarachote *et al.* (1996a) compared the carcass quality of different types of crossbreeds with native chicken (i.e. Shanghai, Barred Plymouth Rock and Rhode Island Red –Barred Plymouth Rock) and found that there were no significant differences in carcass weight and quality. Slaughtering at 16 weeks provided the best economic return.

Chomchai *et al.* (1998b) studied the influence of the level of protein and rearing system on the production and carcass composition of native chicken and 4-line crossbreeds (Thai native chicken x Rhode Island Red – Barred Plymouth Rock, *Shanghai*) and found that 4-line crossbreeds had a higher growth rate, lower FCR, higher dressed carcass, higher protein content and less fat than native chickens. Punyavee *et al.* (2002) compared the carcass composition of native chicken, *Shanghai* and Rhode Island Red at different ages (i.e. 2, 3, 4, 5 and 6 months). Thai native chicken had a higher percentage of dressed carcass than other breeds. Gender had no influence. Fast growing breeds (*Shanghai* and Rhode Island) had a higher proportion of thigh and leg but a lower proportion of breast than Thai native chicken, with slower growth. The percentage of edible visceral organs of the Thai native chicken was higher than for the faster-growing breeds. Rhode Island reached puberty at an earlier age and had higher abdominal fat as well as larger ovaries than the other two lines. Intarachote *et al.* (1996) reported that 20 weeks was a suitable slaughtering period for native chickens and their crossbreeds as they have the highest proportion of carcass meat. They found that a 2-line crossbreed (75% native chicken and *Shanghai*) had a higher proportion of meat (boneless breast meat) than a 3-line crossbreed (native chicken x Barred Plymouth Rock x *Shanghai*) and a 4-line crossbreed (native chicken x *Shanghai* x Barred Plymouth Rock x Rhode Island Red). The higher proportion of muscle in the carcass of the native breed created better taste and palatability. Thus, at 14 weeks, 4-line crossbreed meat had lower fat content, moisture and higher protein content than the meat of native chickens. However, the percentage of moisture and protein was not significantly different. The 4-line crossbreed had lower fat content in its meat than the native chicken. Thus the 4-line crossbreed received the higher dietary protein level (18%) and had a higher proportion of protein in meat (Chomchai *et al*. 1998b).

2.14 Commercial production systems and technologies used in Thailand

Poultry production systems in many developing countries can be classified as intensive commercial systems or extensive/scavenger systems. The commercial units compare favorably with Western production standards, and are characterized by environmentally controlled housing, automated feeding and utilization of chicken strains selected for high production (van Marle-Köster and Nel, 2000). Smith (1990) stated that the actual development that has taken place has been in the organization of the poultry industry. Whereas historically all stages of production were controlled by different individuals or companies, there has been a tendency over the past 30 years for one firm (normally either a poultry breeding company or a food manufacturing company) to take over the whole industry from start to finish, i.e. from the egg to marketing of the dressed birds. This type of development is known as vertical integration. Every part of the industry can be closely monitored and supplies regulated to meet demands both in terms of quantity and quality. Hennry and Rothwell (1996) stated that technological change in the livestock industry is usually juxtaposed by capital intensification. These developments can reduce – and eventually eliminate – the poor small-scale village-level livestock keepers. In Brazil, four integrators cover about 40% of the broiler market; the number of farms with less than 1,000 birds decreased by 25%, while the number of birds doubled (de Haan *et al.,* 2001 cited by de Haan *et al.*, 2003).

Thailand plays a major role in the world poultry meat market. However, the fluctuation of the market price of chicken (meat type) makes large-scale chicken-rearing enterprises a risky business. Many rearers – especially those who are not financially strong – become contract rearers for larger companies in order to reduce the marketing risk. Although currently there is an increase in the number of contract rearers, in the near future the major share of the chicken-rearing business will be in the hands of only large-scale companies which control the complete production cycle (AOE, 1991). Chicken production in Thailand has been developing into an industry/business with high productivity and capacity to compete well on the international market. This is attributable to three main characteristics:

1) The breeds of chicken have been improved significantly, both in terms of growth and meat quality; the most widely used chickens are commercial hybrids.
2) Feed quality and feed manufacturing have been improved to meet the nutrient requirements of high-performance chickens.
3) The management of chicken enterprises has adapted well to the requirements of the world market. However, at the moment, 80% of the poultry produced now comes from only 10 large vertically integrated companies, which supply feed and day-old chicks to medium and large producers under contract farming (de Haan *et al.,* 2001 cited by de Han *et al.,* 2003).

Table 2.5 gives an overview of the characteristics of chicken production systems in Thailand. There are three types of producers, i.e. (1) independent rearers, (2) contract rearers and (3) company integrators (vertical integrators). Independent rearers have the highest risk in the business; contract rearers have a lower risk, but this usually depends entirely on the contract agreement. Normally the rearers have little influence on the contract conditions.

Production technology is mainly used by large-scale companies. Chicken rearing in a closed system has been adopted in Thailand for over 10 years. The closed house system involves the controlling of environmental conditions in the housing to meet the requirements of the chicken, i.e. temperature, humidity, ventilation, wind speed and lighting. The purpose is to improve production efficiency. The advantages are manifold: (1) efficient disease and pest prevention, (2) increase of stocking density (for broilers up to 8-9 birds/m^2; for parent stock up to 5-6 birds/m^2), (3) better feed-use efficiency, (4) reduced rearing period to 5 to 6 batches per year, (5) higher average final weight of chicken, (6) better light control, (7) decreased mortality and (8) lower labor requirement. The cost of construction of a closed housing type tunnel with an evaporation cooling system

(10.0 x 72.0 x 1.9 m) and a diesel engine for electricity generation to stock 7,000 broilers was estimated at Bt472,381. This was an initial fixed-cost investment of Bt67.48/bird. For the construction cost of the evaporation cooling system (10 x 72 x 2.0 m) and direct farm electricity, the initial fixed-cost investment was Bt280,637 or Bt40.09/bird. The estimated production capacity was a stock of 7,000 chickens per housing, raised over a 41-day period, with a final weight of 1.97 kg/bird, an FCR of 1.89 (standard = 1.959), a 5% mortality rate and 6 batches per year, with a return of Bt6.00t/bird. This would earn the rearer Bt40,000 per batch, i.e. an annual return of Bt240,000 (Isriyodom, 2000).

Temperature and humidity control inside the housing is important for adequate development of the chickens. During the first 21 days the suitable temperature range is 30-35ºC with humidity between 55-80%. After this, the temperature should be between 20-30ºC with 60-90% humidity. The feeding standard (Table 2.6) ensures that the chickens receive adequate nutrition according to age and breed. Critical periods for an adjustment (i.e. increase) of feed supply are 0-7 days and 28-30 days. These are important periods for the growth of the bones. If the chickens grow too fast or become too fat during the first period, this may cause leg problems. Feeding should also not be more than 10% below the standard, especially during the first 21 days. Otherwise, the chickens will become stunted and the immune system will not function well, leading to higher incidence of diseases. Normally, broilers drink water at the rate of 100-120 ml/bird/100g of feed intake – or 1.0-1.2 times of the total feed intake. In a closed housing system this will be 1.5-3.0 times of the total feed intake, depending on the climate. This also depends on the type of water-supply devices. With auto watering, this will be 1.2-1.5 times of the total feed intake. During periods when antibiotics are administered, drinking will decrease by about 10-30% of the normal rate. The monitoring of drinking water consumption is indispensable for closed housing chicken rearing systems (Pornrawee, 2003).

Table 2.5 Main characteristics of chicken production systems in Thailand, (Teankaew, 2001).

Characteristic	**Independent Rearer**	**Type of Contract System***			**Vertical Integrator**
		Contract farming	Contract Rearer	Open Account	
Investments: Housing and equipment, and raising facilities	By rearer	By rearer	By rearer	By rearer	Large-scale company that covers all supplies on its own (seed, feed mill, drugs, farm, slaughter and meat processing factory.. Markets own products (meat, processed meat) within the country and for export
Seed (chicks)/ feed/drugs &/ vaccines	Purchase by cash or credit and management by farmers	Supplied by contractor, managed by farmer	Supplied and managed by contractors	Supplied by contractor but farmers purchase	
Markets	Flexible for any market by rearers	By contractor	By contractor	By contractor	
Farm gate price	Dependent on market mechanism	Contract price	Contract price	Fluctuation; depends on market mechanism	
Income	High fluctuation; depends on inputs and outputs	More consistency; depends on production	Consistent earning (Bt1.0-1.5/bird		
Risks	High	Low	No risk	High	
Advantages for rearers	Needs experience; Needs a niche market	New farmers will be trained by contractor	Business could start at once as housing available; experienced farmers	Farmers have available capital; expenses could be deducted directly from contract	

* Contract between farmers and the chicken-meat company or feed mill

Table 2.6 Standard of feed intake, body weight and FCRs of broilers raised in closed housing (evaporation cooling system) (Pornrawee, 2003)

Age (day)	Feed cumulative per birds (g)	Body weight per bird (g)	Feed conversion ratio
7	149	167	0.89
14	472	391	1.21
21	986	705	1.40
28	1,698	1,087	1.56
35	2,535	1,489	1.70
42	3,498	1,896	1.84
49	4,590	2,324	1.98

2.15 Improvement and adoption of crossbreed native chickens

As the population of Thailand has been increasing rapidly, native chicken supply has become a major constraint. Increasing productivity is necessary in order to produce enough food for consumers. To meet this demand, the native chicken rearing system has changed from the backyard approach to a more intensive and more commercial system. However, because of slow growth, attempts have been made to improve the production of native chickens by crossbreeding with pure breeds (Panja, 2000).

Phalarak (1985) and Rattanpanya *et al.* (1989) stated that native crossbreeds were inferior to pure native chickens because of poorer disease resistance, high mortality, inadequate adaptation to the rural environment, poorer hatchability, neglect of and high mortality among chicks due to poor mother brooding and chick rearing. They also require good quality feed and they lack the scavenging behavior of pure native chickens. However, the advantages of raising crossbreeds with native chickens are their higher egg-laying rate and their faster growth. Nevertheless, they found that native chickens raised at the village level generally showed the same level of productivity as crossbreeds, but generally fetched higher market prices. Thus, native chicken have a higher resistance to diseases than common crossbreeds and commercial hybrids (Ratanasethagul, 1983). However, it is well accepted that village chickens are much smaller than commercial chickens at the same age. The genetic factor is also very important for the improvement of egg production and growth (Chantalakhana and Skummun, 2002).

Currently, native chickens and crossbreeds have become popular among farmers. The DLD has launched a program to promote native chicken rearing in order to increase the production of native breeds. In the 8^{th} National Economic and Development Planning Program from 1997 to 2001, the DLD aimed to distribute over a million day-old chicks to farmers (Leotaragul and Pimkamlai, 1999). Later, the DLD supplied 1.5-2.0 million day-old chicks of native chickens and crossbreeds to farmers from 2001 to 2003 (DLD, 2003). The general characteristics of the crossbreeds were similar to the pure native chicken, especially in their ability to utilize low-quality feed; but they grew faster, thus having a higher egg yield. Raising native crossbreeds for extra income, farmers usually feed them with a commercial diet with some additional feed available on the farm, such as rice bran, broken rice, and maize. Sometimes, only local feed is given (Leotaragul *et al.*, 2000). Supplying crossbreed chicks has been a constraint in terms of quantity and distribution. Crossbreed chicks were available mainly in the research center and a few private hatcheries. Loupaibol *et al*. (1999 a) recommended that strategies to improve the availability of one-day chicks at reasonable prices should entail the establishment of breeding and hatchery centers on a cooperative basis, and improved market channels. However, current supply of native chickens in the market is irregular.

2.16 Native chickens production of small-scale farms

2.16.1 Rearing systems for native chickens and their crossbreeds

Commercial poultry production has become a successful and highly competitive enterprise in Thailand but backyard chicken raising in villages continues to share a fairly substantial portion of domestic chicken meat consumption. About 90-95% of the rural households raise native chickens ranking from 5 to 50 birds per household (Chantalakhana and Skunmun, 2002). Farmers keep chickens either under the farm house, in a separate small structure or under the rice store. The major feed sources for native chickens are polished paddy rice and broken rice. Most farmers broadcast the feed on the ground; very few farmers use feeding trays. A single feeding per day is common. Drinking water is available either in simple basins or the chickens drink standing water available in patches near the house. Village chicken raising normally requires no cash input for breeding stocks, feed, medical supplies, etc. Breeding stocks are available from household chickens (Loupaibol and Jitpraneechai, 1999). Native chickens scavenge for natural feed – such as earthworms, termites, insects and green leaves – for protein and vitamins around the homestead or in the fields (Phoesri, 1984). The most popular area for chicken housing is under the house or rice storage, with pieces of bamboo railing for roosting during the night. Some villagers let their chickens roost in the trees. The chickens take care of themselves otherwise (Loupaibol and Jitpraneechai, 1999).

The output in this system is low, with low egg production due to usually high mortality rates (Smith, 1990). Bunddy and Diggin (1968) recommended the improvement of free-range chicken rearing by providing range shelters. An area enclosed with wire netting will permit the confinement of chickens at night to prevent losses to predators. The range should be moved from time to time to maintain good sanitary conditions. There should also be plenty of fresh water and ample feed. However, such a system needs additional feed which is often not available in poor communities.

A study was made in Cambodia to compare free-range and fully caged chicken rearing systems under on-farm conditions with local and exotic breeds. Chickens – 30 of each breed – with an initial weight of about 500 g were kept under (a) total confinement, (b) scavenging on a pasture and (c) scavenging in an integrated farm area with fruit trees, a bio-digester and duck-weed ponds. Until the end of the 70-day experiment – during the rainy season – only 9 of the exotic chickens survived compared with 24 of the local breed. Newcastle was the main cause of mortality although all birds were vaccinated against this disease. The nature of the area available for scavenging influenced the feed intake pattern of the chickens strongly when they had access to both energy-rich and protein-rich supplements. Like in Cambodia, birds with access to the integrated farm area ate significantly less ground soybean (8 g soybean/day or 2.7 g protein) compared to when the scavenging area was totally pasture (16 g/day), while the intake of broken rice was similar in both scavenging treatments (40-50 g/day). There were differences (P = 0.001) in the final live weight of the local chickens between the two scavenging treatments. Values were 1,390 g in the pasture group and 1,478 g in the biomass group compared with 667 g for the confinement group (Samnang, 1998).

2.16.2 Marketing system and economic benefits

Marketing is important for generating income. Village chicken raising is a subsistence activity without cash cost; the total value of production is regarded as the net return. The main reason for selling chickens is the need for cash rather than the culling of excessive stock (Chantalakhana and Skunmun, 2002). Farmers market their poultry in two ways: 1) Selling the birds on a by-number basis. The consumers come from the village or the local market and the price of the chicken is negotiated. 2) Selling the birds by weight. Merchants from the town buy from the villages (Kajareon *et al.,* 1988). The local buyers will sell these chickens to the Amphoe (District) merchants, who will then take them to the provincial market. The sale of chickens takes place any time in the year, but most sales occur from January to March, especially during February at the Chinese New Year. At this time, village chickens are in prime condition due to abundant feed supply after the rice harvest (Chantalakhana and Skunmun, 2002).

In local markets, native chickens usually fetch higher market prices than commercial breeds. Price determination is based mainly on chicken body weight using the Chinese-type scale (Chantalakhana and Skunmun, 2002). Over the past 15 years, the price of native chicken has been Bt27-35/kg live weight depending on the season or on the time of local or national festivals (Aaron *et al.*, 1988). Currently the market price of native chicken is higher (Bt45-50/kg) than commercial broilers by almost 50% (Bt25-30/kg) (Panja, 2000). This makes native chickens a promising investment for low-income rural people (Chunjula, 1998). Although native chickens grow more slowly than commercial hybrid chickens (Panja, 2000), this is still an attractive investment to supplement family income or improve self-reliance. Commonly, the objective of rearing native chickens is for family consumption and therefore the number of birds reared is usually small with no apparent threat to the environment.

In the free range system, feed cost for native chicken rearing is extremely low as the chickens are allowed to scavenge freely. Kajarern *et al.* (1988) conducted a study on native chicken rearing in five districts in northeast Thailand. Daily feed intake was about 22 g/bird/day (the range was 14.8-27.5 g), with a cost of Bt0.775/bird/day. The total feed cost over a fattening period of 16-18 weeks varied between about Bt8 and 9/bird, or Bt7.8 -7.9/kg live weight. Therefore, the economic return for native chickens raised in a feedlot system in a confinement pen was investigated by Loupaibol *et al.* (1999). Production costs (excluding labor cost and depreciation cost of the housing) of the rearing unit at Khon Kaen University, Hin Tang Village and None Sawan Village were 36.49±0.78, 42.89±4.53 and 43.46±4.98 baht per kg live weight, respectively. Feed costs were 77.42%, 74.63 and 74.00%, respectively while the cost of day-old chicks was 21.27%, 24.15% and 24.76 %, respectively.

The economic return of native chickens on a research station by feeding them *ad libitum* with commercial layer feed was studied. Selling chickens at 16 weeks (1,362 g/bird) gave the highest benefit (Bt12.98/bird); loss was incurred if the chickens were sold at 8 weeks (Bt-5.02/bird) when the selling price was Bt45/kg live weight. The study also found that 2-line crossbreeds (native chicken and Rhode Island Red) which were fed with the same diet reached the same marketable size earlier in 12 weeks (1,395 g/bird). For chickens over 1.5 kg, the crossbreed native chickens were fed with broiler commercial feed mixed with rice bran at the ratio of 50:50; they reached their weight in 16 weeks, therefore giving the highest profit per bird**.** Nevertheless, a 2-line crossbreed (native chicken and Rhode Island Red) could reach marketable size at 8 weeks when it received the commercial diet for broilers, layers and mixed feed (50% commercial broiler diet and 50% fine rice bran) (Leotaragul and Pimkamlai, 1999).

Improved rearing systems reduced feed cost as feed utilization efficiency was enhanced. For instance, Chichi *et al.* (1998a) found that rearing 4-line crossbreeds in pens and free-range had no significant difference in growth, but feed utilization efficiency in the pen was better so feed cost was lower. Four-line crossbreeds fed with 18% dietary protein had the lowest feed cost per kg body weight gain. The total feed costs at 2-14 and 2-16 weeks were Bt26.23 and Bt27.63/kg. However, extending the rearing period from 14 to 16 weeks, feed cost increased by Bt1.30/kg, except for the 4-line crossbreeds (fed with 18% and 11% dietary protein for 2-8 weeks and 8-16 weeks, respectively); raised in the feedlot system, feed cost per body weight gain increase decreased at a rate of Bt0.76/kg.

Using local feed resources reduces feed cost for crossbreed rearing. Purintrapiban (2004) aimed to reduce feed cost for 3-line crossbreeds by using palm kernel cake at different feed levels. The study found that supplementary palm kernel cake could reduce feed cost per kilogram of body weight increasing at a rate of 14.19, 13.2 and 13.26% when compared with soybean meal in the rations, with no effects on growth, feed intake and feed utilization.

2.16.3 Problems and constraints

In Thailand, native chicken production has been developing for over 30 years since the 5th National Economic and Development Planning Program in 1977. Currently, the total number of native chickens varies between 100-120 million birds (Chantalakhana and Skunmun, 2002). Six million households raise native chickens with an approximate value of Bt5,000-7,000 million[2] (Satyawadhana, 2003). Ninety percent of these birds – and their eggs – are for household consumption. It is estimated that in future, the value will increase to Bt9,000-10,000 million, with medium-scale farmers tending to raise more crossbreeds with native chickens (Choprakarn, 2003). In northeastern Thailand, the number of native chickens per household is very low, i.e. less than 30 birds. Only 5-10 birds are for household consumption; around 10-20 birds are for sale. The return from the sale of chickens is only Bt300 (€6.3) per year or less than 1 baht per day. Home consumption is also very low and thus does not contribute significantly to human nutrition in the region (RDI/KKU, 1989).

However, rearing native chickens has been overlooked as this is non market-oriented production and the number per household is so small. However, daily village life depends on these chicken when quick cash or an instant source of meat for food is needed. Village chicken raising has not received sufficient attention from government extension service programs. State technical and husbandry services have never reached chickens in villages, mainly because village people lack bargaining power, economically and politically. Furthermore social and economic incentives for government officers are also lacking. At the same time, village people generally do not seek these services because they have been living without them for all of their lives. There are two major constraints to native chicken rearing: 1) high mortality rate due to infectious diseases; 2) low productivity. Problems in chicken rearing confronting farmers in villages can be summarized as: a) the loss of chickens due to infectious disease is around 50-70%; b) the outbreak of diseases may not occur again in the same village in the next year; it is a rather uncertain event; 3) most farmers do not know about vaccines, and do not appreciate vaccination until there is a disease outbreak; 4) technical information, especially vaccination against diseases, does not reach farmers effectively; 5) it is too troublesome and uneconomical for an individual farmer to vaccinate his chickens due to village remoteness, lack of cold storage and insufficient number of chickens; 6) most farmers do not know standard practices for disease control, hence, disease can spread rather quickly; 7)

[2] Bt48 = €1.00 (April 2006)

available chicken feed or feedstuffs are generally of low quality – improvement in this aspect is not economically feasible; 8) most farmers produce their own chicken stocks (more than 70%) which reduce the chance for new introductions, and consequently induce inbreeding in the flock, resulting in regressed performance; 9) the extension of husbandry services to villagers is rather difficult due to poor farmer organization (Chantalakhana and Skunmun, 2002).

Nevertheless, native chickens are still a minor component in the typical small-holder farming system. Farmers' priorities are rice cultivation, rain-fed field crops and livestock rearing such as beef cattle and buffaloes, and paid external labor. On-farm labor constraints are the major problem for chicken rearing in the village, especially during the cropping season. Farmers do not manage their time and labor efficiently, especially during peak labor-demand periods. A major problem with improvement of chicken rearing is the lack of cash to buy vaccines, chicken feed, etc. The improvement of native chicken rearing should focus on simple and low-cost technology that helps the farmers to improve their self-reliance. Improved advisory services should be comprehensive, including all aspects of chicken rearing, e.g. farm-level breed improvement, vaccination, feeding, construction of simple chicken housing and marketing techniques. This would help the farmers to develop a more positive attitude towards native chicken rearing, eventually enhancing productivity and output from chicken rearing (Rattanawaraha, 1988).

2.16.4 Improvement potential for native chicken rearing

Although village chicken productivity is lower in relation to commercial chicken rearing, village chickens are a household resource which villagers can utilize effectively. The sustainability of native chicken rearing is also higher in terms of the adaptation of the chickens to poor feed resources and their disease resistance. Currently, flock management by farmers is already appropriate, and improvements should emphasize disease prevention and reduction of the mortality of chicks (Palarak, 1985). RDI/KKU (1989) recommended that improvement of native chicken production should first focus on increasing household consumption rather than commercial rearing.

There should be a promotion strategy to convince farmers to participate in vaccination programs to prevent chicken disease outbreaks, e.g. Newcastle (Palarak, 1985). Attempts have been made to improve vaccination for native chickens at the village level. A study found that there were three factors affecting adoption by farmers: (1) because native chickens have a high general resistance to diseases, farmers felt it was unnecessary to vaccinate their chickens; (2) the usually small flocks of chickens make them less important to the household in economic terms and therefore the farmer does not consider it worthwhile to vaccinate; and (3) vaccines are often difficult to obtain and are definitely not available at the village level. It was suggested that improved availability of vaccines in the village may help promote the use of vaccines for disease prevention (Ratanapanya *et al.*, 1989). Consequently, the DLD played a major role in instructing veterinary personnel about the integration of women in poultry raising through a project conducted in the northeast by the Thai-German project "NERVRDC/TG-AHP". The project aimed to improve poultry health and production in villages by introducing simple, inexpensive housing and feeding technology combined with vaccination and de-worming as preventive measures. This service is offered to farmers by selected and trained village keymen (KM) who must be male due to traditional beliefs that women cannot handle large animals like buffalo and cattle. Chicken rearing seems to fit with this prevailing social attitude concerning women, as chicks are small, easy to handle and are kept near the house. But as this poultry project is supervised by KM, their customers are mainly men with little interest in the nutritional aspects of poultry rearing. A study found that fewer women participated in native chicken rearing, but it was noticed that women were more enthusiastic and cooperative compared to men; moreover, women can monitor their own chicks very well, despite their poor literacy. But native chicken rearing is not exclusively a women's approach as interest relies upon an individual enthusiast or family situation (Polpak *et al.*, 1992). A program is needed to improve native chicken raising through better dissemination of information on chicken raising, emphasize support to village-level interest groups of farmers, establish native chicken markets in all provinces and conserve native chicken species. Although native chicken meat is popular among Thais, the chickens are not produced on a large commercial scale because they take longer to grow and provide less meat than commercially raised broiler chickens (Porn-Amart, 2003).

2.16.5 Sustainable agriculture and livestock development

The concept of sustainable agriculture originated from the fact that serious concerns for the survival of future human generations have received greater attention during the past decades, as environmental degradation, pollution and resource depletion have been on the rise juxtaposed by human population growth and demand for food. The concept of sustainable agriculture not only provides guidelines for agricultural research but also development, including related socioeconomic, political and administrative aspects. In Thailand, various agricultural systems such as natural farming, organic farming, NISA (no-input sustainable agriculture), LISA (low-input sustainable agriculture), integrated farming systems, new royally-initiated farming systems (self-sufficiency economy), and others, have been reported within the context of sustainable agriculture. All of these technologies are based on low external input use of locally available resources, less dependence on use of chemicals, minimum generation of pollution and conservation of the environment. Sustainable agriculture systems primarily emphasize the concept of self sufficiency for farm economy, while maximum productivity is not an absolute requirement. The concept of sustainable agriculture aims at *optimum production* with efficient use of external inputs as well as locally available or lower cost or renewable inputs. Where soil is poor, sustainable agriculture needs inputs such as chemical fertilizer, organic matter, humus, manure, and green manure. Some other examples of sustainable agricultural technology are IPM (Integrated Pest

Management), DAP (draught animal power), alley farming, agro-forestry, biogas production, utilization of wastes and byproducts as animal feed or fertilizer (Chantalakhana and Skunmun, 2002).

Small-scale farmers in the rural areas are mostly people who are relatively poor. They are commonly deficient in basic knowledge and technical information, capital and credits, economic and political bargaining power, access to markets and necessary production inputs. They are highly disadvantaged being unable to upgrade or modify their traditional farming practices based on the strength of their existing knowledge. Animals provide a vital role in food production and for services; they can be secondary to the roles several species play for cultural needs. Animals provide a form of savings: poultry provide a short-term current savings account for daily small cash needs. Pigs or small non-ruminant animals serve as medium-term or semi-annual accounts to pay for relatively larger expenses such as clothes or educational needs for children. Large ruminants such as cattle and buffaloes serve as a long-term savings or permanent savings account to provide bigger amounts of cash for very important family needs e.g. purchase of land or a small tractor, expenses for children's marriage or significant religious events. It is very common for village farmers to raise simultaneously backyard poultry, especially chickens and ducks, some pigs or small ruminants such as sheep and/or goats, and a few draught cattle and buffalo in the same household in order to meet multipurpose socioeconomic needs (Chatalakhana and Skunmun, 2002).

2.16.6 Genetic conservation and improvement of native chickens

During the past three decades, it is important to note the increasing trend of commercialization especially in poultry production. Many indigenous poultry breeds have disappeared from the production system. Some indigenous chicken breeds or strains have already become extinct, while other local chicken strains can only be found in villages and are in danger of extinction in the future. Most of these indigenous chickens are well adapted to local environments and widespread diseases and parasites. These genetic qualities are very valuable for future use. However, it has been observed that modern animal production in which a very narrow genetic base of exotic breeds is produced within a controlled environment has dominated a certain area of animal production and destroyed animal biodiversity in developing countries. Scientists in developing countries should slow down or stop the destruction of animal genetic resources. Some genetic resources such as the indigenous chicken can be maintained *in situ* through the promotion of village chicken production as in many countries these chickens receive higher prices than commercial broilers. Despite the fact that native chickens play a significant role in rural household economies, scientists have not paid much attention to the improvement of village chicken production, while almost all poultry scientists in developing countries are mainly concerned with modern large-scale poultry enterprises. There is a need for scientists to work in the area of production and conservation of native chickens, not only to preserve animal biodiversity but also to protect some of these breeds from extinction generated by crossbreeding with introduced exotic breeds (Chatalakhana and Skunmun, 2002; Phalarak, 2001).

3 METHODOLOGY

3.1 Breeds and sources of chickens

The experiments were conducted to evaluate performance traits of various breeds of chicken on the following characteristics: body weight, weight gain, feed consumption, feed conversion efficiency, mortality and carcass quality. Four different types of chicken were tested. A: Commercial hybrid; B: 3-lines crossbreed; C: 4-lines crossbreed; D: Native chicken. ***Commercial hybrids:*** the day-old chicks were obtained from Centaco Company Ltd, Pathumthani Province. The hybrid from the Centaco Company is representative for the hybrids widely on the market. ***Three-line crossbreed***: the day-old chicks were obtained from Kaset Farm Company Ltd., Samut Songkhram Province. It was a crossbreed between native chicken (50%), Rhode Island Red (25%), and Barred Plymouth Rock (25%) ***Four-line crossbreed*****:** The day-old chicks were obtained from Kaset Farm Company Ltd., Samut Songkhram Province. **T**he of four-lines crossbreed used in experiment consisted of Rhode Island Red (12.5%), Barred Plymouth Rock (12.5%), Shanghais (25%) and native chicken (50%). ***Native chicken*****:** The days-old chicks were obtained from the Faculty of Agriculture, Kasetsart University, Bangkok.

3.2 Experimental design

The experiments were arranged in a complete randomized design (CRD). There were two experiments.

3.2.1 Experiment 1 There were three breeds (treatments) with two replicates (Figure 3.1). A: Commercial hybrid; B: 3-lines crossbreed; C: 4-lines crossbreed. The treatments in experiment 1 received feeding system 1 (commercial dietary feed for broilers) throughout the growing stages.

3.2.) Experiment 2 there were the 4 breeds (treatments) (Figure 3.2). A: Commercial hybrid, B: 3-lines crossbreed, C: 4-lines crossbreed, D: Native chicken.
The treatments A, B and C had 1 replicate; treatment D had 3 replicates. The growing period varied depending on the marketable weights specific to the each breed. The growing period for treatment A, B, C, and D were 7, 12, 12 and 20 weeks, respectively. The treatments in experiment 2 received formulated feed in the research station.

Pen no.	1	2	3	4	5	6
Exp. Unit	A1	C2	A2	B1	C1	B2

Figure 3.1 Design of experiment 1

Pen no.	1	2	3	4	5	6
Exp. Unit	A3	D2	C3	D1	B3	D3

Figure 3.2 Design of experiment 2

3.3 Site and period of study

The experiments were conducted on the Agricultural Research Farm of the Asian Institute of Technology. Experiment 2 was conducted during February to May 2003; experiment 2 from July to November 2003.

3.4 Housing management

The chicken house was divided into 6 units (pens) of 5.625 m^2 (2.25m x 2.50m). The pens were completely enclosed by steel netting (2.5 cm wire mesh). The floor was made of bamboo slats with diameters between 2.5 – 3.5 cm and gaps between the slats of 0.5 –1.5 cm. The floor was covered nylon net mesh with 2.5 cm mesh size. This allowed chicken manure to pass through and accumulate underneath for collection. In the experiment, plastic sheet lining was used to receive the manure. Electric lights supplemented natural light during the night, which was quite uniform during the experimental period. Against wind and rainfall, the chicken house was protected from all directions with blue plastic sheeting. The sheeting was lowered into place at 17:00 hours every day, and opened in the morning at 07:30 hours, except for windy or rainy days. The temperature was controlled by electrical fans that operated when the temperature rose above 32 °C. On a normal day, this was the case between 11:00 and 17:00 hours. A washing room was available in the chicken house, next to the pens, for the cleaning of all equipment, e.g. feeding tray, racks, water bottles, etc. Tap water was used in the experiment. Feed was stored in a separate room in the chicken house.

3.5 Stocking and chick rearing

Two weeks prior to stocking, the housing was sprayed with disinfectants and the ground below and surrounding the housing was limed. Feet dipping was done during the stocking of the pens. Each pen (experimental unit) was stocked with 51 mixed sex one-day-old chicks. The stocking density was 9.28 chicks per m^2. They were brooded in plywood boxes of one m^2 with a height of 0.45 m. For each pen there was one brooding box. The inside the box was divided to 2 chambers to provide a warm room and a cool room. The brooding chicks could access each chamber freely through a hole in the partition. A layer of about 5 cm of rice husk was placed inside the boxes as insulation and filter material. One of the chambers was provided with an electrical lamp (100W), which was placed about 15-20 cm above the floor. Feeding and watering devises were placed inside the other chamber for easy and unlimited access to feed and water. At 7 days, all chicks were wing-band tagged and weighed for the first time (initial weight). The number of chicks was then reduced to 50 chicks per pen (i.e. stocking density of 8.9 birds per m^2). Chicken tagging was done in order to enable the monitoring of each individual chicken throughout the growing period. During the three weeks of brooding, continuous lighting was provided for 2 weeks, thereafter lighting was only provided at night. At the end of week 3, the brooding boxes were removed. For treatment A, the boxes were emoved after 2 weeks because of the fast development of the chicks (hybrid broilers). During the period of brooding, the chicks were vaccinated according to the recommendations of the Department of Livestock Development (DLD) and de-beaked with an electric de-beaker at 10 days after stocking.

3.6 Feed and feeding management

Feed and feeding was similar in all experimental units (pens) of the same experiment. The chickens were fed *ad libitum* over the entire growing period. They were encouraged to feed as much as possible throughout the day and the night. Feeding frequency was 2 times a day in the morning (08:00 h) and in the afternoon (16:30 h). During the first 3 weeks, the chicks were fed 3-4 times a day. The amount of feed remaining in the morning and afternoon was monitored in order to increase or to reduce the quantity for the next day. The watering devices were cleaned and refilled twice a day. Vitamins and minerals were provided through the drinking water for 3 weeks. Two types of feed were tested, i.e. ‘feeding system 1’ for experiment 1 and ’feeding system 2’ for experiment 2.

3.6.1 Types of feed

A – Feeding system 1: Feeding system 1 was commercial feed for broilers normally available in the market in pelleted form. Three different rations were fed, depending on the growth stages of chicken. During the first stage (0-3 weeks), the feeds contained 21% crude protein. For the second stage (4-6 weeks), the protein content was decreased to 19%. During the third stage (over 6 weeks) the crude protein content was 17%. Table 3.1 gives details of the feed composition of the commercial feed.

B – Feeding system 2: Feeding system 2 was composed for the experiments. It contained maize as a typical on-farm available feed and mixed with commercial feed for broiler. The composition of the feed varied depending on the growth stage.. The maize was purchased as whole grain and grinding was done at the experimental site with a small grinding machine. For the first growing stage the maize was ground twice to obtain a finer maize meal. From week 6 onwards, the grains were only broken (4-5 pieces per grain). The ground maize then mixed with commercial fed for broiler at different ratio as show in table 3.2. Feed was prepared weekly.

Table 3.1 Formulation of feeding system 2 (*: By weight)

Feed characteristics	Mixing proportion*		
	0-3 weeks	4-5 weeks	6 weeks up
Commercial broiler feed (%)	70	50	30
Ground maize (%)	30	50	70
Total (%)	100	100	100

3.6.2 Nutrient composition of the feeds used in the experiments

Nutrient compositions of the experimental feed in feeding system 1 and feeding system 2 were analyzed using the standard method of proximate analysis. The results are presented in table 3.2. Feeding system 1, the three diets consisted of combinations of protein (% of DM) to gross energy (Kcal/kg) of 20.8:3649, 18.9:3441 and 17.2: 3608, with E:P ratios of 175.43, 182.06 and 209.76 Kcal/g protein. The three growing stages receiving different diet compositions were the periods of 0-3, 4-6 and 6-12 weeks. The feeding system was formulated and manufactured by a commercial feed-mill according to standard nutrient requirements for hybrid broilers.

Feeding system 2 The nutrient composition was lower than for the commercial diet. There were three levels of crude protein (% of DM): gross energy (Kcal/kg) combinations, i.e. 17.1:3680, 15.2:3623 and 2.7:3636 with E:P ratios of 215.29, 238.35 and 290.88 Kcal/g protein, respectively. Feeding system 2 was fed to the chicken for the same periods as feeding system 1.

Feeding system 1 consisted of different dietary protein levels of 21%, 19% and 17% and feeding system 2 consisted of 17%, 15% and 12 % dietary protein for the growing stages of 0-3 weeks, 4-6 weeks and 7 weeks onwards until slaughter weight was reached. For feeding system 1, the feed analysis showed that each ration contained crude protein (CP) (% of DM) and gross energy (GE) (Kcal GE/kg) of 20.8:3649, 18.9:3441and 17.2:3608; with energy: protein ratios (E:P) of 175.43, 182.06 and 209.76 Kcal/g protein, respectively. Feed system 1 was formulated and manufactured by a commercial feed-mill according to hybrid broiler requirements. Feeding system 2 contained crude proteins (% of DM): gross energy (Kcal GE/kg) of 17.1:3680, 15.2:3623, 12.7:3636, and E: P ratios of 215.29, 238.35 and 290.88 Kcal/g protein. According to the nutrient requirement of broilers standardized by NRC (1994) for the growing stages of 0-3 weeks, 3-6 weeks and 6-8 weeks, the dietary protein requirement was 23%, 20% and 18%, respectively, with 3200 Kcal ME/kg feed for all growing stages.

Table 3.2 Nutrient composition of the feeds used in the experiments (feeding system 1 and feeding system 2)

Nutrients	Feed system 1 and Growth stages			Feeding system 2 and Growth stages				
	0-3 wk	4-6 wk	7 –12 wk	0-3 wk Feed 1io	4-6 wk feed 2	7 –20 Feed 3[1]	Maize	Commercial feed
Moisture (%)	9.6	11.7	8.0	8.9	10.0	9.4	11.2	9.5
Dry matter (DM) (%)	90.4	89.3	92.0	91.1	90.0	90.6	88.8	89.5
Crude protein (CP) (% of DM)	20.8	18.9	17.2	17.1	15.2	12.5	7.8	21.4
Ether extracted (EE) (% of DM)	4.7	3.4	5.8	3.9	3.3	3.8	3.0	4.9
Crude fiber (CF) (% of DM)	4.8	6.1	6.9	4.3	4.1	5.2	5.7	4.3
Nitrogen Free Extracted (NFE) (% of DM)	53.6	53.8	54.8	61	63.4	66.2	71.0	52.0
Ash (% of DM)	6.5	7.1	7.3	4.8	4.0	3.0	1.3	6.9
Calcium (Ca) (% of DM)	1.1	0.8	1.2	0.8	0.6	0.5	0.02	1.3
Phosphorus (P) (% of DM)	0.5	0.4	0.4	0.4	0.3	0.4	0.3	0.5
Gross Energy (GE) (kcal/kg)[2]	3649	3441	3608	3680	3623	3636	3516	3634
Energy (E):Protein (P) ratio (Kcal/g protein)	175.43	182.06	209.76	215.20	238.35	290.88		

Kcal=Kilocalories; Kg= Kilogram; g= gram; wk = week.

[1]: Including fattening stages of native chicken from 13 to 20 weeks.

[2]: by calculating with basic a factor of energy from nutrients, Crude protein = 5.2 Kcal/g, Crude lipid = 9.0 Kcal/g, Carbohydrate= 4.0 Kcal/g.

3.7 Vaccination program

The chickens were vaccinated following the schedule shown in table 3.3. The vaccination program developed based on Chinrasri (2004)[1] and Kaset Farm (2004)[2]

Table 3.3 Vaccination schedule

Vaccines	Age of chickens (days)	Method of vaccination
Newcastle and Infectious Bronchitis vaccine [1]	5	Dropping
Gumboro vaccine [1]	10	Dropping
Fowl pox vaccine [2, 3]	21	Wing web
Fowl Cholera vaccine [2, 3]	30	Intramuscular injection

Note: [2] for native chickens and native crossbreeds only

3.8 Data collection

Determination of body weight

Body weight (BW) of each individual chicken was monitored from initial stocking to the day of slaughter following the sampling program shown in table 3.4. As a routine, the weighing started at 15:00 h. from pen no 1 to pen no 6. Before weighing, feeding was stopped around 10:00 h. Weighing was done with a digital balance with a resolution of 1 g.

Determination of feed intake

Feed intake (FI) was measured at the same times as the body weight (see table 3.4). From the feed intake (FI), the feed conversion ratio (FCR) and feed conversion efficiency (FCE) were determined.

Sex identification

For each chicken the sex was identified on the final day of weighing by external characteristics, such as comb, feather color and body shape.

Mortality

Mortality was recorded. The dead birds were weighed and the primary symptoms diagnosed to identify the cause of death. The dead birds were not included for calculating the feed consumption, feed conversion ratio, and other growth performance indicators, e.g. weight gain and average daily gain.

Table 3.4 Program of measurements of body weight, feed intake and carcass sample

Treatments	Parameter traits	Growing Stages (weeks)																				
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	Body weight	✓	✓		✓		✓		✓													
	Feed intake		✓		✓		✓		✓													
	Carcass sample								✓													
B	Body weight	✓	✓		✓		✓		✓		✓		✓	✓								
	Feed intake		✓		✓		✓		✓		✓		✓	✓								
	Carcass sample													✓								
C	Body weight	✓	✓		✓		✓		✓		✓		✓	✓								
	Feed intake		✓		✓		✓		✓		✓		✓	✓								
	Carcass sample													✓								
D	Body weight	✓	✓		✓		✓		✓		✓		✓		✓		✓			✓		✓
	Feed intake		✓		✓		✓		✓		✓		✓		✓		✓			✓		✓
	Carcass sample																					✓

Determination of carcass quality

At slaughtering, sample birds were processed to determine the carcass quality. Depending on the type of chicken and the marketable body weight, the slaughtering ages were 7 weeks (commercial hybrid), 12 weeks (3-lines and 4-lines crossbreeds) and 20 weeks (native chicken). After the final weighing (evening before slaughtering), the chickens were not fed for at least 12 hours before slaughtering. From each experimental unit (pen), three males and three females were randomly selected. All samples were weighed, slaughtered and allowed to bleed out. The slaughtered chickens were weighed again and then scalded in hot water (about 70°C) for 1-2 minutes so that the feathers could be easily removed. The washed and de-feathered chickens were weighed again before eviscerating the gut and the other internal organs. The chickens then remaining were called "total carcass". From the total carcass, the legs (thigh and shank), the head and neck were then removed. The remaining body was called "dressed carcass". The gut system and the other internal organs (visceral organs) were also weighed and then separated. Then, liver, gizzard, heart, spleen, intestine, and the abdominal fat pad were weighed separately. The dressed carcasses were separated into the different 'marketable' parts (cut up), i.e. back, drumstick, thigh, total wing (wing stick, tulip wing and end of wing. From each part the skin was removed, and meat, bone and fat separated and separately weighed.

3.9 Laboratory tests

Samples of the feed and feed ingredients were analyzed for nutrient composition using the standard proximate analysis techniques (Association of Official Analytical Chemist: AOAC, 1994). The parameters measured (see tables 3.1 and 3.2) were dry matter (DM), moisture contents, crude protein (CP), Ether-extracted crude lipid (EE), crude fiber (CF), nitrogen free extract (NFE), ash, calcium (Ca) and phosphorus (P). The results were expressed on a dry-weight basis (% of DM). Gross energy was calculated from the energy content in the nutrients, i.e. 5.2 cal/g of CP, 9 cal/g Crude Lipid and 4 cal/g of NFE.

3.10 Data analysis

Data processing and analysis

The computer software used for the data analysis was SPSS, version 11. All data – from stocking to slaughtering– were tabulated and arranged by tag number, so that the development of each chicken and its growth performance could be followed individually. Chickens that died during the experiment were excluded from the dataset. From each pen (experimental unit), a random sample of 36 chickens (18 males and 18 females) –72% of the flock of each pen– was used for data analysis.

The general statistical test used was means comparison by the least significant difference (LSD) method, with $p \leq 0.01$. For the growth performance, feed utilization performance and carcass quality assessment, an analysis through the models for trait performance was done.

Growth performance

The following general model (*Model 1*) was used to identify the effects of breed and sex on the dependent variables in each experiment.

Model 1: $Y_{ijk} = \mu + B_i + S_j + R_k + BS_{ij} + e_{ijk}$

Where:

Y_{ijk} = Observation value
μ = Overall mean
B_i = Effect of breed (i = A, B and C for experiment 1; A, B, C and D for experiment 2)
S_j = Effect of sex (j = male and female)
R_k = Effect of replicates (k = 1,2,3,…,36)
BS_{ij} = Effect of interaction of breed and sex
e_{ijk} = Experimental error

To determine the effects of the feeding system on growth performances the following model (*Model 2*) was applied. There were 3 breeds to compare. The observed values from breed A, B and C were the average of experimental unit by sex and sequenced (A1 and A2; B1 and B2; C1 and C2)

Model 2: $Y_{ijkm} = \mu + F_i + B_j + S_k + R_m + FB_{ij} + FS_{ik} + BS_{jk} + FBS_{ijk} + e_{ijkm}$

Where:

Y_{ijkm} = Observation value
μ = Overall mean of Experiment 1 and 2
F_i = Effect of feed system (i = feed system 1 and feed system 2)
B_j = Effect of breed (j = A, B, C)
S_k = Effect of sex (k= male anf female)
R_m = Effect of replicates (k = 1, 2, 3,…, 36)
FB_{ij} = Effect of interaction of feed system and breed
FS_{ik} = Effect of interaction of feed system and sex
BS_{jk} = Effect of interaction of breed and sex
FBS_{ijk} = Effect of interaction of feed system, breed and sex
e_{ijkm} = Experimental error

Growth analysis prediction model

Following Tzeng and Bercker (1981; cited by Aggrey, 2002), a polynomial regression model was used to fit the growth data. Polynomials have greater flexibility than simple regressions because they can encompass data that exhibit behavior in one region that may be unrelated to behavior of another region (Aggrey, 2002).

Feeding utilization performance

Feed consumption was recorded as feed input and remaining feed at the final day of monitoring. Total feed intake per pen and per period were computed throughout the growing stages. Feed intake per bird per day was computed by total feed intake divided by the number of chickens and the total days for each stage.
Analysis of Variance was done to test the breed performance for each feeding system. Statistical analysis used *Model 3.*

Model 3: $Y_{ij} = \mu + B_i + R_j + e_{ij}$

Where:

Y_{ij}	=	Observation value
μ	=	Overall mean
B_i	=	Effect of breed (i = A, B and C for experiment 1; A, B, C and D for experiment 2)
R_j	=	Effect of replicates (j = 1, 2)
e_{ij}	=	Experimental error

To test the influence of the feed system and breed on feeding performance, the general *Model 4* was used.

Model 4: $Y_{ijk} = \mu + F_i + Bj + R_k + FB_{ij} + e_{ijk}$

Whereas:

Y_{ijk}	=	Observation value
μ	=	Overall mean of Experiment 1 and 2
F_i	=	Effect of feed system (i = 1, 2)
B_j	=	Effect of breed (j = A, B and C)
R_k	=	Effect of replicates (k = 1,2)
FB_{ij}	=	Effect of interaction of feed system and breed
e_{ijk}	=	Experimental error

Carcass quality

To test the influence of breed and sex on carcass quality, the general *Model 5* used for all experiments.

Model 5: $Y_{ijk} = \mu + B_i + Sj + R_k + BS_{ij} + e_{ijk}$

Whereas:

Y_{ijk}	=	Observation value
μ	=	Overall mean
B_i	=	Effect of breed (i = A, B and C for experiment 1; A, B, C and D for experiment 2)
S_j	=	Effect of sex (j = male and female)
R_k	=	Effect of replicates (k = 1, 2 and 3)
BS_{ij}	=	Effect of interaction of breed and sex
e_{ijk}	=	Experimental error

Effect of feeding system

To determine the effects of the feeding system on carcass performance the following model (*Model 6*) was applied. There were 3 breeds to compare. The observed values from breed A, B and C were the average of experimental unit by sex and sequenced (A1 and A2; B1 and B2; C1 and C2)

Model 6: $Y_{ijkm} = \mu + F_i + B_j + S_k + R_m + FB_{ij} + FS_{ik} + BS_{jk} + FBS_{ijk} + e_{ijkm}$

Where:

Y_{ijkm}	=	Observation value
μ	=	Overall mean of Experiment 1 and 2
F_i	=	Effect of feed system (i = feed system 1 and feed system 2)
B_j	=	Effect of breed (j = A, B, C)
S_k	=	Effect of sex (k= male and female)
R_m	=	Effect of replicates (k = 1, 2, 3)
FB_{ij}	=	Effect of interaction of feed system and breed
FS_{ik}	=	Effect of interaction of feed system and sex
BS_{jk}	=	Effect of interaction of breed and sex
FBS_{ijk}	=	Effect of interaction of feed system, breed and sex
e_{ijkm}	=	Experimental error

4 RESULTS

4.1 Feeding system 1: Commercial feed

4.1.1 Growth performance of the chickens

The results of the analysis of the growth performance of the three breeds of chicken fed with feeding system 1 using statistical *Model 1* is shown in Table 4.1. During the first 7 weeks of the growing period, all three types of chicken grew significantly different ($p \leq 0.01$); i.e. the average body weight of the hybrid broiler chicken, 3-line and 4-line crossbreeds were 2506, 659 and 779 g per bird, respectively. The 4-line crossbreed clearly showed significantly higher weight gains ($p \leq 0.01$) than the 3-line crossbreed for the entire growing period (0-12 weeks), i.e. mean weight gains were 1486.64 and 1334.78g per bird, respectively. During the weeks 3-5 and 5-7, the weight gains between 3-line and 4-line crossbreeds were slightly different and the differences were not significant ($p > 0.01$). However, the trend of weight gain of the 4-line crossbreed was higher. The sex of the chicken influenced the weight gain for all breeds. From the age of one week onwards, males had a higher body weight than females for all growth stages ($p \leq 0.01$). The interaction between breed and sex had an effect on the growth of chicken during first 0-7 weeks ($p \leq 0.01$). The females of the hybrid broilers grew faster than both sexes of the crossbreeds. There was no interaction between breed and sex on the growth rate of the two crossbreeds ($p \leq 0.01$)

The average daily weight gain (ADG) –a parameter, which indicated the rate of daily growth of individual chickens–, was related to weight gain. The results of the analysis of ADG using statistical *Model 1* are presented in Table 4.2. During the first week, the growth rates of the 3-line and 4-line crossbreeds were extremely low at the rate of 3.88 g and 6.03 g per bird per day, respectively. During the same period, the growth rate of the hybrid broilers was 20.80 g per bird per day ($p \leq 0.01$). The hybrid broilers had significantly better growth performance than the other 2 types during the first 7 weeks after the hybrid broilers reached slaughter weight ($p \leq 0.01$) with an overall ADG of 51.15 g per bird per day. The highest growth rate of hybrid broilers was found during the period 3rd-5th week, reaching 65.00 g per bird per day. For the overall growing period (0-12 weeks), the 3-line crossbreeds had a growth rate of 15.89 g per bird per day which was considerably lower than the 4-line crossbreeds (17 g per bird per day) ($p \leq 0.01$). The highest ADG of the 3-line and 4-line crossbreeds was found during week 5-7 at the rates of 20.38 and 22.83 g per bird per day, respectively. As expected, the ADG of the males –from week 1 onwards– was higher than the ADG of the females. The interaction between breed and sex had an effect on weight gain of the chickens during the first 7 weeks ($p \leq 0.01$).

Table 4.1 Weight gain of chickens by breeds and sexes at each growth stage, feeding system 1

Growth Stage (week)	Breed of Chicken			Sex		Significance level		
	Hybrid[1]	3-Line Crossbreeds	4-Line Crossbreeds	Males	Females	B	S	B x S
	Weight gains g/bird ±SD			Weight gains g/bird ±SD				
0-1	145.6 ± 20.00^{A}	27.18 ± 9.04^{C}	42.22 ± 9.76^{B}	73.47 ± 56.41	69.86 ± 52.79	**	ns	ns
2-3	629.86 ± 69.26^{A}	143.76 ± 16.2^{C}	173.53 ± 23.73^{B}	327.41 ± 230.78^{A}	304.02 ± 223.84^{B}	**	**	ns
4-5	910.04 ± 180.71^{A}	233.28 ± 45.67^{B}	284.39 ± 57.82^{B}	511.77 ± 360.51^{A}	416.04 ± 302.74^{B}	**	**	**
6-7	820.97 ± 302.86^{A}	285.28 ± 60.86^{B}	319.58 ± 61.63^{B}	549.44 ± 335.41^{A}	401.11 ± 251.51^{B}	**	**	**
8-9		281.11 ± 77.92^{b}	303.19 ± 75.28^{a}	337.36 ± 60.42^{A}	246.94 ± 64.73^{B}	*	**	ns
10-11		251.04 ± 71.09^{b}	274.58 ± 71.13^{a}	305.00 ± 65.18^{A}	220.61 ± 51.77^{B}	*	**	ns
12		113.13 ± 24.56^{B}	125.14 ± 34.03^{A}	131.67 ± 23.91^{A}	106.60 ± 30.72^{B}	**	**	ns
0-7	2506.38 ± 347.42^{A}	659.92 ± 99.93^{C}	779.49 ± 115.84^{B}	1450.57 ± 939.78^{A}	1179.95 ± 782.59^{B}	**	**	**
8-12		645.27 ± 133.83^{B}	702.92 ± 139.30^{A}	774.03 ± 98.52^{A}	574.17 ± 95.09^{B}	**	**	ns
6-12		930.56 ± 173.34^{B}	1022.50 ± 181.49^{A}	1113.47 ± 116.69^{A}	839.58 ± 124.98^{B}	**	**	ns
0-12		1334.78 ± 209.07^{B}	1486.64 ± 233.73^{A}	1588.21 ± 152.04^{A}	1233.71 ± 151.70^{B}	**	**	ns

g: Gram; B : Breed; S: Sex
[1]: hybrids reached slaughter weight at 7 weeks
Different letters within growth stage (same row) show significant differences between types and sex of chicken at the 0.05 level (*, with a, b, c) and at the 0.01 level (**, with A, B, C), ^{ns}: Non-significant difference at the 0.01 level

Table 4.2 Average Daily Gain (ADG) of chickens at each growth stage by breeds and sexes, feeding system 1

Growth Stage (week)	Breed of Chicken			Sex		Significance level		
	Hybrid[1]	3-Line Crossbreeds	4-Line Crossbreeds	Males	Females	B	S	B x S
	Weight gains g/bird ±SD			Weight gains g/bird ±SD				
0-1	20.80 ± 2.86^{A}	3.88 ± 1.29^{C}	6.03 ± 1.39^{B}	10.52 ± 8.06	9.97 ± 7.54	**	ns	ns
2-3	44.99 ± 4.95^{A}	10.27 ± 1.16^{C}	12.39 ± 1.70^{B}	23.39 ± 16.48^{A}	21.71 ± 15.99^{B}	**	**	ns
4-5	65.00 ± 12.91^{A}	16.66 ± 3.26^{B}	17.74 ± 4.13^{B}	36.55 ± 25.75^{A}	29.72 ± 21.26^{B}	**	**	**
6-7	58.64 ± 21.63^{A}	20.38 ± 4.35^{B}	22.83 ± 4.40^{B}	39.25 ± 23.96^{A}	28.65 ± 17.96^{B}	**	**	**
8-9		20.08 ± 5.57^{b}	21.66 ± 5.38^{a}	24.10 ± 4.31^{A}	17.64 ± 4.62^{B}	*	**	ns
10-11		17.93 ± 5.08^{b}	19.61 ± 5.15^{a}	21.79 ± 4.66^{A}	15.76 ± 3.70^{B}	*	**	ns
12		16.16 ± 3.51^{B}	17.87 ± 4.86^{A}	18.81 ± 3.42^{A}	15.23 ± 4.39^{B}	**	**	ns
0-7	51.15 ± 7.10^{A}	13.47 ± 2.04^{C}	15.91 ± 2.36^{B}	29.60 ± 19.18^{A}	24.08 ± 15.97^{B}	**	**	**
8-12		18.44 ± 3.82^{B}	20.08 ± 3.98^{A}	22.11 ± 2.81^{A}	16.41 ± 2.72^{B}	**	**	ns
6-12		18.99 ± 3.54^{B}	20.86 ± 3.70^{A}	22.72 ± 2.38^{A}	17.13 ± 2.55^{B}	**	**	ns
0-12		15.89 ± 2.44^{B}	17.70 ± 2.78^{A}	18.91 ± 1.81^{A}	14.68 ± 1.81^{B}	**	**	ns

B: Breed; S: Sex

[1]: hybrids reached slaughter weight at 7 weeks

Different letters within growth stage (same row) show significant differences between types and sex of chicken at the 0.05 level (*, with a, b, c) and at the 0.01 level (**, with A, B, C); [ns]: Non significant at the level of 0.01level

4.1.2 Feed utilization efficiency

Feed intakes of chicken fed with feeding system 1 –analyzed using statistical *Model 3*– are presented in Table 4.3. There were highly significant differences in feed intake among the breeds of chicken from the beginning until the 7th week of the growing period ($p \leq 0.01$). The daily feed intakes of the hybrid broilers, the 3-line and 4–line crossbreeds were 108.03, 31.66 and 35.42 g per bird per day, respectively. Hybrid broilers had a higher rate of feed intake than the crossbreeds chickens ($p \leq 0.01$). Nevertheless, there were no significant differences in the quantities of feed intake among the crossbreed chickens throughout growing period ($p>0.01$). However, the feed intake of the 4-line crossbreeds tended to be higher than that of the 3-line crossbreeds, except during the first week when the 4-line crossbreeds had a higher feed intake than the 3-line crossbreeds ($p \leq 0.05$).

Feed efficiency was expressed as Feed Conversion Ratio (FCR). The analysis was made using statistical *Model 3*. The results are presented in Table 4.4. FCR of all breeds of chicken were significantly different in week 0-1 and week 2-3 ($p \leq 0.01$). Hybrid broilers had the lowest FCR (1.09) with the best of FCR (91.74%) significantly different from the 4-line crossbreeds ($p \leq 0.05$) and also significantly different from 3-line crossbreeds ($p \leq 0.01$). Among the crossbreeds, there were significant differences at the level of $p \leq 0.05$. During the period of 0-7 weeks, the FCR of hybrid broilers, 3-line and 4-line crossbreeds were 1.99, 2.31 and 2.20, respectively, which were not significantly different ($p > 0.01$). During the period of week 7-12 and 0-12, there were no significant differences in FCR among the crossbreeds ($p \leq 0.01$). However, the 4-line crossbreeds gave a slightly lower FCR than the 3-line crossbreeds for all growing stages ($p > 0.01$). It was shown that the 4–line crossbreeds had better feed utilization than the 3-line crossbreeds.

Table 4.3 Feed intake of chickens at each growth stage, feeding system 1

Growth Stage (week)	Breed of Chicken			Significance level
	Hybrid[1]	3-Line Crossbreeds	4-Line Crossbreeds	
	(g/bird/day) ±SD			
0-1	22.31±1.39^{A}	5.15±1.15^{c}	9.48±0.20^{b}	**
2-3	70.87±6.98^{A}	22.59±0.45^{B}	21.38±1.82^{B}	**
4-5	130.17±6.02^{A}	37.57±1.22^{B}	41.63±2.52^{B}	**
6-7	150.98±3.66^{A}	47.46±1.30^{B}	55.06±1.40^{B}	**
8-9		59.03±4.29	63.39±3.03	ns
10-11		66.76±5.32	70.58±1.82	ns
12		76.58±0.01	78.14±1.41	ns
0-7	108.03±6.50^{A}	31.66±0.01^{B}	35.42±1.27^{B}	**
8-12		58.40±4.74	60.56±1.94	ns
0-12		47.08±3.38	49.50±1.67	ns

g: Gram; B: Breed; S: Sex
[1]: hybrids reached slaughter weight at 7 weeks
Different letters within growth stage (same row) show significant differences between types of chicken at the 0.05 level (*, with a, b, c) and at the 0.01 level (**, with A, B, C); ^{ns}: Non significant

Table 4.4 Feed conversion ratio (FCR) of chickens at each growth stage; feeding system 1

Growth Stage (week)	Breed of Chicken			Significance level
	Hybrid[1]	3-Line Crossbreeds	4-Line Crossbreeds	
	(g feed/g live weight) ±SD			
0-1	1.09±0.06^{C}	1.82±0.07^{A}	1.64±0.18^{b}	**
2-3	1.58±0.13^{C}	2.17±0.02^{A}	1.80±0.89^{b}	**
4-5	1.98±0.10	2.32±0.08	2.34±0.13	ns
6-7	2.63±0.62	2.42±0.01	2.48±0.31	ns
8-9		3.04±0.13	2.96±0.06	ns
10-11		3.71±0.04	3.50±0.07	ns
12		4.91±0.20	4.31±0.23	ns
0-7	1.99±0.14	2.31±0.02	2.20±0.04	ns
8-12		3.63±0.08	3.41±0.03	ns
0-12		2.94±0.05	2.78±0.04	ns

g: Gram
[1]: hybrids reached slaughter weight at 7 weeks
Different letters within growth stage (same row) show significant differences between types of chicken at the 0.05 level (*, with a, b, c) and at the 0.01 level (**, with A, B, C); ^{ns}: Non significant at the 0.01 level

4.1.3 Carcass quality

The analyses of variance related to the traits of carcass quality were done using the statistical *Model 5*.

Composition of the total carcass

The results and analyses of the composition of the total carcass for breeds and sex of chicken fed with feeding system 1 are shown in Table 4.5. The results show that the percentages of the total carcass were not affected by breed of chicken ($p>0.01$), but by the sex ($p\leq 0.01$). Male chicken had a higher proportion of total carcass than female chicken. Live weights were highly significantly different ($p\leq 0.01$) by breed and sex. Breed and sex affected the proportion of the dressing carcass. Hybrid broilers had higher percentages of dressing than the crossbreeds ($p\leq 0.01$), whereas among the crossbreeds the differences were not significant ($p>0.01$). Percentages of meat, skin, bone and total fat of hybrid broilers were greater higher than of the crossbreeds ($p\leq 0.01$) while there were no significant differences among the crossbreeds ($p>0.01$). The percentages of meat and skin were not significantly different between males and females ($p>0.01$). However, male chickens had higher percentages of bone than female chickens ($p\leq 0.05$) but less total fat than females ($p\leq 0.01$). The interaction between breed and sex had only an effect on the skin percentage ($p\leq 0.01$),

Different parts of the carcass

The carcasses were dissected into their different parts in order to study the proportion of each part of the dressing carcass. The results of analysis of the different parts of the carcass are shown in Table 4.6. Hybrid broilers had a greater percentage of breast than crossbreeds ($p\leq 0.01$). The percentages of wing and drumstick of hybrid broilers were lower than of the crossbreeds ($p\leq 0.01$). Percentages of thigh and back were not significantly different between the breeds. Crossbreeds had a higher proportion of all parts of the wing than hybrid broilers ($p\leq 0.01$). There were no significant differences among the crossbreeds for all parts of the dressing carcass ($p\leq0.01$), except the percentage of drumstick of the 3-line crossbreed, which was higher than that of the 4-line crossbreed ($p\leq 0.05$). The percentages of drumstick and thigh in male chickens were higher than in female chickens ($p\leq 0.05$). However, female chickens had a greater percentage of breasts than the males ($p\leq 0.05$). Sex had no effect on the proportion of wings ($p\leq0.01$). The effect of interaction between breed and sex was only significant for the percentage of thigh ($p\leq 0.01$).

Meat proportion of carcass parts

The data on percentages of meat in each part of dressing carcass were statically analyzed and the results are presented in Table 4.7. Total breast meat of hybrid broilers was 24.63 % of the total dressing weight, which was considerably higher than of the crossbreeds ($p\leq0.01$). In contrast, the percentages of drumstick meat, wing stick meat and the total wing meat were higher in crossbreeds ($p \leq 0.05$). Among the crossbreeds, the percentages of meat in each part of the dressing carcass were not significantly different ($p > 0.01$). Male chicken had higher percentages of thigh meat than females ($P \leq 0.01$). On the contrary, female chicken had a higher percentage of breast meat than males ($P \leq 0.05$). The percentage of meat in other parts of the dressing carcass was not significantly different between the sexes ($p \leq 0.01$). There was no significant interaction between breed and sex.

Bones proportion of carcass parts

Proportion of bone is indicated by the skeleton. The results of the analyses of variance are presented in Table 4.8. It was found that the percentages of bone in each part of the dressing carcass of the 3-line and 4-line crossbreeds were not significantly different ($p > 0.01$). The percentages of bone from almost all parts of dressing carcass of the crossbreeds were significantly higher than of the hybrid broilers ($p \leq 0.01$), breast bone was also significant ($P \leq 0.05$). The backbone takes the largest proportion of the skeleton of chicken. Crossbreeds had a higher backbone proportion than hybrid broilers ($p \leq 0.01$). There were no significant differences between male and female birds ($p \leq 0.05$), except for the breastbone, which was higher in males ($p \leq 0.05$). The order of the breeds within the sexes is the same.

Skin proportion of the carcass

The proportion of skin indicates the quality of the carcass as skin normally has a high proportion of fat accumulation. Statistical analysis was applied in order to analyze the percentage of skin and the results are presented in Table 4.9. It was found that the breast part had the largest proportion of skin, which, however was not significantly different between the breeds ($p \leq 0.01$). The four-line crossbreeds had a lower percentage of skin in most parts of the dressing carcass. There were no significant differences between male and female chickens ($p > 0.01$), except for the drumstick skin, which was found higher in males ($p \leq 0.05$). Also in this trait, the order of the breeds within the sexes is the same.

Table 4.5 Total carcass composition of chickens, feeding system 1

Treatment	Live weight g ±SD	Proportion of					
		Carcass	Dressing[1]	Meat	Skin	Bone	Total Fat[2]
		% of live weight ±SD					
Breed[3]							
Hybrid	2607.50 ± 295.80^{A}	83.15 ± 2.02	72.54 ± 1.54^{A}	38.19 ± 1.56^{A}	8.06 ± 0.44^{A}	18.89 ± 1.30^{A}	6.57 ± 2.09^{A}
3-line crossbreeds	1339.17 ± 223.29^{c}	81.62 ± 2.80	68.47 ± 2.05^{B}	33.14 ± 2.04^{B}	6.94 ± 0.97^{B}	24.10 ± 1.42^{B}	3.23 ± 1.74^{B}
4-line crossbreeds	1455.83 ± 319.71^{b}	81.62 ± 2.35	68.31 ± 1.89^{B}	33.28 ± 2.28^{B}	6.53 ± 1.19^{B}	24.33 ± 1.81^{B}	2.45 ± 1.29^{B}
Sex							
Male	2051.67 ± 613.65^{A}	83.29 ± 2.16^{A}	70.36 ± 2.26^{a}	35.34 ± 2.95	7.08 ± 1.33	23.05 ± 2.63^{a}	3.36 ± 1.87^{B}
Female	1550.00 ± 582.24^{B}	80.96 ± 2.20^{B}	$68.90+-2.62^{b}$	34.40 ± 3.18	7.27 ± -0.86	21.83 ± 3.19^{b}	4.81 ± 2.83^{A}
Significance							
Breed	**	ns	**	**	**	**	**
Sex	**	**	*	ns	ns	*	**
B x S	ns	ns	ns	ns	**	ns	ns

g: Gram; B: Breed; S: Sex
[1]: Dressed carcass excluding head, neck and legs.
[2]: Total Fat described the fat from abdominal fat pad and adipose fat accumulated in each part of carcass part
[3]: Slaughtered hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds slaughtered at 12 weeks.
Different letters in the same column shows significant differences between breeds of chicken and between sexes at the 0.05 level (*, with a, b, c) and at the 0.01 level (**, with A, B, C); ns: Non significant at the 0.01 level

Table 4.6 Carcass-part proportion of chickens, feeding system 1

Treatment	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass [2] ±SD						
Breed[3]							
Hybrid	15.00 ± 1.02^{C}	17.38±0.95	5.54 ± 0.34^{B}	4.53 ± 0.39^{B}	11.35 ± 0.46^{B}	35.63 ± 2.63^{A}	20.90±2.02
3-line crossbreeds	17.00 ± 0.83^{a}	16.82±0.94	7.24 ± 0.61^{A}	5.63 ± 0.28^{A}	14.94 ± 0.76^{A}	30.10 ± 1.31^{B}	20.92±1.39
4-line crossbreeds	16.38 ± 0.89^{b}	16.87±0.65	7.06 ± 0.69^{A}	5.37 ± 0.22^{A}	14.80 ± 1.06^{A}	31.24 ± 1.42^{B}	19.97±1.99
Sex							
Male	16.42 ± 1.06^{a}	17.33 ± 0.75^{a}	6.62±1.01	5.33±0.68	13.72±1.83	31.65 ± 3.06^{b}	20.41±1.96
Female	15.81 ± 1.34^{b}	16.72 ± 0.89^{b}	6.60±0.92	5.29±0.61	13.67±1.93	33.00 ± 2.93^{a}	20.79±1.72
Significance							
Breed	**	ns	**	**	**	**	ns
Sex	*	*	ns	ns	ns	*	ns
B x S	ns	**	ns	ns	ns	ns	ns

g: Gram; B: Breed; S: Sex

[1]: Total wing includes wing stick, tulip wing and end wing

[2]: Dressed carcass, excluding, head, neck and legs

[3]: Slaughtered hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds slaughtered at 12 weeks.

Different letters show significant differences between types of chicken and between sexes at the 0.05 level (*, with a, b, c) and at the 0.01 level (**, with A, B, C); ns: Non significant at the 0.01 level

Table 4.7 Carcass-part meat proportion of chickens, feeding system 1

Treatment	Meat of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Breed[3]							
Hybrid	9.50 ± 0.75^{B}	10.75 ± 0.88	2.57 ± 0.36^{B}	1.67 ± 0.26	4.20 ± 0.49^{B}	24.63 ± 1.80^{A}	4.83 ± 1.09^{A}
3-line crossbreeds	10.55 ± 0.80^{A}	10.48 ± 0.71	3.22 ± 0.50^{A}	1.83 ± 0.28	5.05 ± 0.59^{A}	19.97 ± 1.33^{B}	2.85 ± 0.97^{B}
4-line crossbreeds	10.11 ± 0.98^{AB}	10.77 ± 0.75	3.45 ± 0.32^{A}	1.72 ± 0.52	5.07 ± 0.54^{A}	20.59 ± 2.01^{B}	2.84 ± 0.97^{B}
Sex							
Male	10.29 ± 0.84	11.21 ± 0.55^{A}	2.98 ± 0.54	1.85 ± 0.25	4.83 ± 0.62	21.11 ± 2.70^{b}	3.46 ± 1.28
Female	9.81 ± 0.99	10.13 ± 0.56^{B}	3.11 ± 0.51	1.63 ± 0.44	4.72 ± 0.72	22.34 ± 2.61^{a}	3.56 ± 1.48
Significance							
Breed	**	ns	**	ns	**	**	**
Sex	ns	**	ns	ns	ns	*	ns
B x S	ns	ns	ns	ns	ns	ns	ns

g: Gram; B: Breed; S: Sex
[1]: Total wing includes wing stick, tulip wing and end wing
[2]: Dressed carcass, excluding, head, neck and legs
[3]: Slaughtered hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds slaughtered at 12 weeks.
Different letters show significant differences between types of chicken and between sexes at the 0.05 level (*, with a, b, c) and at the 0.01 level (**, with A, B, C); [ns]: Non significant at the 0.01 level

Table 4.8 Carcass-part bone proportion of chickens, feeding system 1

Treatment	Bone of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Breed[3]							
Hybrid	3.94 ± 3.70^{B}	2.44 ± 0.25^{B}	1.88 ± 0.21^{B}	1.39 ± 0.23^{B}	1.29 ± 0.18^{B}	5.61 ± 0.87^{b}	10.44 ± 1.06^{B}
3-line crossbreeds	5.04 ± 0.60^{A}	3.56 ± 0.53^{A}	2.72 ± 0.34^{A}	2.03 ± 0.20^{A}	2.06 ± 0.52^{A}	6.20 ± 1.33^{ab}	13.86 ± 1.06^{A}
4-line crossbreeds	4.83 ± 0.42^{A}	3.48 ± 0.39^{A}	2.61 ± 0.50^{A}	2.18 ± 0.38^{A}	1.97 ± 0.51^{A}	6.59 ± 0.84^{a}	14.24 ± 1.25^{A}
Sex							
Male	4.72±0.61	3.16±0.65	2.41±0.49	1.86±0.42	1.76±0.54	6.49 ± 1.00^{a}	12.97±1.75
Female	4.48±0.72	3.15±0.68	2.39±0.56	1.87±0.48	1.78±0.57	5.78 ± 1.08^{b}	12.73±2.36
Significance							
Breed	**	**	**	**	**	*	**
Sex	ns	ns	ns	ns	ns	*	ns
B x S	ns	ns	ns	ns	ns	ns	ns

g: Gram; B: Breed; S: Sex

[1]: Total wing includes wing stick, tulip wing and end wing

[2]: Dressed carcass excluding head, neck and legs.

[3]: Slaughtered hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds slaughtered at 12 weeks.

Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, with a, b, c) and at the 0.01 level (**, with A, B, C); [ns] :Non significant at the 0.01 level

Table 4.9 Carcass-part skin proportion of chickens, feeding system 1

Treatment	Skin of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Breed[3]							
Hybrid	1.12 ± 0.26^{a}	2.59 ± 0.38^{A}	0.98±0.13	1.31 ± 0.20^{b}	2.20 ± 0.40^{b}	2.86±0.43	2.54 ± 0.58^{A}
3-line crossbreeds	1.01 ± 0.25^{a}	2.27 ± 0.31^{AB}	1.06±0.16	1.54 ± 0.22^{ab}	2.60 ± 0.36^{a}	3.02±0.35	1.63 ± 0.58^{B}
4-line crossbreeds	0.91 ± 0.21^{b}	1.96 ± 0.40^{C}	0.96±0.20	1.59 ± 0.45^{a}	2.55 ± 0.54^{ab}	2.82±0.59	1.43 ± 0.88^{B}
Sex							
Male	1.12 ± 0.29^{a}	2.39±0.46	0.96±0.18	1.52±0.39	2.43±0.58	2.88±0.48	1.74 ± 0.81^{ns}
Female	0.97 ± 0.18^{b}	2.15±0.40	1.04±0.15	1.43±0.24	2.47±0.32	2.91±0.45	2.00 ± 0.86^{ns}
Significance							
Breed	*	**	ns	*	*	ns	**
Sex	*	ns	ns	ns	ns	ns	ns
B x S	ns	ns	ns	ns	ns	ns	ns

g: Gram; B: Breed; S: Sex
[1]: Total wing includes wing stick, tulip wing and end wing
[2]: Dressed carcass excluding head, neck and legs.
[3]: Slaughtered hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds slaughtered at 12 weeks.
Different letters show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), ^{ns}: Non significant at the 0.01 level.

4.1.4 Mortality

The cumulative mortality of chickens in experiment 1 is shown in figure 4.1. During the first 7 weeks, the hybrid broilers had the highest mortality (i.e. 15%) ($p \leq 0.01$). The mortality was particularly high during week 1-3 and week 6-7. The main reason for the fatalities was injury of the legs caused by unstable and imbalanced walking since the bamboo sticks used for the floor were relatively thin compared to the chicken feet. The rapid gain in body weight along -with a high proportion of accumulated fat in the abdominal cavity- made the birds lie down most of the time. Their bodies were too heavy to be carried easily and they were lazy to move. The three-line and four-line crossbreeds had a lower mortality until the slaughtering stage (week 12) at the rate of 0% and 1%, respectively. The mortality of the 3-line crossbreeds was due to accidents inside the pen, e.g., in one case, the head was trapped in the pen floor, in another case the chicken fell into the feeding device and got stuck inside.

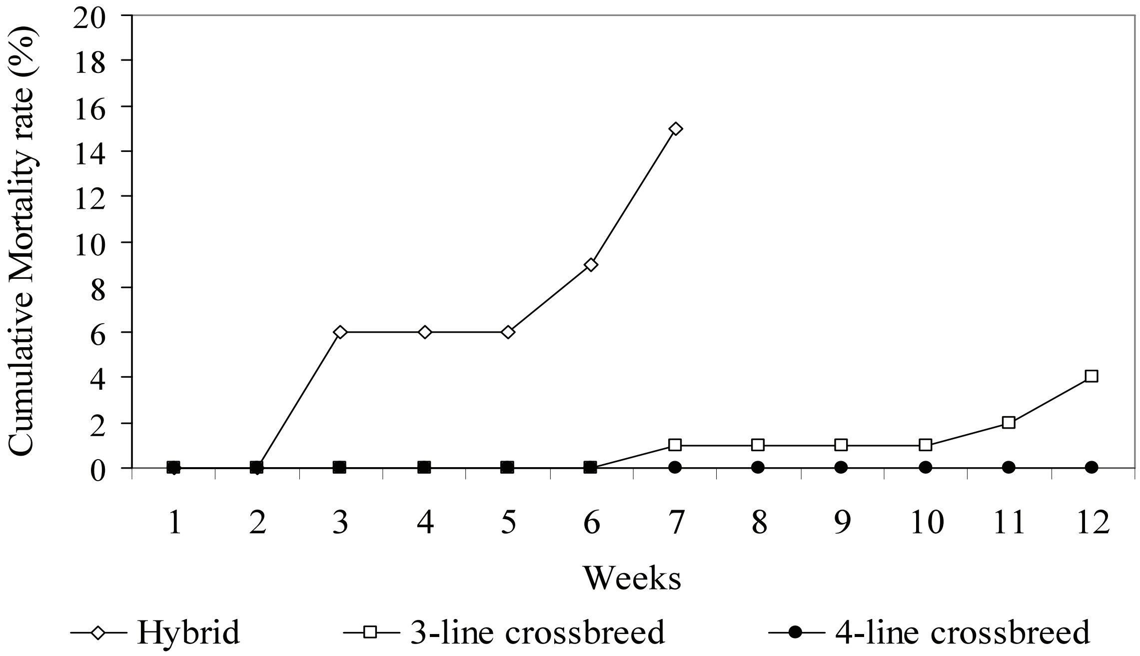


Figure 4.1 Cumulative mortality of chickens in experiment 1 (feeding system 1)

4.2 Feeding system 2: Formulated feed

4.2.1 Growth performance of chickens

Weight gains for all growth stages until slaughter for the 4 breeds are presented in Table 4.10 (statistical *Model 1*). The results show that during the growing stage from week 0 to 7 week, hybrid broilers had a significantly greater weight gain than the other 3 types of chicken ($p \leq 0.01$). They reached a mean weight gain of 1,764g per bird whereas the weight gain of the 3–line crossbreeds, 4-line crossbreeds and the native chicken was 507, 534 and 438 g per bird at the end of week 7, respectively. For the periods of week 8-12 and week 0-12, 3-line and 4-line crossbreeds gained significantly greater weight than native chicken ($p \leq 0.01$). At the end of week 12, the average final weight gain of the 3-line crossbreeds, 4-line crossbreeds and native chicken were 1,177, 1242, and 922 g/bird, respectively. The crossbreeds took about 12 weeks to reach the same weight as the hybrid broilers at the age of 5 weeks. The average weight gains of native chicken at 15 weeks and 20 weeks were 1,178 and 1,583 g/bird, respectively. They grew very slowly, and therefore they needed another 3 weeks to reach the weight of the 3-line and 4-line crossbreeds at the age of 12 weeks ($p \leq 0.01$). It would take 3 months longer for the native chicken to reach the same weight as the hybrid broilers at the age of 7 weeks. Male chickens gained a higher body weight than females in all growing stages and for all breeds ($p \leq 0.01$), except for the first week ($p > 0.01$). Hybrid broiler females gained greater body weight than the males of the crossbreeds and the native chicken. For the first 7 weeks of the fattening period there are significant interactions between breed and sex ($p \leq 0.01$ and $p \leq 0.05$).

The data on average daily weight gain (ADG) are presented in Table 4.11. The analysis was done using statistical *Model 1*. During the first week, the ADG of hybrid broilers (10.83 g/bird/day) was the highest (i.e. 2-3 fold higher than the other breeds), while the lowest growth rate was found with the 3-line crossbreeds (3.12 g/bird/day) ($p \leq 0.05$). The ADG of hybrid broilers was 48.83 g/bird/day at week 7, which is 3.5-4 folds greater than that of the crossbreeds and the native chicken for the same period ($p \leq 0.01$), respectively. The peak of the ADG of the 3-line and 4-line crossbreeds were 21.17 and 22.66 g/bird/day during week 12 ($p \leq 0.05$), respectively. The highest ADG of the native chicken was 14.64 g/bird/day during week 11, which was still lower than that of the crossbreeds for the same period ($p \leq 0.05$). For the period of 0-7 weeks (i.e., the slaughtering age for the broilers), the ADG of the broilers (36.01 g/bird/day) was significantly higher than all other breeds ($p \leq 0.01$). The native chickens had the lowest ADG at the rate of 8.95 g/bird/day, which were significantly different from the 3-line (10.35 g/bird/day) and 4-line crossbreeds (10.90 g/bird/day).

During the period of week 8-12, the 4–line crossbreeds had a significantly higher ADG than the 3–line crossbreeds ($p \leq 0.05$) and the native chicken ($p \leq 0.01$). The highest growth rates for all 3 types of chicken were found during week 8-12 (hybrid broilers were slaughtered after week 7). The ADG of the 3-line and 4-

line crossbreeds were 38.30% and 46.04%, respectively, which were higher than the ADG of the native chicken. There were no significant differences ($p \leq 0.01$) between the 3-line and 4-line crossbreeds on ADG throughout the growing period (week 12) and until they reached slaughtering age. There were, however, significant differences when compared to native chicken ($p \leq 0.01$). It was found that for the entire growing period (20 weeks), the ADG of native chicken was 11.31 g/bird/day. Growth rate of native chicken began declining in week 13 until slaughter age. During all growing stages the males higher weight gains than the females. There was also significant interaction between breed and sex during the first stages of fattening.

4.2.2 Feed utilization efficiency

The results of feed intake for all breeds of chicken and through out the growing period (statistical *Model 3*) are presented in Table 4.12. During the first week of growing, the daily feed intake of the 3–line (5.84 g), 4–line (4.71 g) crossbreeds and the native chicken (4.40 g) were rather low ($P>0.01$), whereas the feed intake of the hybrid broilers was 12.55 g during the same period ($P \leq 0.01$). The intake of the native chickens remained extremely low towards the end of week 3 (7.37 g per bird per day). This explains the slow growth of native chicken. At the age of 3 weeks, feed intake of the 3-line and 4-line crossbreeds had increased from 4.71 and 4.40 g to 18.00 and 18.29 g, respectively, i.e. four folds of the first week. Daily feed intake of the hybrid broilers increased from week to week. It reached a rate of 127.42 g per bird per day at the end of week 7, which was significantly different from the crossbreeds and the native chicken ($P \leq 0.01$). The feed intake of the 3-line and 4-line crossbreeds had increased slowly up to about 39.48 and 38.71 g/bird/day ($P>0.01$), respectively, which were significantly different from the native chicken ($P \leq 0.01$) whose feed intake was only 31.4g per bird per day. The overall average daily feed intake per bird over a period of 7 weeks (i.e. the slaughtering age of the hybrid broilers) was 76.08 g for the hybrids with a significant difference to the other breeds ($P \leq 0.01$). The feed intakes of the 3-line crossbreeds, 4-line crossbreeds and native chicken, however, were not significantly different ($P>0.01$), with 24.29, 24.04 and 18.34 g/bird/day, respectively. Native chicken showed an extremely low feed intake, i.e. only one forth of that of the hybrid broilers. In week 12, the feed intakes of the 3-line and 4-line crossbreeds were 74.40 and 76.18 g/bird/day ($p>0.01$), respectively. Their feed intakes were significantly larger different ($P \leq 0.01$) than those of the native chicken (61.88 g/bird/day). It reached the same level of 79.44 g in week 20, with an average daily feed intake of 48.91 g/bird/day for the period of 0-20 week. In comparison to the crossbreeds chicken, the quantity of feed intake of the native chicken throughout the growing period was extremely low. The feed intakes among the crossbreeds were not significantly different during the period of week 0-7 ($P>0.01$). The significant differences among the chicken were during the period of week 8-12 ($P \leq 0.01$). Thus, the feed intake of the crossbreeds was not significantly different
throughout the growing period ($P>0.01$).

Table 4.10 Weight gain of chickens at each growth stage, feeding system 2

Growth Stage (week)	Breed of Chicken[2]				Sex		Significance		
	Hybrid	3-Line Crossbreeds	4-Line Crossbreeds	Native Chicken	Male	Female	B	S	BxS
	Weight gain (g/bird) ±SD				Weight gain (g/bird) ±SD				
0-1	75.78±16.09^{A}	21.86±8.89^{c}	32.20±11.48^{b}	33.21±9.13^{b}	43.13±25.48	38.39±21.94	**	ns	ns
2-3	399.35±58.76^{A}	129.87±28.58^{b}	129.29±27.89^{b}	102.50±21.66^{c}	202.09±139.87^{A}	178.41±112.60^{B}	**	**	**
4-5	605.69±89.15^{A}	155.75±36.50^{b}	165.81±40.63^{b}	133.08±24.62^{c}	289.36±224.75^{A}	240.81±180.83^{B}	**	**	**
6-7	683.61±147.28^{A}	199.86±49.42^{b}	206.92±48.42^{b}	169.56±27.95^{c}	347.57±241.40^{A}	282.40±212.78^{B}	**	**	*
8-9		252.50±62.49^{a}	241.94±47.80^{a}	181.33±50.08^{b}	253.46±57.22^{A}	197.06±53.41^{B}	**	**	ns
10-11		266.11±47.76^{b}	307.50±46.81^{a}	205.00±69.51^{c}	286.48±70.37^{A}	232.59±57.66^{B}	**	**	ns
12		151.94±33.71^{b}	158.61±59.19^{a}	98.47±32.31^{c}	162.04±51.27^{A}	110.65±35.44^{B}	**	**	ns
12-13				95.37±9.87	228.15±56.71^{A}	162.59±42.96^{B}		**	
14-15				184.91±64.38	221.30±63.10^{A}	148.52±41.09^{B}		**	
16-18				250.38±95.25	309.63±84.07^{A}	190.93±63.82^{B}		**	
19-20				154.81±67.04	195.19±63.59^{A}	114.44±41.33^{B}		**	
0-7	1764.43±224.66^{A}	507.35±102.27^{b}	534.21±97.54^{b}	438.36±55.14^{c}	882.15±619.27^{A}	740.02±509.33^{B}	**	**	**
8-12		670.56±122.17^{b}	708.06±137.53^{a}	484.81±116.06^{c}	701.98±152.80^{A}	540.30±118.29^{B}	**	**	ns
0-12		1177.90±193.42^{b}	1242.26±207.40^{a}	922.28±148.36^{c}	1234.02±220.06^{A}	994.28±169.91^{B}	**	**	ns
0-15				1178.40±207.92	1332.12±168.90^{A}	1024.69±102.87^{B}		**	
0-20				1583.47±323.15	1837.27±244.05^{A}	1329.68±141.45^{B}		**	

g: Gram, B: Breed, S: Sex,
[1]: During 12-20 weeks growth stages of native chicken were no significant difference among replicates (Pens)
[2]: Slaughtered hybrid broilers at 7 weeks, 3-line and 4-line crossbreeds slaughtered at 12 weeks and native chicken slaughtered at 20 weeks.
Different letters in the same row show significant differences between breed of chicken and between sexes at the 0.05level (*, a, b, c) and at the 0.01level (**, A, B, C), ^{ns}: Non-significant at the 0.01 level

Table 4.11 Average Daily Gain (ADG) of chickens at each growth stages of chickens, feeding system 2

Growth Stage (week)[1]	Weight gain (g/bird) ±SD						Significance		
	Breed of Chicken[2]				Sex				
	Hybrid	3-Line Crossbreeds	4-Line Crossbreeds	Native Chicken	Male	Female	B	S	B x S
0-1	10.83 ± 2.30^{A}	3.12 ± 1.28^{c}	4.60 ± 1.64^{b}	4.74 ± 1.30^{b}	6.16 ± 3.64	5.48 ± 3.13	**	ns	ns
2-3	28.52 ± 4.20^{A}	9.28 ± 2.04^{b}	9.24 ± 1.99^{b}	7.32 ± 1.55^{c}	14.43 ± 9.99^{A}	12.74 ± 8.04^{B}	**	**	**
4-5	43.26 ± 6.37^{A}	11.12 ± 2.61^{b}	11.84 ± 2.90^{b}	9.59 ± 1.76^{c}	20.67 ± 16.05^{A}	17.20 ± 12.92^{B}	**	**	**
6-7	48.83 ± 10.52^{A}	14.28 ± 3.53^{bc}	14.78 ± 3.46^{b}	12.11 ± 2.00^{c}	24.83 ± 17.24^{A}	20.17 ± 15.20^{B}	**	**	*
8-9		18.04 ± 4.46^{a}	17.28 ± 3.40^{b}	12.95 ± 3.58^{c}	18.10 ± 4.09^{A}	14.07 ± 3.81^{B}	**	**	ns
10-11		19.01 ± 3.40^{b}	21.96 ± 3.34^{a}	14.64 ± 4.97^{c}	20.46 ± 5.03^{A}	16.61 ± 4.12^{B}	**	**	ns
12		21.71 ± 4.82^{b}	22.66 ± 8.46^{a}	14.07 ± 4.62^{c}	23.15 ± 7.32^{A}	15.81 ± 5.06^{B}	**	**	ns
12-13				13.95 ± 4.28	16.30 ± 4.04^{A}	11.61 ± 3.07^{B}		**	
14-15				13.21 ± 4.60	15.81 ± 4.51^{A}	10.61 ± 2.93^{B}		**	
16-18				11.92 ± 4.54	14.74 ± 4.00^{A}	9.09 ± 3.04^{B}		**	
19-20				11.06 ± 4.79	13.94 ± 4.54^{A}	8.17 ± 2.95^{B}		**	
0-7	36.01 ± 4.59^{A}	10.35 ± 2.09^{b}	10.90 ± 1.99^{b}	8.95 ± 1.13^{c}	18.00 ± 12.64^{A}	15.10 ± 10.39^{B}	**	**	**
8-12		16.76 ± 3.05^{b}	17.70 ± 3.44^{a}	12.12 ± 2.90^{c}	17.55 ± 3.82^{A}	13.51 ± 2.96^{B}	**	**	ns
0-12		14.02 ± 2.30^{b}	14.79 ± 2.47^{a}	10.98 ± 1.77^{c}	14.69 ± 2.62^{A}	11.84 ± 2.02^{B}	**	**	ns
0-15				11.22 ± 1.98	12.69 ± 1.61^{A}	9.76 ± 0.9^{B}		**	
0-20				11.31 ± 2.31	13.12 ± 1.74^{A}	9.50 ± 1.01^{B}		**	

g: Gram, B: Breed; S: Sex;

[1]: During 12-20 weeks growth stages of native chicken were no significant difference among replicates (Pens)

[2]: Slaughtered for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds slaughtered at 12 weeks; native chicken slaughtered at 20 weeks.

Different letters in the same row show significant differences between types of chicken and between sexes at the 0.05 level (*, with a, b, c) and at the 0.01level (** with A, B, C); ns: Non significant at the 0.01 level

The results of feed conversion ratio (FCR) are shown in Table 4.13 (statistical *Model 3*). FCR of all types of chicken increased weekly and showed a relatively similar pattern. FCR was not significantly different among the tested breeds of chicken during the first week (p>0.01). A significant difference found during week 2 when the FCR of 3-line and 4-line crossbreeds were higher than of the other breeds (P≤0.05). The average FCR for the period of week 0-7 were not significantly different between the breeds (P≤0.05). FCR of hybrid broilers, 3-line, 4-line crossbreeds and native chicken were 2.15, 2.40, 2.29 and 2.30, respectively. During week 0-12, the feed conversion efficiency (FCE) was significantly different between the crossbreeds chicken and the native chicken. The results demonstrated that native chicken had the highest FCE. At the end of week 20, FCR of the native chicken reached the value of 7.10. However, the overall average of FCR was 4.33 despite the low feed conversion efficiency; maintained of the growth rate through the increase of daily feed intake by the chicken.

Table 4.12 Feed intake of chickens at each growth stage, feeding system 2

Growth Stage (week)[1]	Feed intake (g/bird) ±SD				Significance
	Hybrid Broiler[2]	3-Line Crossbreeds	4-Line Crossbreeds	Native Chicken	
0-1	12.34±2.54^{A}	4.00±1.64^{B}	5.38±1.92^{B}	4.40±0.11^{B}	**
2-3	39.36±5.71^{A}	18.55±4.08^{B}	18.29±3.94^{B}	7.37±0.81^{C}	**
4-5	91.29±13.45^{A}	25.59±6.00^{B}	25.58±6.27^{B}	23.27±0.09^{B}	**
6-7	125.42±35.54^{A}	40.54±10.02^{B}	39.32±9.20^{BC}	31.40±0.67^{C}	**
8-9		56.99±14.11^{A}	53.92±10.65^{A}	40.46±0.53^{B}	**
10-11		70.71±12.69^{A}	72.48±11.03^{A}	52.94±2.03^{B}	**
12		81.04±17.98^{A}	79.13±29.53^{A}	61.88±1.62^{B}	**
12-13				61.88±1.62	
14-15				69.36±2.34	
16-18				75.87±2.84	
19-20				79.44±2.74	
0-7	77.42±9.70^{A}	24.85±5.01^{B}	24.97±4.56^{B}	18.34±0.36^{CB}	**
8-12		68.69±12.51^{A}	68.13±13.23^{A}	54.54±1.15^{B}	**
0-12		44.24±7.27^{A}	43.77±7.31^{A}	31.73±0.49^{B}	**
0-15				38.96±0.88	
0-20				48.91±0.71	

g: Gram

[1]: During 12-20 weeks growth stages of native chicken were no significant difference among replicates (Pens).

[2]: Slaughtered for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks; native chicken at 20 weeks.

Different letters in the same row show significant differences between breeds of chicken at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), ^{ns}: Non significant at the 0.01 level

Table 4.13 Feed conversion ratio (FCR) of chickens at each growth stage, feeding system 2

Growth Stage (week)[1]	Feed Conversion Ratio (FCR) ±SD				Significance
	Hybrid Broiler[2]	3-Line Crossbreeds	4-Line Crossbreeds	Native Chicken	
0-1	1.14±0.23	1.28±0.26	1.17±0.23	1.33 ±0.09	ns
2-3	1.38±0.28[d]	2.00±0.40[a]	1.98±0.40[ba]	1.60 ±0.06[cd]	*
4-5	2.11±0.42	2.30±0.46	2.16±0.43	2.50 ±0.70	ns
6-7	2.69±0.54	2.84±0.57	2.66±0.53	2.75 ±0.05	ns
8-9		3.16±0.63	3.12±0.62	3.14 ±0.10	ns
10-11		3.72±0.74[A]	3.30±0.66[B]	3.77 ±0.01[A]	**
12		4.80±0.96	4.49±0.90	4.45 ±0.12[A]	ns
12-13				4.45 ±0.12	
14-15				5.26 ±0.01	
16-18				6.21 ±0.28	
19-20				7.10 ±0.43	
0-7	2.15±0.43	2.40±0.48	2.29±0.46	2.30 ±0.04	ns
8-12		3.73±0.76	3.56±0.71	3.82 ±0.05	ns
0-12		3.19±0.65[A]	3.03±0.61[A]	2.75 ±0.02[B]	**
0-15				3.48 ±0.02	
0-20				4.33 ±0.05	

g: Gram
[1]: During 12-20 weeks growth stages of native chicken were no significant difference among replicates (Pens)
[2]: Slaughtered for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks; native chicken at 20 weeks.
Different letters in the same row show significant differences between types of chicken at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), [ns]: Non significant at the 0.01 level

4.2.3 Carcass quality

The analyses of variance were done to the traits of the performance of carcass quality using the statistical *Model 5*.

Composition of the total carcass

The results and analyses of the composition of the total carcass of breeds and sex are shown in Table 4.14. The body weights of the different breeds at the final stage were significantly different at the p≤0.05 level. It found that the percentages of total carcass of the hybrid broilers, 3-line crossbreeds, 4-line crossbreeds and the native chicken were 82.15%, 80.80%, 80.80% and 79.90% of live weight, respectively. The total carcass percentage of the native chicken was significantly lower than of the other 3 types of chicken (p≤0.05); but there were no significant differences between the other types of chicken (p>0.01). There is a slight difference in the percentage of the dressing carcass between the breeds ($p \leq 0.01$). The males had a higher percentage of carcass ($p \leq 0.01$) and dressing ($p \leq 0.05$) than the females. The percentages of meat, skin and bone were not significantly different between the breeds and sexes ($p \leq 0.01$), except the percentages of meat in females, which was higher than in males ($p \leq 0.05$). The sex did not affect the percentage of the total fat in the carcass ($p > 0.01$). The total fat composition influenced by the differences between the chicken breeds; the native chicken had the lowest percentage of total fat with a significant difference to hybrid broilers ($p \leq 0.01$) and crossbreeds ($p \leq 0.05$). There was no significant interaction between breed and sex.

Different parts of the carcass

The proportions of different parts of the carcass were measured for the different breeds; the results are presented in Table 4.15. Male and female birds were not different in the percentages of the different parts ($p \leq 0.01$), but there were differences between the breeds. There were no significant differences between the 3-lines and 4-lines crossbreeds ($p > 0.01$), except for the percentage of tulip wing, which was higher for the 4-line crossbreeds ($p \leq 0.05$). The native chicken had a higher percentage of breast than the crossbreeds ($p \leq 0.01$), but there was no significant difference to the hybrid broilers ($p > 0.01$). The other carcass parts of the native chicken, such as thigh and wing stick, were higher than of the hybrid broilers ($p \leq 0.01$). Of all breeds, the native chicken had the lowest percentages of the back part ($p \leq 0.01$). There was no interaction between breed and sex.

Meat proportion of carcass parts

Calculation was done based on the weight of the dressed carcass. The results are presented in Table 4.16. Sex had no effect on meat proportion for the carcass parts ($p > 0.01$), except in breast meat, which was higher in male than female birds ($p \leq 0.01$). On the other hand, the breeds did not influence the percentages of drumstick and tulip wing ($P > 0.01$). The native chicken had a greater percentage of breast and thigh meat than the other breeds ($p \leq 0.01$). The percentage of total wing meat of native chicken was not significantly different from the crossbreeds chicken ($p > 0.01$). But, they were higher than of hybrid broiler ($p \leq 0.01$). There were no significant differences between the 3-line and 4-line crossbreeds in the percentages of meat in any carcass part ($p > 0.01$). Also there was no interaction between breed and sex.

Bones proportion of carcass parts

The percentages of bone in each carcass part were calculated on the basis of dressed carcass weight and the results of the analyses of variance are presented in Table 4.17. It was found that the percentages of bone in all parts of the carcass were significantly different between the different breeds ($p \leq 0.01$), except for the tulip wing-bone and the back bone ($p > 0.01$). There were no significant differences in the percentage of drumstick bone between native chicken and the crossbreeds ($p > 0.01$); they were, however, higher than the commercial hybrids.

The percentage of thighbone of native chicken and of crossbreeds was higher than for the commercial hybrids ($p \leq 0.01$). The percentage of breastbone of the 4-line crossbreeds was significantly lower than of other breeds ($p \leq 0.05$). There were no differences between male and female birds, except in the breastbone and wing stick –which was higher in males– and in tulip wing, which was higher in females. The major parts, such as drumstick, thigh, total wing and back were not significantly different ($p > 0.01$). There was no interaction of breed and sex.

Skin proportion of carcass parts

The calculation on skin percentages in each carcass part was based on dressed weight carcass. The results of the statistical analyses are presented in Table 4.18. The results demonstrated that the percentages of skin in the carcass parts were affected slightly by the breed, e.g. skin from thigh, tulip wing, total wing and back ($p \leq 0.05$). The hybrids had higher percentages of skin for thigh and back and lower percentages for tulip wing and total wing. There were no significant differences between 3-line and 4-line crossbreeds ($p > 0.05$). For the proportion of skin in the rest of carcass, there were no significant differences between the breeds ($p > 0.01$). There were no interactions between sex and breed.

Table 4.14 Carcass composition of chickens, feeding system 2

Treatment	Live weight ±SD (g)	Proportion of					
		Carcass	Dressing[1]	Meat	Skin	Bone	Total Fat[2]
		% of live weight ±SD					
Breeds[3]							
Hybrid	1668.33±239.62^{a}	82.15±1.41^{a}	66.69±2.86^{AB}	32.31±2.52	8.68±1.28	20.64±1.02	5.88±2.26^{A}
3-line crossbreeds	1158.33±238.62^{b}	80.80±2.71^{a}	68.13±5.06^{A}	35.32±6.34	8.21±1.55	23.96±4.47	3.48±1.21^{AB}
4-line crossbreeds	1261.67±162.66^{b}	80.80±1.74^{a}	65.28±3.70^{B}	31.28±3.75	6.70±0.94	22.03±2.49	3.98±1.13^{AB}
Native Chicken	1546.67±228.81^{a}	79.90±1.57^{b}	66.70±1.24^{AB}	36.11±2.09	7.43±0.63	20.13±1.08	2.62±0.63^{B}
Sex							
Male	1561.67±289.77^{A}	80.18±2.03^{B}	65.18±3.72^{b}	31.95±3.65^{b}	7.49±1.84	21.11±1.76	4.04±1.40
Female	1255.83±214.32^{B}	81.65±1.69^{A}	68.21±2.38^{a}	35.56±4.23^{a}	8.02±1.07	22.27±3.72	3.94±2.21
Significance							
Breed	**	*	**	ns	ns	ns	**
Sex	**	**	*	*	ns	ns	ns
B x S	ns	ns	ns	ns	ns	ns	ns

g: Gram, B: Breed, S: Sex
[1]: Dressed carcass, excluding, head, neck and legs.
[2]: Total Fat were from abdominal fat pad and adipose fat accumulated from each part of dressed carcass
[3]: Slaughter for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks; native chicken at 20 weeks of age
Different letters in the same column show significant differences between breeds of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01 level (**, with A, B, C), ^{ns}: Non significant at the 0.01 level

Table 4.15 Carcass-part proportions of chickens, feeding system 2

Treatment	Carcass part of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Breed[3]							
Hybrid	16.00±0.02 ^{b}	17.85±0.40 ^{B}	6.23±0.48^{B}	5.02±0.18^{b}	12.90±0.78^{C}	32.87±1.73^{A}	21.29±2.05^{A}
3-line crossbreeds	17.67±1.06 ^{a}	16.65±0.77 ^{C}	7.72±0.54^{A}	5.36±1.23^{b}	15.56±0.87^{A}	29.36±2.36^{B}	20.80±1.23^{A}
4-line crossbreeds	17.53±1.21^{a}	16.88±0.38 ^{C}	7.93±0.59^{A}	5.80±0.59^{a}	15.73±0.53^{A}	29.14±0.83^{B}	20.71±0.91^{A}
Native chicken	17.01±0.69 ^{b}	18.92±0.23 ^{A}	7.47±0.21^{A}	5.61±0.25^{b}	14.82±0.50^{b}	32.51±1.52^{A}	16.62±0.62^{B}
Sex							
Male	17.34±1.43	17.62±1.07	7.51±0.93	5.60±0.54	14.99±1.48	30.43±2.57	20.02±2.56
Female	16.76±0.76	16.52±1.02	7.17±0.67	5.30±0.86	14.51±1.13	31.51±2.11	19.70±2.07
Significance							
Breed	*	**	**	*	**	**	**
Sex	ns	ns	ns	ns	ns	ns	ns
B x S	ns	ns	ns	ns	ns	ns	ns

g: Gram; B: Breed; S: Sex

[1]: Total wing includes wing stick, tulip wing and end wing

[2]: Dressed carcass, excluding, head, neck and legs

[3]: Slaughtered for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks, and native chicken at 20 weeks of age.

Different letters show significant differences between types of chicken and between sexes at the 0.05 level (*, with a, b, c) and at the 0.01 level (**, with A, B, C), [ns]: Non significant at the 0.01 level

Table 4.16 Carcass-parts meat proportion of chickens, feeding system 2

Treatment	Meat of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Breed[3]							
Hybrid	9.95±0.91	11.17±0.75^{B}	2.99±0.51^{b}	1.76±0.33	4.64±0.85^{b}	19.81±0.68^{B}	3.45±0.83^{ab}
3-line crossbreeds	10.53±0.79	10.55±0.40^{B}	3.34±0.4^{ab}	1.93±0.19	5.19±0.35^{ba}	19.12±2.00^{B}	4.04±0.52^{ab}
4-line crossbreeds	10.41±0.72	10.64±0.46^{B}	3.52±0.32^{a}	1.79±0.24	5.31±0.27^{a}	18.83±1.36^{B}	4.06±0.29^{a}
Native chicken	10.62±0.41	13.15±0.40^{A}	3.41±0.14^{b}	1.94±1.00	5.35±0.17^{a}	21.99±1.34^{A}	3.31±0.41^{b}
Sex							
Male	10.29±0.67	11.21±0.55	3.29±0.37	1.88±0.25	5.08±0.60	20.88±1.44^{A}	3.66±0.68
Female	10.47±0.81	10.13±0.56	3.34±0.44	1.83±0.22	5.17±0.49	19.00±1.74^{B}	3.77±0.57
Significance							
Breed	ns	**	*	ns	*	**	*
Sex	ns	ns	ns	ns	ns	**	ns
B x S	ns	ns	ns	ns	ns	ns	ns

g: Gram, B: Breed, S: Sex

[1]: Total wing includes wing stick, tulip wing and end wing

[2]: Dressed carcass, excluding, head, neck and legs.

[3]: Slaughter for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks; native chicken at 20 weeks of age

Different letters show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), [ns] : Non significant at the 0.01level

Table 4.17 Carcass-parts bone proportion of chickens, feeding system 2

Treatment	Bone of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Breed[3]							
Hybrid	4.34 ± 0.57^{B}	2.66 ± 0.25^{B}	2.09 ± 0.27^{B}	1.79±0.26	1.66 ± 0.17^{b}	6.60 ± 0.61^{a}	12.65 ± 1.20^{s}
3-line crossbreeds	5.46 ± 0.51^{A}	3.58 ± 0.17^{A}	2.88 ± 0.46^{A}	1.95±0.16	2.03 ± 0.24^{a}	6.14 ± 0.46^{a}	12.79±1.07
4-line crossbreeds	5.49 ± 0.51^{A}	3.65 ± 0.28^{A}	2.58 ± 0.12^{A}	2.01±0.23	2.01 ± 0.23^{a}	5.92 ± 0.67^{b}	11.95±0.72
Native chicken	5.09 ± 0.33^{A}	3.30 ± 0.14^{A}	2.52 ± 0.17^{A}	1.92±0.18	1.90 ± 0.13^{b}	6.22 ± 0.36^{a}	12.46±0.48
Sex							
Male	5.26±0.64	3.32±0.39	2.64 ± 0.43^{a}	1.81 ± 0.20^{a}	1.90±0.23	6.47 ± 0.45^{b}	12.58±1.14
Female	4.93±0.66	3.27±0.51	2.39 ± 0.32^{b}	2.02 ± 0.18^{b}	1.90±0.25	5.97 ± 0.56^{a}	12.34±0.63
Significance							
Breed	**	**	**	ns	*	*	ns
Sex	ns	ns	*	*	ns	*	ns
B x S	ns	ns	ns	ns	ns	ns	ns

g: Gram, B: Breed, S: Sex

[1]: Total wing includes wing stick, tulip wing and end wing

[2]: Dressed carcass, excluding, head, neck and legs.

[3]: Slaughter for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks; native chicken at 20 weeks of age

Different letters show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), [ns]: Non significant at the 0.01level

Table 4.18 Carcass-parts skin proportion of chickens; feeding system 2

Treatment	Skin of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Breed[3]							
Hybrid	1.60±0.54	2.33±0.38^{a}	1.16±0.25	1.29±0.60^{b}	2.69±0.63^{b}	3.55±0.90	2.70±0.98^{a}
3-line crossbreeds	1.37±0.31	1.83±0.52^{b}	1.18±0.20	1.63±0.27^{ab}	2.81±0.27^{ab}	2.84±0.72	1.86±0.35^{ab}
4-line crossbreeds	1.25±0.37	1.76±0.30^{b}	1.32±0.20	1.72±0.36^{a}	3.21±0.48^{a}	2.98±0.77	2.53±0.88^{a}
Native chicken	1.22±0.08	2.31±0.17^{a}	1.36±0.18	1.61±0.11^{ab}	2.97±0.19^{ab}	3.37±0.27	1.28±0.08^{b}
Sex							
Male	1.27±0.28	2.17±0.33	1.27±0.21	1.44±0.48	2.77±0.38	3.23±0.55	2.16±0.89
Female	1.44±0.44	1.94±0.51	1.24±0.22	1.66±0.29	3.06±0.48	3.14±0.88	2.03±0.86
Significance							
Breed	ns	*	ns	*	*	ns	*
Sex	ns	ns	ns	ns	ns	ns	ns
B x S	ns	ns	ns	ns	ns	ns	ns

g: Gram, B: Breed, S: Sex
[1]: Total wing includes wing stick, tulip wing and end wing
[2]: Dressed carcass, excluding, head, neck and legs.
[3]: Slaughter for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks; native chicken at 20 weeks of age
Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), [ns]: Non significant at the 0.01 level.

4.2.4 Mortality

The cumulative mortality of chicken in experiment 2 is illustrated in Figure 4.2. During the first 7 weeks, the 3-line crossbreeds had the highest mortality, i.e. 4%. Mortality of hybrid broiler was lower (2%/, but there was no significant difference (p>0.01). The four-line crossbreeds had a lower mortality at 12 weeks than the 3-line crossbreeds. But it was higher than for the native chickens during the same growth stages. The native chickens had a low overall mortality throughout the growing period of 4%.

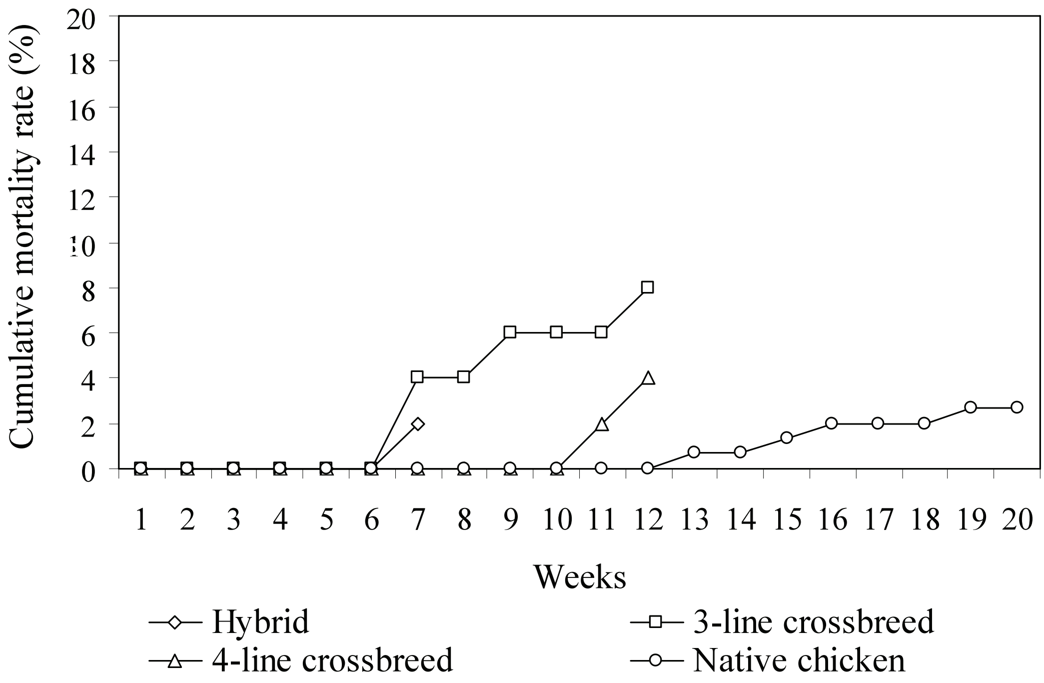


Figure 4.2 Cumulative mortality of chickens in experiment 2 (feeding system 2)

4.3 Effect of feeding system

4.3.1 Growth of chickens

The growth of chicken fed with the two types of feeding system was analyzed using statistical model 2. The results are presented in Tables 4.19 and 4.20

During weeks 0-7, the hybrid broilers had a significantly higher growth performance than the crossbreeds with both feeding systems (p≤0.01). Between the crossbreeds, 4-line crossbreeds demonstrated better growth than the 3-line crossbreeds with feeding system1. Growth of the 3-line and 4-line crossbreeds with feeding system 2 was not significantly different (p>0.01). During the 0-7 week fattening period, the interaction between the breeds and the feeding systems was significant (p≤0.01). It was clearly shown that the growth of chicken receiving feeding system 1 was higher than of the same breed fed with feeding system 2 (p≤0.01). At the second stage of growth (week 8-12), the growth performance of the 4-line crossbreeds was higher than of the 3-line crossbreeds with both feeding systems ($p \leq 0.01$). Thus, the feeding systems did not have any significant effect on weight gain of both types of crossbreeds ($p > 0.01$). It was shown that the crossbreeds responded well to both feeding systems, i.e. feeding system 2 (maize based feed) and feeding system 1 (commercial feed).

Table 4.19 Comparison on weight gains (g/bird) of chickens between feeding systems, breeds and sexes at the same growing stage

Treatment	Growth stage (weeks)[I]		
	0-7	8-12	0-12
	g/bird ±SD		
Feeding system 1:			
Hybrid	2493.98 ± 243.92^{A}		
3-Line Crossbreeds	665.25 ± 109.56^{D}	628.33 ± 121.22^{B}	1322.38 ± 209.34^{BC}
4-Line Crossbreeds	800.19 ± 113.88^{C}	712.78 ± 136.88^{A}	1492.98 ± 226.73^{A}
Feeding system 2:			
Hybrid	1764.43 ± 224.66^{B}		
3-Line Crossbreeds	507.35 ± 102.27^{E}	670.56 ± 122.17^{AB}	1177.90 ± 193.47^{C}
4-Line Crossbreeds	534.21 ± 97.55^{E}	708.06 ± 137.53^{A}	1242.26 ± 207.40^{C}
Sex			
Male	1226.84 ± 809.60^{A}	767.22 ± 110.60^{A}	1458.81 ± 205.20^{A}
Female	1028.25 ± 704.13^{B}	592.64 ± 88.41^{B}	1158.95 ± 164.70^{B}
Significance			
Feeding system	**	ns	**
Breed	**	**	**
Sex	**	**	**
Feed x Breed	**	ns	**
Feed x Sex	ns	ns	ns
Breed x Sex	**	ns	ns
Feed x Breed x Sex	ns	ns	ns

g: Gram

[I]: Slaughter age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks.

Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01level (**, A, B, C), [ns]: Non-significant at the 0.01 level.

Table 4.20 Comparison on the average daily gain (ADG) of chickens among feeding systems, breeds and sexes of chickens in the same growth stages

Treatment	Growth Stage (week)[1]		
	0-7	8-12	0-12
	g/bird/day ±SD		
Feeding system 1:			
Hybrid	50.90±4.98^{A}		
3-Line Crossbreeds	13.58±2.24^{D}	17.95±3.46^{B}	15.74±2.49^{AB}
4-Line Crossbreeds	18.11±1.39^{C}	20.36±3.91^{A}	17.77±2.70^{A}
Feeding system 2:			
Hybrid	36.01±4.59^{B}		
3-Line Crossbreeds	10.35±2.09^{E}	16.76±3.05^{B}	14.02±2.30^{B}
4-Line Crossbreeds	10.90±1.99^{E}	17.70±3.44^{B}	14.79±2.47^{B}
Sex			
Male	25.04±16.52^{A}	20.54±3.18^{A}	17.37±2.44^{A}
Female	20.98±14.37^{B}	15.85±2.50^{B}	13.80±1.96^{B}
Significance			
Feeding system	**	*	**
Breed	**	**	**
Sex	**	**	**
Feed x Breed	**	ns	**
Feed x Sex	ns	ns	ns
Breed x Sex	**	ns	ns
Feed x Breed x Sex	ns	ns	ns

g: Gram
[1]: Slaughter age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks.
Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), ^{ns}: Non significant at the 0.01 level.

Considering the overall growing period (0-12 weeks), the weight gain of the 4-line crossbreeds was higher when fed with feeding system 1 but there was no significant difference in weight gain when the crossbreeds were fed with feeding system 2 ($p>0.01$). Weight gain of the 4-line crossbreeds fed with feeding system 1 was greater if they were fed with feeding system 2 ($p\leq0.01$). Also, the sex influenced the body weight gain; male chicken had a greater body weight gain than female chicken in all growth stages ($p\leq0.01$). There were no significant interactions between effect of sex and the other effects.

4.3.2 Feed utilization efficiency

The feed utilization efficiency was evaluated by integration of feed intake and feed conversion ratio (FCR). Statistical analysis was done using model 4; the results are presented in Tables 4.21 and 4.22. There were significant differences in feed intake between the breeds ($p\leq0.01$) during the 0-7 weeks growing stage. During weeks 8-12 and for the overall growing period (week 0-

12), the feed intake of the crossbreeds was not influenced by the feeding system ($p>0.01$).

The results in Table 4.21 show that during the 0-7 week growing stage, the feed intake of the chicken fed with feeding system 1 was higher than of those fed with feeding system 2 ($p\leq0.01$). The hybrid broilers had a greater feed intake than the crossbreeds with both feeding systems ($p\leq0.01$), i.e. about 3-3.5 fold. With feeding
system 1, the feed intake of the 4-line crossbreeds was higher than of the 3-line ($p\leq0.01$), but intake was not significantly different with feeding system 2 ($p>0.01$).

During the second growing stage (weeks 8-12), the 4-line crossbreeds still showed a higher feed intake with feeding system 1 than with feeding system 2. For the overall growing period (0-12 weeks), the 3-line crossbreeds showed no significant difference in feed intake to 4-line crossbreeds with feeding system 2, but less feed intake than the 4-line crossbreeds when they were fed with feeding system 1.

Table 4.21 Comparison on feed intake of chickens among feeding systems and breeds at each growing stage

Treatment	Growth Stage (week)[1]		
	0-7	8-12	0-12
	g/bird/day ±SD		
Feeding system 1:			
Hybrid	106.37 ± 10.39^{A}		
3-Line Cross-Breed	31.09 ± 5.12^{D}	64.09±12.36	54.39 ± 10.46^{B}
4-Line Cross-Breed	35.60 ± 5.08^{C}	69.04±13.26	57.33 ± 9.54^{A}
Feeding system 2:			
Hybrid	77.42 ± 9.86^{B}		
3-Line Cross-Breed	24.85 ± 5.01^{E}	68.69±12.51	44.24 ± 7.27^{C}
4-Line Cross-Breed	24.97 ± 4.56^{E}	68.13±13.23	43.77 ± 7.31^{C}
Significance			
Feed	**	ns	ns
Breed	**	ns	**
Feed x Breed	ns	ns	ns

g: Gram
[1]: Slaughter age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks.
Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), [ns]: Non-significant at the 0.01 level.

Feed conversion ratio (FCR) is presented in Table 4.22. During 0-7 week, hybrid broilers that fed with feeding system 1 gave the higher performance in feed utilization efficiency (lowest FCR of 1.99) ($p\leq0.05$). FCR of crossbreeds chicken was not significant different under both feeding systems (p>0.05), at first period of growing However, 4-line crossbreeds expressed the better feed utilization efficiency by showing lower FCR than 3-line crossbreeds in all growing stages. Crossbreeds responded better when fed with feeding system 1 at the second stage of growing period (8-12 weeks) (P≤0.05).

Table 4.22 Comparison on feed conversion ratio (FCR) of chickens among feeding systems and breeds at each growth stage

Treatments	Feed Conversion Ratio (FCR) ±SD		
	Growth Stage (week)[1]		
	0-7	8-12	0-12
Feeding system 1:			
Hybrid	1.99±0.14[b]		
3-Line Crossbreeds	2.30±0.02[a]	3.63±0.08[ab]	2.93±0.05[bc]
4-Line Crossbreeds	2.20±0.03[a]	3.41±0.03[b]	2.77±0.03[c]
Feeding system 2:			
Hybrid	2.15±0.43[a]		
3-Line Crossbreeds	2.40±0.48[a]	3.73±0.76[a]	3.19±0.65[a]
4-Line Crossbreeds	2.29±0.46[a]	3.56±0.71[ab]	3.03±0.61[ab]
Significance			
Feed	ns	*	*
Breed	*	*	*
Feed x breed	ns	ns	ns

[1]: Slaughter age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks.
Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), [ns]: Non significant at the 0.01 level.

4.3.3 Carcass quality

The analysis of variance was done to the traits of the performance of carcass quality using the statistical Model 6.

Composition of total carcass

The comparisons of the effect of feeding systems on carcass quality presents in Table 4.23 The results show that final body weight and percentage of carcass of hybrid broilers were greater than of the other breeds. There are significant interactions between feeding system and breed in the percentages of dressing, meat and bone. The hybrid broilers, which were fed with feeding system 1 had greater percentages of total carcass (83.21%) and dressing (72.02%), which were significantly different to the 3-line crossbreeds (80.11% and 67.24%) fed with feeding system 1 (p≤0.05). Feeding system 2 did not have any significant effect on the percentage of total chicken carcass (p>0.01) but on the dressing percentage (p≤0.05). The hybrid broilers fed with feeding system 1 had a higher meat proportion of 38.60% of the live weight, which was significantly different from the other types of chicken under both feeding systems

($p \leq 0.01$). There was no significant difference between the other chicken types in the percentage of meat in the carcass. The proportion of chicken skin was slightly different; the percentage of hybrid broiler skin (8.12%) was not significantly different from the other types of chicken with either feeding system ($p > 0.01$). The 4-line crossbreeds had the lowest percentage of skin in the carcass. Therefore, hybrid broilers had lower proportions of bone (i.e.18.91% of live weight) than both feeding systems.

Less body fat content indicates a higher quality of the carcass. It was found that hybrid broilers had highest percentage of total fat when they were fed with feeding system 1. The percentages of total fat of the 3-line crossbreeds were not affected by the feeding systems. There were therefore no significant differences between the crossbreeds ($p > 0.01$). However, the 4-line crossbreeds fed with feeding system 1 had the lowest percentage of total fat (2.28%), which was different to the hybrid broiler ($P \leq 0.01$). There were no significant differences between the crossbreeds in the proportion of total carcass, dressing carcass, meat, skin, bone and total fat. Between the sexes there were no significant difference in the composition of the carcass, also in the interaction between breed and sex ($p > 0.01$), but the interaction between feed and sex was significant in the percentage of total carcass, dressing and meat ($p \leq 0.05$ and $p \leq 0.01$), respectively.

Different parts of the carcass

A comparison of the effect of feeding systems and breeds on the carcass parts is presented in Table 4.24. In most of the tested traits of the proportions of the carcass there were significant effects of the feeding system and of the breed. The hybrids had higher percentages of thigh and breast. It was found that the feeding systems did not make any differences in the carcass parts of the 3-line and 4-line crossbreeds ($p > 0.01$). Some of carcass parts of the crossbreeds showed a higher proportion than for the hybrid broilers, such as drumstick, wing stick, tulip wing and total wing ($p \leq 0.01$). There were no significant differences between the breeds in the proportion of back for both feeding systems ($p > 0.01$). However, hybrid broilers fed with feeding system 1 had the greatest percentage of breast (35.63%), more than the crossbreeds with either feeding system ($p \leq 0.01$). Sex did not have any significant effects on the percentage in either parts of the carcass. Also the interactions between the factors of variance were not significant in all cases ($p > 0.01$).

Meat proportion of carcass parts

A comparison of the effects of feeding system and breed on meat proportions of all carcass parts is presented in table 4.25. The largest proportion of meat was from the breast, which is normally called the "white meat". No significant differences in the proportions of meat were found between the feeding systems ($p > 0.01$), except for the percentage of breast meat. The interaction between feeding system and breed for the meat percentage of the breast and the back was significant ($p > 0.01$). In the other tested traits the interactions between feeding system and breed were not significant ($p>0.01$). The hybrid broilers had lower percentages of drumstick, wing stick and total wing. The hybrid broilers fed with feeding system 1 had a higher proportion of breast meat (24.63% of the dressed carcass) than the other breeds, also under feeding system 2 ($p\leq0.01$). The percentages of breast meat were not significantly different between the three types of chicken with feeding system 2. Therefore, among the crossbreeds which were fed with two types of feeding system, the percentages of meat in each part were not significantly different ($p>0.01$). It was clearly seen that the female chicken had a higher percentage of breast meat and a lower percentage of thigh meat than the males ($p\leq0.01$). There was no important interaction between sex and the other effects.

Bones proportion of carcass parts

Comparisons of the effects of feeding system and breed on the percentage of bone in all carcass parts presented in table 4.26 It was found that the feeding systems influence the percentage of drumstick bone and breast bone ($p\leq0.01$). The bone proportion of the other carcass parts was not influenced by the feeding systems ($p>0.01$). The sexes did not have any effects on bone proportion of either part of the carcass ($p>0.01$), except for the male breastbone, which was higher than the female's ($p\leq0.01$). The types of breeds affected the proportion of bone of the carcass. The hybrid broilers had a significantly lower percentage of bones of the carcass than the crossbreeds in both feeding systems, such as drumstick bone, thigh bone, wing stick bone, tulip wing bone and back bone ($p>0.01$). Thus, the skeleton ratio of the dressing carcass of the hybrid broilers was smaller than that of the crossbreeds. However, the proportion of bones of any of the carcass parts of the crossbreeds was not significantly different ($p>0.01$), except for the back bone of the 4-line crossbreeds with feeding system 1, which was higher than for same breeds fed with feeding system 2 ($p\leq0.01$)

Skin proportion of carcass parts

Comparisons of the effects of feeding system and breed on the percentage of skin for all carcass parts present in table 4.27 In general, skin considered as an edible part. The proportion of skin in all parts of the carcass was relatively low compares to the proportions of meat and bone. The proportion of skin varied from 1.0 to 3.0 % of the dressing weight of the chicken. However, the results showed that the breeds of chicken had a significant effect on the proportion of thigh skin, tulip wing skin and back skin at the confident level of 99%, 95% and 95%, respectively. Nevertheless, the same type of chickens fed with different feeding systems had no significant difference on percentage of skin in every carcass parts ($p>0.01$). The proportion of skin in the major carcass part such as drumstick, total wing and breast were not significant differences among the types of chicken, feeding systems and sexes ($p>0.01$). The interactions between the main effects were not significant ($p>0.01$), except for tulip wing ($p>0.01$).

Table 4.23 Effects of feeding systems, chicken breeds on carcass-parts proportion

Treatment	Live weight[3] ±SD (g)	Proportion of: Total carcass	Dressing[1]	Meat	Skin	Bone	Total fat[2]
		% of live weight ±SD					
Feeding system 1							
Hybrid	2615.00 ± 255.32^{A}	83.21 ± 2.63^{A}	72.02 ± 1.84^{A}	38.60 ± 1.80^{A}	8.12 ± 0.47^{AB}	18.91 ± 1.54^{C}	6.64 ± 1.91^{A}
3-line crossbreeds	1349.17 ± 230.44^{CD}	80.11 ± 2.52^{B}	67.24 ± 1.77^{B}	31.99 ± 2.13^{B}	7.11 ± 0.99^{AB}	23.90 ± 1.86^{AB}	4.30 ± 1.72^{ABC}
4-line crossbreeds	1448.33 ± 316.19^{C}	82.27 ± 1.62^{AB}	68.73 ± 1.64^{AB}	34.01 ± 1.86^{B}	6.58 ± 1.43^{B}	24.96 ± 1.26^{A}	2.28 ± 1.16^{C}
Feeding system 2							
Hybrid	1668.33 ± 239.61^{B}	82.14 ± 1.41^{AB}	66.68 ± 2.86^{B}	32.31 ± 2.52^{B}	8.68 ± 1.28^{A}	20.64 ± 1.02^{C}	5.88 ± 2.26^{AB}
3-line crossbreeds	1158.33 ± 238.53^{D}	80.80 ± 2.71^{AB}	68.13 ± 5.06^{AB}	33.68 ± 2.66^{B}	8.21 ± 1.54^{AB}	22.33 ± 1.04^{C}	3.48 ± 1.21^{C}
4-line crossbreeds	1261.67 ± 162.66^{CD}	80.80 ± 1.74^{AB}	65.28 ± 3.70^{B}	31.52 ± 3.34^{B}	6.70 ± 0.94^{B}	22.55 ± 1.26^{B}	3.98 ± 1.13^{BC}
Sex							
Male	1769.44 ± 545.13^{A}	81.66 ± 2.61	67.33 ± 4.42	33.29 ± 3.91	7.45 ± 1.32	22.26 ± 2.03	4.20 ± 1.46
Female	1397.50 ± 489.33^{B}	81.46 ± 1.98	68.69 ± 2.33	34.08 ± 2.61	7.69 ± 1.42	22.17 ± 2.75	4.65 ± 2.62
Significance							
Feeding system	**	ns	**	**	**	ns	ns
Breed	**	**	**	**	**	**	**
Sex	**	ns	ns	ns	ns	ns	ns
Feed x Breed	**	ns	*	**	ns	**	ns
Feed x Sex	*	*	**	**	ns	ns	ns
Breed x Sex	ns	ns	ns	ns	ns	ns	*
Feed x Breed x Sex	ns	ns	ns	ns	ns	ns	ns

g: Gram
[1]: Dressed carcass, excluding, head, neck and legs.
[2]: Total fat, including abdominal fat pad and adipose fat from dressing.
[3]: Slaughter age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks.
Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.0 level (**, A, B, C), [ns]: Non significant at the 0.01 level

Table 4.24 Effects of feeding systems, chicken breeds on carcass-parts proportion

Treatments	Carcass Parts[1]						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[2]	Breast	Back
	% of dressed carcass[3] ±SD						
Feeding system 1							
Hybrid	15.00±0.58^{C}	17.38±0.68^{AB}	5.54±0.13^{E}	4.53±0.27^{B}	11.35±0.38^{C}	35.63±2.33^{A}	20.90±1.65
3-line crossbreeds	7.00±0.21^{AB}	16.82±0.74^{B}	7.24±0.36^{BC}	5.63±0.20^{A}	14.94±0.40^{A}	30.10±1.06^{C}	20.90±1.01
4-line crossbreeds	16.92±0.70^{ABC}	16.87±0.43^{B}	7.06±0.26^{C}	5.77±0.15^{A}	14.80±0.66^{A}	31.24±1.11^{BC}	19.97±0.99
Feeding system 2							
Hybrid	16.02±1.09^{BC}	17.85±0.40^{A}	6.23±0.48^{D}	5.02±0.18^{AB}	12.90±0.78^{B}	32.87±1.73^{B}	21.29±2.05
3-line crossbreeds	17.64±1.06^{A}	16.65±0.77^{B}	7.72±0.54^{AB}	5.36±1.23^{AB}	15.56±0.87^{A}	29.36±2.36^{C}	20.80±1.23
4-line crossbreeds	17.53±1.21^{A}	16.88±0.38^{B}	7.93±0.59^{A}	5.80±0.59^{A}	15.73±0.53^{A}	29.14±0.83^{C}	20.71±0.91
Sex							
Male	16.86±1.37	17.25±0.65	7.08±1.08	5.43±0.62	14.32±1.82	30.88±2.94	20.78±0.96
Female	16.32±1.08	16.90±0.70	6.82±0.78	5.28±0.80	14.10±1.62	31.89±2.60	20.75±1.66
Significance							
Feeding system	**	ns	**	**	**	**	ns
Breed	**	**	**	**	**	**	ns
Sex	ns	ns	ns	ns	ns	ns	ns
Feed x Breed	ns	ns	ns	ns	ns	ns	ns
Feed x Sex	ns	ns	ns	ns	ns	ns	ns
Breed x Sex	ns	ns	ns	ns	ns	ns	ns
Feed x Breed x Sex	ns	ns	ns	ns	ns	ns	ns

[1]: including bones and skin, meat
[2] : Total wing includes wing stick, tulip wing and end wing
[3]: Dressed carcass, excluding, head, neck and legs, slaughtered age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks;
Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01level (**, A, B, C), [ns] :Non significant at the 0.01 level.

Table 4.25 Effects of feeding systems, chicken breeds on carcass-parts meat proportion

Treatments	Meat of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Feeding system 1							
Hybrid	9.50 ± 0.51^{b}	10.76 ± 0.87	2.57 ± 0.24^{B}	1.67 ± 0.22	4.21 ± 0.26^{CB}	24.63 ± 1.75^{A}	4.84 ± 0.71^{a}
3-line crossbreeds	10.56 ± 0.45^{a}	10.49 ± 0.66	3.23 ± 0.21^{A}	1.88 ± 0.22	5.06 ± 0.29^{A}	19.97 ± 0.97^{B}	2.86 ± 0.59^{c}
4-line crossbreeds	10.11 ± 0.82^{ab}	10.78 ± 0.59	3.35 ± 0.27^{A}	1.72 ± 0.49	5.07 ± 0.42^{A}	20.59 ± 1.58^{B}	2.84 ± 0.43^{c}
Feeding system 2							
Hybrid	9.95 ± 0.91^{ab}	11.17 ± 0.75	2.99 ± 0.51^{AB}	1.76 ± 0.33	4.64 ± 0.85^{AB}	19.80 ± 0.68^{B}	3.44 ± 0.83^{bc}
3-line crossbreeds	10.53 ± 0.79^{a}	10.55 ± 0.40	3.34 ± 0.41^{A}	1.93 ± 0.19	5.19 ± 0.35^{A}	19.12 ± 2.00^{B}	4.04 ± 0.52^{ab}
4-line crossbreeds	10.41 ± 0.72^{a}	10.64 ± 0.46	3.52 ± 0.32^{A}	1.79 ± 0.24	5.31 ± 0.27^{A}	18.84 ± 1.36^{B}	4.06 ± 0.29^{ab}
Sex							
Male	10.34 ± 0.76	11.02 ± 0.55^{A}	3.15 ± 0.49	1.81 ± 0.19	4.96 ± 0.51	19.72 ± 2.45^{B}	3.67 ± 0.90
Female	10.01 ± 0.75	10.44 ± 0.60^{B}	3.18 ± 0.41	1.76 ± 0.36	4.87 ± 0.63	21.26 ± 2.10^{A}	3.69 ± 0.93
Significance							
Feeding system	ns	ns	ns	ns	ns	**	ns
Breed	*	ns	**	ns	**	**	*
Sex	ns	**	ns	ns	ns	**	ns
Feed x Breed	ns	ns	ns	ns	ns	**	**
Feed x Sex	ns	**	ns	ns	ns	ns	ns
Breed x Sex	ns	ns	ns	ns	ns	ns	ns
Feed x Breed x Sex	ns	ns	ns	ns	ns	ns	ns

[1]: Total wing includes wing stick, tulip wing and end wing

[2]: dressed carcass, excluding, head, neck and legs, slaughter age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks;
Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01level (**, A, B, C), [ns] :Non significant at the 0.01 level

Table 4.26 Effects of feeding systems, chicken breeds on carcass-parts bone proportion

Treatment	Bone of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Feeding system 1							
Hybrid	3.94 ± 0.25^{D}	2.44 ± 0.23^{B}	1.89 ± 0.18^{B}	1.39 ± 0.11^{C}	1.29 ± 0.15^{B}	5.61 ± 0.66^{B}	10.45 ± 0.73^{D}
3-line crossbreeds	5.04 ± 0.37^{AB}	3.57 ± 0.46^{A}	2.72 ± 0.21^{A}	2.03 ± 0.17^{AB}	2.06 ± 0.28^{A}	6.20 ± 1.04^{A}	13.86 ± 0.87^{AB}
4-line crossbreeds	4.83 ± 0.20^{CB}	3.48 ± 0.23^{A}	2.61 ± 0.35^{A}	2.18 ± 0.22^{A}	1.98 ± 0.41^{A}	6.59 ± 0.66^{A}	14.24 ± 1.09^{A}
Feeding system 2							
Hybrid	4.34 ± 0.57^{CD}	2.66 ± 0.25^{B}	2.09 ± 0.27^{B}	1.79 ± 0.26^{B}	1.66 ± 0.17^{AB}	6.60 ± 0.61^{A}	12.65 ± 1.20^{BC}
3-line crossbreeds	5.46 ± 0.51^{A}	3.58 ± 1.67^{A}	2.88 ± 0.46^{A}	1.95 ± 0.16^{AB}	2.03 ± 0.24^{A}	6.14 ± 0.46^{A}	12.79 ± 1.07^{ABC}
4-line crossbreeds	5.49 ± 0.51^{A}	3.65 ± 0.28^{A}	2.58 ± 0.12^{A}	2.02 ± 0.23^{AB}	2.01 ± 0.28^{A}	5.92 ± 0.67^{A}	11.95 ± 0.72^{CD}
Sex							
Male	4.99±0.66	3.21±0.61	2.53±0.46	1.98±0.20	1.83±0.35	6.48 ± 0.60^{A}	12.54±1.67
Female	4.71±0.72	3.25±0.52	2.39±0.43	2.00±0.14	1.84±0.40	5.87 ± 0.76^{B}	12.78±1.46
Significance							
Feeding system	**	ns	ns	ns	ns	**	ns
Breed	**	**	**	**	**	**	**
Sex	ns	ns	ns	ns	ns	**	ns
Feed x Breed	ns	ns	ns	**	ns	**	**
Feed x Sex	ns	**	ns	ns	ns	ns	ns
Breed x Sex	ns	ns	ns	ns	ns	ns	ns
Feed x Breed x Sex	ns	ns	ns	ns	ns	ns	ns

[1: Total] wing includes wing stick, tulip wing and end wing

[2]: dressed carcass, excluding, head, neck and legs, slaughter age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks; Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01level (**, A, B, C), [ns] :Non significant at the 0.01 level

Table 4.27 Effects of feeding systems, chicken breeds on carcass-parts skin proportion.

Treatment	Skin of						
	Drumstick	Thigh	Wing stick	Tulip wing	Total wing[1]	Breast	Back
	% of dressed carcass[2] ±SD						
Feeding system 1							
Hybrid	1.12±0.16	$2.59±0.31^{A}$	$0.98±0.09^{ns}$	$1.31±0.15^{ab}$	$2.20±0.26^{ns}$	2.85±0.35	$2.54±0.37^{ab}$
3-line crossbreeds	1.10±0.26	$2.27±0.32^{ABC}$	$1.06±0.17^{ns}$	$1.54±0.24^{ab}$	$2.60±0.38^{ns}$	3.02±0.37	$1.63±0.61^{ab}$
4-line crossbreeds	0.91±0.18	$1.96±0.21^{BC}$	$0.96±0.16^{ns}$	$1.59±0.39^{ab}$	$2.55±0.48^{ns}$	2.82±0.46	$1.43±0.60^{b}$
Feeding system 2							
Hybrid	1.60±0.54	$2.33±0.38^{AB}$	$1.16±0.25^{ns}$	$1.23±0.80^{b}$	$2.69±0.63^{ns}$	3.55±0.90	$2.70±0.98^{a}$
3-line crossbreeds	1.37±0.31	$1.83±0.52^{BC}$	$1.18±0.20^{ns}$	$1.63±0.27^{ab}$	$2.81±0.27^{ns}$	2.84±0.72	$1.86±0.35^{ab}$
4-line crossbreeds	1.35±0.52	$1.76±0.30^{C}$	$1.33±0.20^{ns}$	$1.72±0.36^{a}$	$3.21±0.48^{ns}$	2.98±0.77	$2.53±0.88^{ab}$
Sex							
Male	1.24±0.45	$2.00±0.47^{b}$	1.14±0.21	1.55±0.33	2.80±0.54	2.96±0.75	2.13±0.76
Female	1.20±0.30	$2.24±0.39^{a}$	1.08±0.22	1.46±0.45	2.55±0.45	3.06±0.52	2.10±0.86
Significance							
Feeding system	ns	*	**	ns	*	ns	*
Breed	ns	**	ns	*	ns	ns	*
Sex	ns	*	ns	ns	ns	ns	ns
Feed x Breed	ns	ns	ns	**	ns	ns	ns
Feed x Sex	ns	ns	ns	ns	ns	ns	ns
Breed x Sex	ns	ns	ns	ns	ns	ns	ns
Feed x Breed x Sex	ns	ns	ns	ns	ns	ns	ns

[1]: Total wing includes wing stick, tulip wing and end wing

[2]: dressed carcass, excluding, head, neck and legs, slaughter age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks;

Different letters in the same column show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01level (**, A, B, C), ^{ns}: Non significant at the 0.01 level.

4.3.4 Mortality

The mortality of chickens is presented in table 4.28. Mortality of the hybrid broilers receiving feeding system 1 during the period of week 0-7 was significantly higher (p>0.01) than of the other breeds in either feeding system 1 or 2. The feeding systems had no effect on the mortality of the crossbreeds at any growing stage of 0-7 or 0-12 weeks. Their mortality was relatively low (p>0.01). The sex ratio did not give any significant effect between the breeds and the feeding system (p>0.01), although the 4-line crossbreeds had a higher sex ratio (1.09). But there was no significant difference to other breeds and between the feeding systems.

Table 4.28 Mortality of chickens in experiment 1 and 2

Treatments	Mortality (%)[1]			Sex ratio (M:F)
	0-7	0-12	0-20	
Feeding system 1:				
Hybrid	15.00±7.07^{A}			0.81±0.01
3-Line Cross-Breed	0.00±0.00^{B}	0.00±0.00		0.82±0.14
4-Line Cross-Breed	1.00±0.41^{B}	4.00±3.65		0.85±0.09
Feeding system 2:				
Hybrid	2.00±0.00^{B}			0.75±0.00
3-Line Cross-Breed	4.00±0.00^{B}	8.00±0.00		0.84±0.00
4-Line Cross-Breed	0.00±0.00^{B}	4.00±0.00		1.09±0.00
Native Chicken	0.00±0.00^{B}	0.00±0.00	3.37±0.58	
Significance				
Feed	ns	ns		ns
Breed	**	ns		ns
Feed x breed	ns	ns		ns

[1]: Slaughter age for hybrid broilers at 7 weeks, 3-Line and 4-Line crossbreeds at 12 weeks.

Different letters show significant differences between types of chicken and between sexes at the 0.05 level (*, a, b, c) and at the 0.01 level (**, A, B, C), ^{ns}: Non significant at the confident 0.01 level.

5 DISCUSSION

5.1 Growth of the chickens

5.1.1 Growth of hybrid broilers

Hybrid broilers overall exhibited better growth than the other breeds. They have been specifically bred for rapid weight gain and high feed utilization efficiency (NRC, 1994). At 7 weeks the hybrid broilers received a commercial broiler diet (feeding system 1). Their individual mean weights were 2,673.7 g for the males and 2,314.3 g for the females, with an average daily gain (ADG) of 54.6 and 47.3 g/bird, respectively. Birds, which were fed with a lower protein diet (feeding system 2), developed much lower body weights, i.e.1,597.8 g/bird for the males and 1,931.1 g/bird for the females, with an ADG of 39.4 and 32.6 g/bird/day, respectively. This shows clearly that the hybrid broilers only demonstrated their full growth potential when they were fed with high protein diet (commercial feed). Body weights of the hybrid broilers from experiment 1 were remarkably higher than those reported by NRC (1994), which were 2,100 g/bird for males and 1,745 g/bird for females at the age of 7 weeks. This indicates that the growth of hybrid broilers has been improving continuously since the NRC report in 1994. This trend is due to continued breeding and improvement of the rearing environment (Chapman, 2003).The growth of the hybrid broilers raised in the bamboo slat floor system was similar to hybrid broilers raised in closed evaporation-cooled housing systems, which typically reach a body weight at 49 days of 2,324 g/bird and have an FCR of 1.98 (Pornrawee, 2003). This was due to simpler management of smaller flock sizes (50 birds/pen) compared to the large number of chicks (7,000 birds) in the housing system.

Hybrid broilers showed significantly higher body weight gain than native crossbreeds in both feeding systems (experiments 1 and 2) (Tables 4.1, 4.10 and 4.19) – four times greater than the native chickens in experiment 2. Genetic disposition was the major factor affecting the growth rate of chickens. Although hybrid broilers received lower quality diet, they had better growth rate than native crossbreeds and native chickens. However, the rapid growth of hybrid broilers also led to higher mortality. Because raised body temperature generates a higher rate of metabolism – which is characteristic for hybrid broilers – their adaptability to the hot and humid climate at the research site was lower and they suffered higher stress levels due to limited space within the pen.

The growth of hybrid broilers in feeding system 1 was greater than those in feeding system 2 at rates of 92, 57.3, 50.2, 20.1 and 42.0% over 0-1, 1-3, 3-5, 5-7 and 0-7 weeks, respectively. It was clear that the overall growth of hybrid broilers decreased approximately 42% in feeding system 2, compared to feeding system 1. Declining growth of hybrid broilers was greater in the early stages of growth. This clearly indicates that feeding system 2 affected the growth rate of hybrid broilers. This information supports the notion that that high genetic disposition requires higher quality of feed.

5.1.2 Growth of crossbred chickens

Native crossbred chickens had better growth rates compared to native chickens. This validates the introduction of some exotic breeds to improve the growth rates of native breeds. The experimental results clearly showed that a 3-line crossbreed (NRB) had lower growth rates than a 4-line crossbreed (NSRB) at 18.1, 8.9 and 11.4% over 0-7, 8-12 and 0-12 weeks, respectively in feeding system 1. Thus, their growth rate was still lower than 4-line crossbreeds at 5.3, 5.6 and 5.5%, respectively but higher than native chickens at 15.6, 38.28 and 27.7% respectively in feeding system 2.

The 3-line is a popular native crossbreed, which was introduced to the poultry market over the last two decades. Growth of 3-line crossbreeds is mostly related to the quality of the dietary and feeding program. The experimental results showed that feeding systems 1 and 2 had no significantly different effects on growth of the 3-line crossbreeds. This means that enhancing the genetic disposition of 3-line crossbreds responded to one level of environment. The final body weight gains (g/bird) and ADG (g/bird/day) of 3-line crossbreeds (NRB) at 12 weeks were 1,334.8, 15.9 and 1,177 g, 14.0g for feeding systems 1 and 2, respectively. Such growth was better than that found in the study of Jeendoung *et al.* (2001) which revealed that 3-line crossbreeds (NRB) in Thailand were fed with a commercial diet for layers, with dietary protein of 19-13% for 16 weeks. The final body weight was 1,275.1 g/bird, with AGD of 14.7 g/bird/day, respectively. Tangtaweewiwat *et al.* (2000) reported from Thailand that the ADG of a 3-line crossbreed during 0-5 weeks and 6-13 weeks was 10-11 and 19-20 g/bird/day, respectively. These values were very similar to the ADG of a 3-line crossbreed (strain Suwan 6, NSB) – also in Thailand – over 0-6 and 7-12 weeks, which was 10-11 and 20-21 g/bird/day respectively (Vorachantra and Tancho, 1996). Panja (2000) found that 3-line crossbreed sources from two commercial companies and the Department of Livestock Development (DLD) were raised with a commercial diet (18% dietary protein and 2,700 Kcal ME/kg) over the growing period of 16 weeks. The average body weights were 2,100.0, 2,005.0 and 1,741.5 g/bird, respectively. Commercial companies produced faster growing chickens than government sources. According to Purintrapiban (2004), 3-line crossbreeds (NRB) received 16% dietary protein supplemented with palm kernel cake (at levels of 10, 20 and 30% in the diet formula) and energy levels of 2,800-3,000 Kcal ME/kg for 16 weeks. The chicks gave the best ADG which varied between 22.25-23.30 g/bird/day, and total weights of 2,492.50 and 2,610.00 g/bird. The higher body weight might be attributable to the palatability of the diet. Thus, feeding 3-line crossbreeds with feeding system 2 is better for small-scale farmers because of its lower production cost and simple feed formulation and manufacturing.

Similarly, for 4-line crossbreeds using feeding system 2, the body weight at 12 weeks (1,242 g/bird) was comparable to the results of Intarachote *et al.* (1996a) who found that the body weights for the same type of crossbreeds (NSRB) at 12, 16 and 20 weeks were 1,146.20, 1,603.72 and 1,806.44 g/bird, respectively. Four-line crossbreeds using feeding system 2 (19-17-12% dietary protein) had higher body weight at 12 weeks than the results of Chomchai *et al.* (1998a) who fed them with 12.13, 13.19, 17.36 and 19.82% dietary protein over 14 weeks for each diet. This also validates that feeding system 2 is suitable for 4-line crossbreed rearing. According to Chomchai *et al.* (1998b), 4-line crossbreeds receiving 18% dietary protein had better growth than those receiving 11% dietary protein and a group that received 18% in the early stages and 11% dietary protein in the final stages for the same growing period. This indicates that higher dietary protein content improves the body weight and daily weight gain.

5.1.3 Growth of native chickens

The productivity of native chickens is generally poor because of genetic disposition, the rural environment, local feed availability, diseases and parasites. Several programs have attempted to improve their production to maximize profitability, availability for household consumption, as well as for marketing purposes. The results of experiment 2 showed that the body weight of native chickens had a lower significant difference from the weights of hybrid broilers and the crossbreeds. Thus, the growth of native chickens still not exceed that of the 3-line crossbreeds in both feeding systems, while 3-line crossbreds exhibited similar performances for both feeding systems. Improving the quality of diet could improve the growth of native chickens.

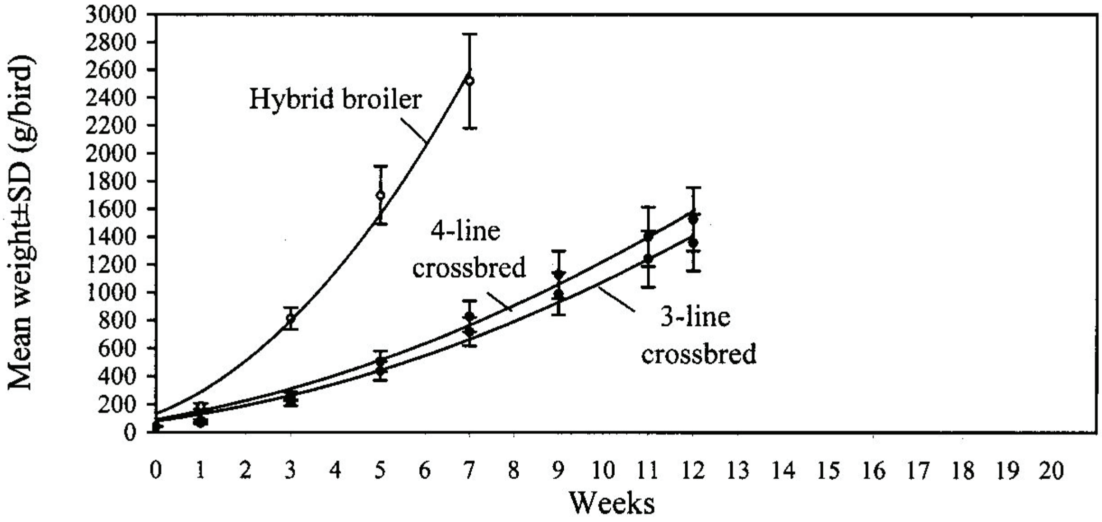
The growth of native chickens (Tables 4.10 and 4.11) was compared to the findings of Panja (2000). Native chicken raising in Thailand received 18% dietary protein for 4 months. The average final body weight was 1,525 g/bird. This was similar to the results of Ratanasetagul (1988). Body weights of native chickens receiving 21-18% and 19-16% dietary protein for 16 weeks were 1,327.6 and 1,302.5 g/bird, respectively. Kajarern *et al.* (1988) in Thailand reported that native chickens reared with a diet of the17-14% protein plus supplementary formulated feed and scavenging had final body weight at 20 weeks of only 1,319 g/bird, although the amount of feed intake from natural scavenging was not measurable. Leotaragul and Pimkamlai (1999) reported that native chickens raised on a research station in Thailand, which received a commercial layer diet *ad libitum* for 16 weeks, reached a body weight of 1,362 g/bird. Panja (2000) reported that native chickens (source – DLD) raised with 18% commercial dietary protein and 2,700 Kcal ME/kg for 16 weeks had an average body weight of 1,525 g/bird. The results of the experiment are also similar to the findings from research in Thailand reported by Teerapantuwat (1988), Thummabood (1994) and Leotaragul *et al.* (1997). In these studies, the body weights of native chickens at 16 weeks were 1,200, 1,395 and 1,415 g/bird, respectively. Chomchai *et al.* (1998b) reported that the body weight at the age of 14 and 16 weeks was 585.63 and 769.33g/bird, respectively when native chickens received 11% dietary protein over the entire growing period. Thus, dietary energy levels did not influence final weight and growth of native chickens i.e. 2,800 and 2,650 Kcal ME/kg for 12 weeks.

Thamabood and Choprakarn (1982) analysed improved native chicken growth at the village level. The growth rate remained at 10.6 g/bird/day over 4 months. These chickens were free scavengers and were supplemented with 10% dietary protein. Improving the growth of native chickens could be achieved by feeding them with a good quality diet. The ADG of native chickens reached 15 g/bird/day when they were fed with a commercial broiler diet (Rotjanasatid *et al.*, 1983), and was 13 g/bird/day when they received 18% dietary protein (Choprakarn *et al.*, 1985). Growth was also affected by environment, i.e less stocking density or individual caging. However, the growth of native chickens could be as low as 5.95 and 6.97 g/bird/day for the growth stages of 2-14 weeks and 2-16 weeks for birds that received 11% dietary protein over the entire growing period (Chomchai *et al.*, 1998). Growth of native chickens varied according to many factors, i.e. inconsistent genetics. This can be distinguished by physical morphology. In some regions contamination of exotic breeds has occurred and there is an unidentified genetic pattern.

Feeding system 2 has better potential for native chickens raised by small farmers. The farmers can enhance performance further by improving the rearing system, such as pen confinement, with bamboo slat floors. However, the raising of native chickens with feeding system 2 is also feasible in a free-range system that allows scavenging for natural food with supplementary 12% dietary protein over 7-20 weeks. This is an appropriate system for farmers.

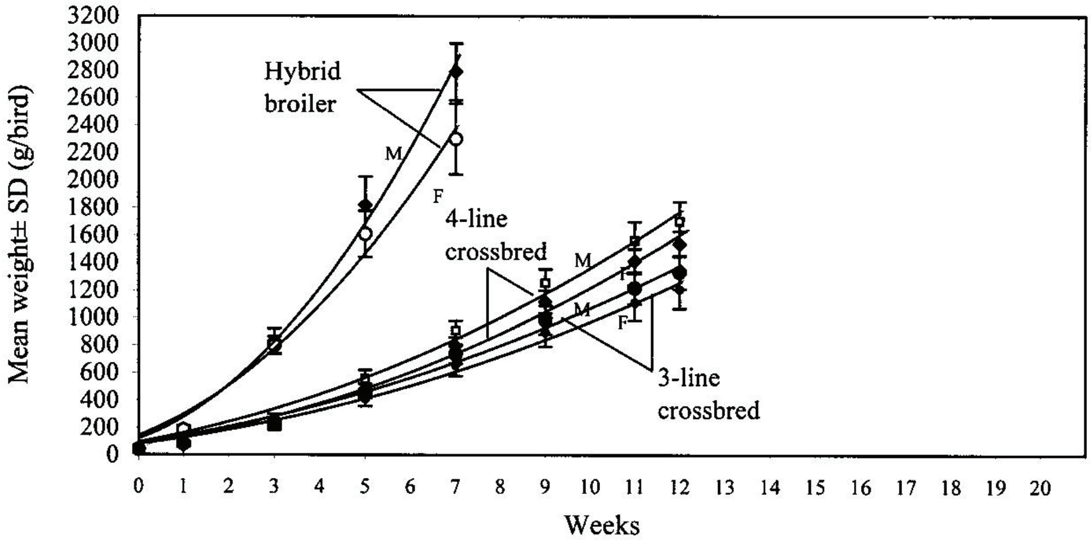
5.1.4 Growth performance models

The growth of the different breeds can be described well with second order polynomial models, i.e. $y = a + bx + cx^2$. Figure 5.1 shows that growths of chickens were very slow in the early stage (i.e. the first 3 weeks); this is especially evident for the crossbreeds and the native chickens. The hybrid broilers displayed a progressively increasing weight until slaughtering, while 3-line and 4-line crossbreeds exhibited a more regular overall growth pattern (Figures 5.1 and 5.2). There were small but significant differences between 3-line and 4-line crossbreeds (the 4-line crossbreeds performed slightly better), which became more pronounced from the fifth week onwards. The different growth patterns between the sexes is shown in Figure 5.2. For all breeds, the body weight of male birds was significantly greater than that of the females.



Breed	Model equation	r^2
Hybrid broilers	$Y= 52.47x^2+59.196x+39.90$	0.9904
3-line crossbreeds	$Y= 5.4423x^2+34.587x+38.93$	0.9908
4-line crossbreeds	$Y= 5.6438x^2+45.489x+39.28$	0.9905

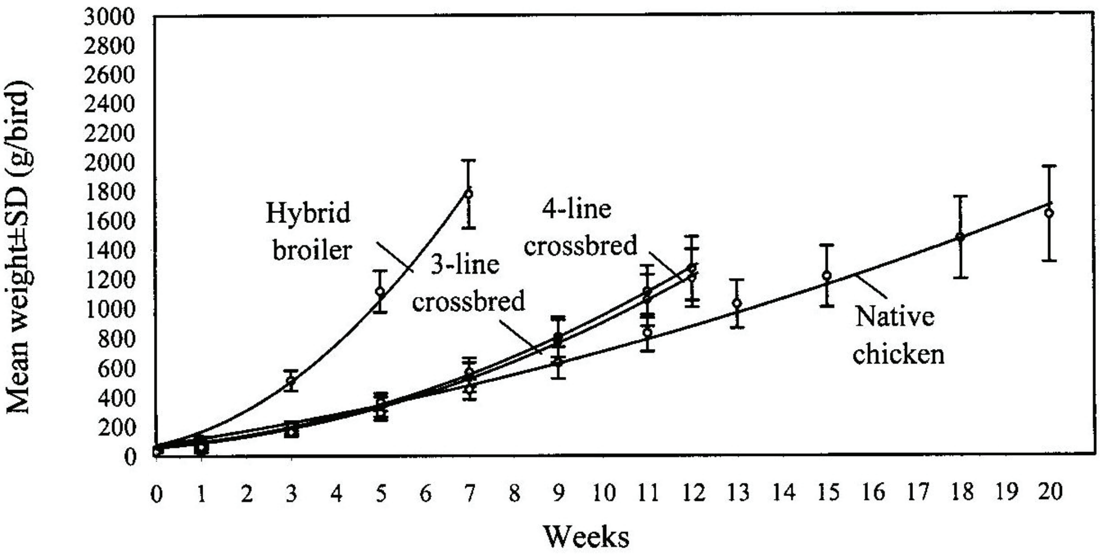
Figure 5.1 Polynomial growth models of chickens by breeds in experiment 1



Breeds	Sex	Model equation	r^2
Hybrid broilers	Male	$Y = 38.935x^2+40.839x+39.90$	0.9933
	Female	$Y = 27.165x^2+74.166x+39.90$	0.9864
3-line crossbreeds	Male	$Y = 6.5652x^2+34.703x+39.28$	0.9908
	Female	$Y = 4.4873x^2+35.171x+39.28$	0.9896
4-line crossbreeds	Male	$Y = 6.4957x^2+48.578x+38.93$	0.9905
	Female	$Y = 4.6693x^2+42.232x+38.93$	0.9905

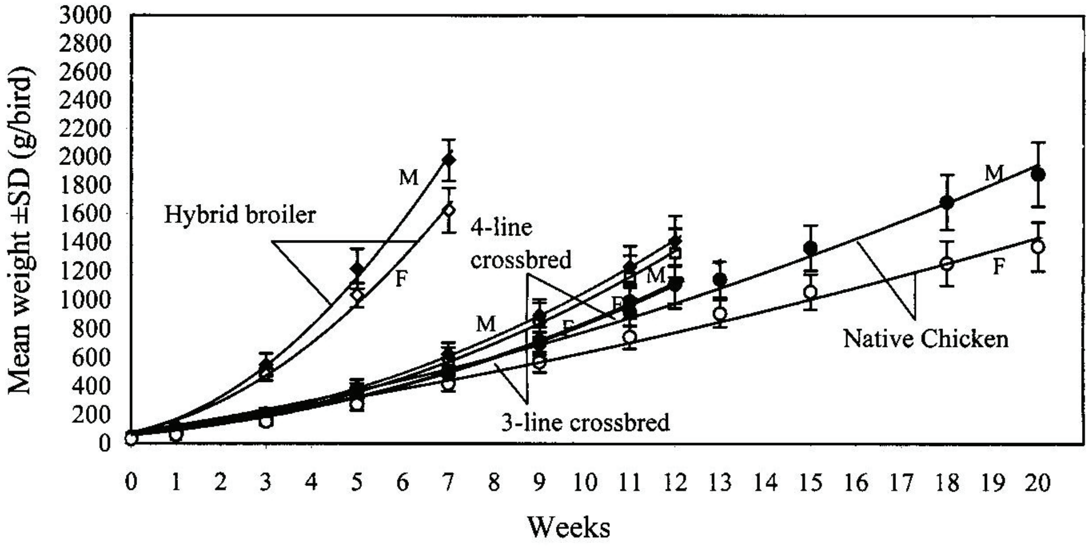
Figure 5.2 Polynomial growth models of chickens by breeds and sexes in experiment 1

There is an important local niche market in Thailand for chickens with light carcass weight, which hybrid broilers reach earlier (Figure 5.1), but they do not reach the slaughter maturity for the acceptable meat quality. Raising chickens for a longer period, therefore, is not always economical for the farmers. The 4-line crossbreeds reach marketable size (1,200-1,400 g/birds live weight) at 9 weeks while the 3-line crossbreeds require another 1 to 2 weeks to reach the same weight. Female chickens require 2 to 3 weeks longer to reach the same weight as the male chicken. The strategy for farmers who raise crossbreeds is to sell the chickens that have reached marketable size earlier, particularly during the period from week 9 to week 12, either slaughtered on demand or alive.



Breeds	Model equation	r^2
Hybrid broilers	$Y = 26.173x^2+11.621x+38.9$	0.9958
3-line crossbreeds	$Y = 5.902x^2+13.519x+37.93$	0.9988
4-line crossbreeds	$Y = 6.217x^2+14.01x+42.10$	0.9905
Native chickens	$Y = 1.7189x^2+42.187x+29.2$	0.9921

Figure 5.3 Polynomial growth models of chicken by breeds in experiment 2



Breeds	Sex	Model equation	r^2
Hybrid broilers	Male Female	$Y = 30.061x^2+5.593x+38.90$ $Y = 23.357x^2+15.266x+38.90$	0.9968 0.9950
3-line crossbreeds	Male Female	$Y = 6.6945x^2+13.122x+37.93$ $Y = 4.9524x^2+17.566x+37.93$	0.9987 0.9983
4-line crossbreeds	Male Female	$Y = 6.9204x^2+15.799x+42.18$ $Y = 5.1058x^2+16.642x+42.18$	0.9993 0.9986
Native chickens	Male Female	$Y = 2.2987x^2+43.017x+29.22$ $Y = 1.175x^2+42.14x+29.29$	0.9937 0.9896

Figure 5.4 Polynomial growth models of chickens by breeds and sexes in experiment 2

The body weight of hybrid broilers was generally higher than that of native chickens and native crossbreeds, even when they were fed with a low nutrient diet (Figure 5.3). This was attributable to the exceptional genetic potential of the hybrid broilers. The growth of native chickens and native crossbreeds showed a similar trend, there was even an overlap until weeks 5 to 7. Then, the trend was more progressive with the crossbreeds. This demonstrated that crossbreeding of local and exotic breeds enhanced the growth of the local breeds. For the hybrid broilers, both male and female birds reached marketable size earlier (Figure 5.4). This was clearly much slower than in experiment 1, where the birds had reached the same size already 3 weeks earlier. There were similar growth trends for the same sex with 3- and 4-line crossbreeds. Male chickens showed faster growth than female chickens. The 3- and 4-line crossbreeds reached marketable size around week 11, about 4 weeks earlier than the native chickens, which reached marketable weight in week 15. Some male native chickens reached marketable size after 13 weeks; this was from week 15 for the females (Figures 5.3 and 5.4). The average body weight of native chickens at 20 weeks was higher than the marketable size reported by Kajarern *et al* (1988); therefore, farmers could start to sell native chickens from week 16 onwards with an average weight size of

1,042 g. Teerapantuwat (1988), however, found that the most suitable size for marketing of native chickens was 1,310 g.

5.2 Feed utilization efficiency

5.2.1 Feed utilization efficiency of hybrid broilers

The hybrid broilers' feed intake was significantly higher than the other breeds; i.e. for the period 0-7 weeks, the slaughter age for the broilers; it was 4-fold higher than the crossbreeds with feeding system 1 and 3-fold higher than the crossbreeds with feeding system 2 (Table 4.20). Feed utilization efficiency of the hybrid broilers was greater than the crossbreeds, especially with feeding system 1, with an FCR of 1.99 and feed conversion efficiency of 50.25%. Feed utilization efficiency of the hybrid broilers raised with feeding system 2 was still better than the crossbreeds, even though the differences were not significant ($P \leq 0.05$). With feeding system 2, the broilers had a lower feed intake than with feeding system 1 ($P \leq 0.01$). This was probably because the diet was not homogenous in grain size. The ground maize was very fine and had a broad grain-size range. This probably affected the intake ability of the broilers and the digestibility of the feed. Choil *et al*. (1986) cited by Nir (1994) confirmed that the texture of the diet affects digestibility, especially in the gizzard. It was found that the gizzard of hybrid broilers was much smaller than native chickens and crossbreeds. The fine particles in the diet caused agglomeration of pasty material on the beak, leading to an increase in water consumption and waste of feed in the water troughs (Eley and Bell, 1948 cited by Nir, 1994). Moran (1982) suggested that particle preference might be related to beak size – as birds age, their preference for large particle size increases (Nir *et al.*, 1990). The higher feed utilization of the broilers is due to their genetic disposition. In commercial systems, they are usually allowed to feed *ad libitum* to ensure rapid growth (NRC, 1994). Particle size affects the feed utilization of the chicken; ground maize grain in particular requires a strong contraction of the gizzard, leading to long retention of food in the gut; this affects the quantity of feed intake, which is clearly evident in experiment 2. However, hybrid broilers had higher capacity for a mixed diet than native chickens and native crossbreeds. As they attempted to eat as much as they could for energy, so behavior was constrained due to bulkiness; texture and palatability of the diet (Smith, 1990).

The feed utilization of hybrid broilers in experiment 1, which were fed with a commercial broiler diet, was better than the report of Sae-tang (1998) with overall a lower FCR, although there was higher mortality (15%). Kajarern and Kajarern (1984) reported that suitable dietary protein was 20 and 17% for 1-4 weeks and 4-8 weeks. Priem-Ngu-luam (2000) found that the level of dietary protein could be reduced by about 10% by supplementing with amino acid (about 20% of the amount recommended by NRC, 1994, i.e. methionine and cystein). Hybrid broilers had the same growth as the control treatment. Maximized growth was generally achieved by improving the quality of diet and feeding regime. Optimum growth performance, dietary quality and investment are factors for hybrid broiler raising by small-scale farmers, who focus on the local market and consumers. Feeding system 2 would be preferable.

5.2.2 Feed utilization efficiency of crossbred chickens

The amount of feed intake of the two types of crossbreeds was significantly different among feeding systems. Higher feed consumption occurred with feeding system 1 compared to feeding system 2 ($P \leq 0.01$). The amount of feed intake by 4-line crossbreeds was higher than 3-line crossbreeds when feeding system 1 was used, but it was the same in feeding system 2 ($P > 0.01$) for the overall growing period (0-12 weeks). During 0-7 weeks, the 4-line crossbreeds responded better to higher quality feed than the 3-line crossbreeds; 3-line crossbreds responded identically to both types of feeding systems. For weeks 8-12, feed utilization of 4-line crossbreeds was not significantly different between the two feeding systems (Table 4.21). Adaptation to feed by the crossbreeds was more clearly shown by a 3-fold increase in feed intake from 9 to12 weeks (the digestibility of coarse particles also increased).

Lower feed quality affected the amount of feed intake for all types of chickens, as their feed intake was lower compared to the good quality diet. Therefore, feed consumption among the crossbreeds was not significantly different. Improving native chickens by crossbreeding with other breeds could improve feed intake because crossbreeds exhibited greater feed intake (40% higher, 0-12 weeks) than native chickens in feeding system 2 in all growth stages, the type of feed being suitable for native chickens. Native chicken feed intake is characteristically low which leads to reduced growth. Chomchai *et al.* (1998b) reported that the feed intake of a 4-line crossbreed (NSRB) was higher than native chickens in all growing stages; also feed conversion efficiency was better in all growing stages.

Good quality diet correlates with a higher rate of feed intake. Three-line crossbreeds consumed 54.4 g and 45.3 g/bird/day for 0-12 weeks when they received feeding system 1 (21-19-17% dietary protein) and 2 (19-17-12% dietary protein), respectively. These observations correspond well with the observations by Panja (2000) who found that average feed intake of 3-line crossbreeds from 3 different sources (commercial), receiving 18% dietary protein with 2,700 kcal ME/kg through 16 weeks was 50.7, 54.8 and 53.2 g/bird/day for the different crossbreeds. It was slightly higher in feeding system 2 of the study. However, these data were much lower than 78.1-81.4 g/bird/day average feed intake over 2-16 weeks reported by Purintrapiban (2004). They fed 3-line crossbreeds (NRB) with 16% dietary protein and an energy level of 2,800-3,000 kcal ME/kg for 16 weeks. Oil palm stimulated feed intake, but less energy was obtained due to palm kernel cake containing higher fiber which poultry digest poorly.

The overall (0-12 weeks) feed intakes of the 4-line crossbreeds were 57.3 and 44.8 g/bird/day for feeding systems 1 and 2, respectively. The intakes were 56.5, 53.5 and 42.8 g/bird/day, respectively. The amount of feed intake was lower in the lower dietary protein scheme. This led to slower growth of chickens because birds did not receive enough protein and other nutrients, especially during the early stages of growth, which affected the growth of tissues and organs (Kantho, 1986). Chomchai *et al.* (1998a) also confirmed that chickens receiving lower levels of dietary protein demonstrate lower daily feed intake than chickens receiving higher dietary protein. This observation corresponded well with the report of Banasitthi (1988). The NRC (1984) states that lack of essential amino acids in the diet leads to a decreased level of amino acid in the blood, and the animals adjust by reducing their feed intake. Nevertheless, energy levels in the diet also influence the amount of feed intake by chickens. Chickens that received a low energy level diet had higher feed intake than chickens that received higher energy level feed.

Feed utilization efficiency of 3-line crossbreeds was lower than 4-line crossbreeds when they received the same type of diet. They responded positively to the good quality diet. The FCR of the 3-line crossbreeds was 2.93 and 3.23 for feeding system 1 and 2, respectively. Whilst the FCR of 4-line crossbreeds fed with both feeding systems was 2.77 and 3.03, respectively. Panja (2000) reported an FCR of 3.11 for 3-line crossbreeds (produced by the DLD) fed with 18% dietary protein and 2,700 kcal ME/kg for 16 weeks. In the same type of chicken (produced by two private companies) fed with the same diet, the FCR was as low as 2.69 and 2.77, respectively. These FCRs were much lower than those reported by Purintrapiban (2004) which were as high as 3.48-3.59 for 3-line crossbreeds (NRB) receiving 16% dietary protein and an energy level of 2,800-3,000 kcal ME/kg for 16 weeks. Intarachote *et al.* (1996b) found that the FCRs of 3-line crossbreeds (NSB) and 4-line crossbreeds (NSRB) receiving commercial broiler diet during the 8-12 weeks of growth were 3.56 and 3.26, respectively, whereas FCRs during 0-12 weeks were 3.16 and 2.49, respectively. This corresponded well with the findings of Chomchai *et al.* (1998a) who found that FCRs at 14 weeks of 4-line crossbreeds receiving 18, 11 and 18-11% dietary protein were 3.43, 4.92 and 4.18, respectively. These findings suggest that 4-line crossbreeds have greater feed utilization capacity than 3-line crossbreeds.

5.2.3 Feed utilization efficiency of native chickens

Native chickens and their crossbreeds consumed less feed during the first three weeks; crossbred chickens demonstrated slightly higher feed intake, adaptation to feed and faster consumption than native chickens. In a typical small-farm environment, high mortalities among chicks were normal. The amount of feed intake was not significantly different among native chickens and crossbreeds during 0-7 weeks, but the feed intake of native chickens was lower. The amount of feed intake was significantly different among the chickens during 8-12 weeks. Nevertheless, feed utilization efficiency was not significantly different. Growth of the native chickens was lower (Table 4.10 and 4.11) indicating that feed intake directly affected the growth performance of native chickens.

Difference in dietary protein did not affect the growth of native chickens according to Teerapantuwat (1988) who found that native chickens in Thailand fed with 17, 16, 15 and 14% dietary protein were not significantly different in their final body weights. However, Rattanasetakul *et al.* (1988) reported that native chickens reared with 18% dietary protein had no significant difference in their growth, but the growth of chickens fed with 19% dietary protein was higher than those that received 18, 16 and 14% dietary protein.

The average daily feed intakes of native chickens during the periods 0-12, 0-15 and 0-20 weeks when they received feeding system 2 (19-17-12%) were 31.7, 39.0 and 49.0 g/bird/day, respectively. This corresponded with the findings of Panja (2000) where native chickens receiving 18% protein and 2,700 kcal ME/kg energy diet over 16 weeks had feed intake of 50.7 g/bird/day. Feeding native chickens with higher dietary protein (19-17%) during the early stage (0-6 weeks), and then fattening them with 12% dietary protein could maintain good feed utilization comparable to feeding with a high protein and energy diet throughout the growing period. The FCRs of native chickens receiving feeding system 2 during 0-12, 0-15 and 0-20 weeks were 2.75, 3.48 and 4.33. This corresponded with the findings of Panja (2000) and Theerapantuwat *et al.* (1988).

These findings demonstrated that feeding system 1 was suitable for high-performance breeds, such as hybrid broilers. However, local improved breeds could respond to a wider range of dietary quality, the different quality of the feed had little significant influence on feed intake and feed utilization. The results of the experiments indicate that native chickens and their crossbreeds could adjust their feed intake and utilization performance, even if they were fed with lower dietary protein.

5.3 Stocking densities and effects on production

Maximizing production through the selection of suitable housing floors and stocking density were investigated to discover types of material and numbers of bird per unit of area. In the more intensive raising of crossbreeds, the number of chicks per unit area was considerable in order to improve growth and feed utilization. But high stocking density leads to be the problem of cannibalism. The stocking density of native chickens and their crossbreds was 8.9 birds/m^2. Stocking densities of 0.33 bird/m^2 and 3 birds/m^2 were suitable for rearing on grass and concrete floors for crossbreeds, respectively (Intarachote *et al*., 1996). Whilst the stocking density was 1.7 birds/m^2 for the poultry run system (with additional space) and 5 birds/m^2 in the litter floor (feedlot and housing system) for 4-line crossbreeds (Chomchai *et al.*, 1998b). Chomchai *et al.* (1998a) found that 2.8 birds/m^2 was suitable for litter floors, whereas as many as 8 birds/m^2 were found in the rice husk hard ground floor system for 3-line crossbreeds as reported by Laopaiboon *et al.* (1999). These levels of stocking density showed there was no significant difference on growth performance.

For hybrid broilers, the stocking density was 8.9 birds/m^2. This was rather low compared with the intensive system. The stocking density of hybrid broilers for each growing stage of 1, 2, 3, 4, 5, 6 and 7 weeks could be 50, 40, 35, 28, 23, 20 and 18 birds/m^2 (Oluyemi and Robert, 1981 cited by Laohakaset, 1997). Thus, stocking density could be 22 birds/m^2 at placement and chickens were grown to 42 days of age according to Veldkamp and Middlekoop (1997) or 29, 21, 16 and 13 birds/m^2 according to Hartmant (1992). However, low stocking density (13 birds/m^2) resulted in significantly higher body weight and carcass weight at 7 weeks than the higher stocking density (29 birds/m$^{2.}$). At 6 weeks of age, the best FCR occurred in broiler stocking density of 29 birds/m^2 whereas the poorest FCR was found in the lowest stocking density (13 birds/m^2). Abdominal fat pads from the lowest stocking density (13 birds/m^2) were significantly larger than either 29 or 21 birds/m^2. There was no significant difference in mortality rate among low and high stocking densities. The highest stocking density had significant occurrence of breast blisters and ammonia burns. Nevertheless, the highest stocking density gave the highest profit per unit of floor.

In experiment 2, hybrid broilers grew much more slowly but there were no effects from the floor space; a few even reached 2.5 kg in body weight and still had enough space to move. The stocking density of native chickens and their crossbreeds was higher than other research. They were crowded in their pens when their body weight exceeded 1 kg. This was solved by providing bamboo roosts inside their pens over the floor. The roosts not only effectively reduced the crowding of birds on the pen floor, but also reduced fighting for space among the chickens, thus improving the carcass quality by reducing breast and foot pad blister. Sometimes they scratched their skin against the iron wire used for fixing the bamboo roost; thus nylon rope or nails should be used to fix the roosts instead of iron wire.

5.4 Effect of pen floor on production

Floor type is a key factor because it affects carcass quality and litter management. Several types of floor were tested: types of mesh (wire, steel and plastic), three types of perforated floor (wood, Styrofoam, and plastic) and three types of dwelling (rigid, rotating and padded) with a solid wood floor with wood shaving litter. Akpobome and Fanguy (1992) recommended that any cage floor system can be used for chicken raising without mortality effects; only a wire mesh floor can cause mortality and a significant reduction in live body weight at 6 and 8 weeks of age. The study suggested that a padded dowel floor system can be used to produce cage broilers of about 2,500 g in weight without leg or breast damage. These birds will be equivalent to those currently produced by the industry on a litter floor system.

Raising chickens on a bamboo slat floor lined with seine netting had great potential for improving the growth performance of hybrid broilers, native chickens and their crossbreeds. It provides a favorable environment for animals in terms of welfare and cleanliness, because manure passes through the floor to accumulate on the receiver underneath the housing. Thus chicken manure can be recovered easily for use as agricultural fertilizer. This system is also beneficial for small-scale farmers as materials are generally available locally. Reece *et al.*

(1971) recommended that raising poultry on cage floors eliminates litter cost, reduces the cost of medication, improves feed conversion, reduces housing cost, controls disease problems, reduces labor cost, decreases incidence of bruising and reduces the cost of moving broilers to the processing plant. However, Veldkamp and Middlekoop (1997) support with the information that overall improvement for hybrid broiler rearing could be 3.3% in weight gain, 1% in feed efficiency and 10% mortality if ventilated floors are used instead of regular litter floors. Dry litter over the ventilated floor resulted in better broiler health. The ventilated flooring concept is an environmentally friendly housing system that improves performance of broilers, especially in summer and at high stocking densities. Economically, however, the system increased broiler production cost by 3%. In Thailand, another system reported by Chomchai *et al* (1998) reported that raising 4-line crossbred chickens (NSRB) in different pen conditions (housing and poultry run) had no effects on growth and feed utilization. However, feed intake of chickens raised in feedlot pens was significantly higher to chickens raised otherwise.

5.5 Mortality of chickens

Tables 4. 4 and 4.28 show that hybrid broilers were more susceptible to the environment than others types of chicken. A major factor affecting mortality was the rapid increase in body weight of hybrid broilers. Mortality and fat levels were also higher in birds on higher energy commercial diets compared to old diets. Birds with high abdominal fat levels were observed to also have much fat throughout the visceral mesentery, around the heart (Harvenstein *et al*., 2003). Mortality of broilers in the tropics is higher due to heat stress (Chaiyabutr, 2004). Ouart *et al*.(1990) reported that during heat stress and unrestricted feeding, the mortality of broilers was as high as 41%, similar to the report of May *et al.* (1987). This could be reduced by spraying water onto the bamboo slats so the water can accumulate on the floor underneath. A wet floor is positive for hybrid broilers because the body temperature is reduced, hence, growth is greater and mortality is reduced.

The mortality of other types of chicken in both experiments was not significantly different among breeds and among feeding systems. Generally, native chicken are tolerance to heat stress. Crossbreeding of exotic breeds with native chickens could increase heat tolerance as well (Gowe and Fairfull, 1995). The mortality of native chickens raised at the village level could be as high as 20-30% from day-old chicks to 4 months of age (Choprakarn, 1988) because of respiratory disorders, higher susceptibility to other infectious diseases, external parasites and internal parasites (Kajarern *et al*., 1988); Namdaeng (1990); Laopaiboon and Jitpraneechai (1999); Chantalakhana and Skunmun (2002).

5.6 Carcass quality

5.6.1 Carcass quality of hybrid broilers

Hybrid broilers had higher carcass proportions than 3- and 4-line crossbreeds when they received feeding system 1. Hybrid broilers had higher fat content and much thicker skin than other types of chicken. Thus, the bone proportion of hybrid broilers was lower than other types of chicken in either feeding system. Feeding system 2 did not affect the total carcass ($p>0.01$) but it affected the dressed percentage ($p\leq0.05$). Nevertheless, hybrid broilers receiving feeding system 2 still had a higher proportion of breast meat than other breeds ($p\leq0.01$). The percentages of breast meat were not significantly different between crossbreeds and native chickens.

Dressed carcass percentages of hybrid broilers were affected by feed and feeding systems and breeds. Hybrid broilers had higher dressed carcass percentages when they received feeding system 1 because they received a completely nutritious diet. Genetics were the major contributor to the change of yield over time. They contributed about 85 to 90% of the differences observed in carcass and part yield, whilst nutritional changes accounted for 10 to 15% of these differences. For example, the breast meat averages at 43 days for the broiler strain in 1957 and 2001 were 11.6 and 20.0% live weight, respectively (Harvenstein *et al.*, 2003).

Meat yield of hybrid broilers decreased by 6% with 2% total bone increase when they received feeding system 2. The quality of diet clearly affected the proportion of meat yield. A decrease in nutritional composition affected the meat yield of hybrid broilers. Harvenstein *et al.* (2003) reported that nutritional changed accounted for 10 to 15% of these differences.

Hybrid broilers had higher percentages of total fat than other types of chicken. Modern diets after 2001 produced consistently better growth rate but also produced considerably higher fat levels than 1957. However, abdominal fat in males was lower than females. Fat-related traits appear to be dependent upon the sex of the progeny (Barbato *et al.,* 1998) and feeding regimen (Barbato *et al.,* 1994) cited by Barbato (1992). Carcass weights averaged 66% of body weight for all crosses.

5.6.2 Carcass quality of crossbreeds

Three-line crossbred chickens that received feeding systems 1 and 2 exhibited higher percentages of total carcass than reported in the study by Panja (2000). The total carcass percentages of 3-line crossbreeds produced by commercial companies and from the DLD were 75.81-77.98 and 75.22, respectively. However, the weight of the carcass was derived mainly from the live weight of the chickens, because a heavier live weight leads to a higher carcass weight. The experiments also confirm the results of the study by Vorachantra and Tancho (1996) which state that a 3-line crossbred strain (Suwan 6) responded non-significantly on the dressed carcass percentage with different levels of dietary protein and energy. Although in general chickens that received a high level of dietary protein also had a higher percentage of total carcasses.

Intarachote *et al.* (1996a) found that the percentages of total carcass of 3-line crossbreeds (NSB) and 4-line crossbreeds (NSRB) at 12, 16 and 20 weeks were not significantly different between the types of chicken. However, the male chickens had higher percentages of total carcass than the females and this led to higher proportions of carcass. However, there were no significant differences in the percentages of total carcass between the breeds of chicken and the age groups at 12, 16 and 20 weeks.

With feeding system 1, the 4-line crossbreds had higher percentages of total carcass than with feeding system 2. This clearly indicates that a lower protein level diet affects the percentages of total carcass. The results correspond to the report of Chomchai *et al.* (1998a). They found that 4-line crossbreeds (NSRB) that received dietary protein levels of 13.91, 17.36 and 19.82% were similar in their percentages of edible carcass (dressed carcass + shank + head-neck + dressed viscera (liver, gizzard, heart and intestines). Nevertheless, the proportions were higher than those receiving 12.13% dietary protein. Chomchai *et al.* (1998b) found that at the age of 14 weeks, the percentages of dressed carcass of the 4-line crossbreeds (NSRB) and native chickens receiving the same type of feed were not significantly different; but when slaughtered at 16 weeks, there were significant differences. However, 4-line crossbreeds had higher percentages of dressed carcass and the protein content in meat was also higher, but the fat content in the meat was lower than that of native chickens. The difference in the percentages of total carcass was influenced by the reduction in meat production due to lower protein uptake (Kantho, 1986).

5.6.3 Carcass quality of native chickens

The carcass quality of native chickens raised with feeding system 2 was better but not significantly different from the crossbreeds ($P>0.01$). However, the general trend of native chicken carcass quality was better, especially in terms of the proportions of meat and fat pad. Native chickens had the highest proportion of meat (36.11%) and the lowest proportions of skin (7.43%) and bone (20.13%). Thus, they had the lowest proportions of total fat (2.62%) and fat pad (1.76%). The proportions of total carcasses, dressed and meat, were similar to the results reported by Teerapantuwat (1988) who found that the carcass proportion of a 1,200 g native chicken (body weight) was 78.41%, with meat proportion of 36.07%. The proportion of native chicken carcass was higher at the age of 16 weeks. The proportions of meat at 12, 16 and 20 weeks of age were 29.5, 36.5 and 33.8%, respectively. This was slightly higher than figures reported by Toomsen (1988), who found that the percentage of total carcass of native chickens was 76.83% at the age of 16-20 weeks. This was lower than the findings of Laopaiboon *et al.* (1983) who reported a total carcass proportion of native chickens of 85.4%.

Although, native chickens were only raised with feeding system 2 in the experiments, the carcass proportion of native chickens was not significantly different ($P<0.01$) from the crossbreeds. Intrachote *et al.* (1996b) and Panyavee *et al.* (2002) confirmed that the dressed carcass proportion of native chickens at 2-6 months was higher than pure-breeds like Shanghai and Rhode Island Red. However, this is contrary to Isriyodom *et al.* (1993) who found that the carcass percentage of native chickens and Rhode Island Red at the age of 16 weeks was not significantly different. Native chickens responded better to higher levels of dietary protein, but did not reach maximum size as the crossbreeds because their genetic potential was lower than the crossbreeds (Tables 4.10 and 4.11). Nevertheless, their carcass characteristics when receiving the lower quality diet were as good as crossbreeds receiving higher quality feed. For this reason, lower level dietary protein was more suitable for native chickens. Teerapantuwat *et al.* (1988) confirmed that there was no significant effect on the percentages of carcasses from different levels of dietary protein.

5.6.4 Comparison of carcass proportions and body composition

For feeding system 2, the body composition ratios (meat: skin: bone: total fat) of native chickens, hybrid broilers, 3- and 4-line crossbreeds were 13.78:2.84:7.68:1.00, 5.81:1.23:2.88:1.00, 10.26:2.15:7.46:1 and 13.58:2.66:9.93:1, respectively. The percentages of meat: bone of native chickens fed with feeding system 2, with hybrid broilers, 3- and 4-line crossbreeds fed with feeding system 1 were 1.79:1, 2.02:1.00, 1.37:1 and 1.36:1, respectively. This clearly indicates that native chicken carcasses slaughtered at 20 weeks were better than hybrid broiler carcasses (7 weeks), 3-line crossbreeds (12 weeks) and 4-line crossbreeds (12 weeks). Native chickens fed with feeding system 2 had better carcass proportion than 3- and 4-line crossbreeds which were fed with feeding system 1 because of the higher meat: bone ratio. The body composition of native chickens was not as good as the hybrid broilers because they had a lower meat: bone ratio. This indicated that native chicken carcasses had higher proportions of bone than the hybrid broilers. However, the meat: fat ratio of native chickens was greater than that of the hybrid broilers. This indicates that native chicken carcasses had less fat, which is considered unhealthy and is therefore not wanted by the consumer (Heath *et al.*, 1980). Hybrid broiler production aims at higher breast: meat yield and lower abdominal fat. This focus responds to the consumers' desire for healthier meat, and to the evolution of the market through a rising demand for portioned and processed products (Barton, 1994 cited by Le Bihand-Duval *et al.*, 1999).

5.7 Marketable size and consequences for chicken rearing

Hybrid broilers raised with feeding system 1 were better than those in feeding system 2. The hybrid broilers grew much faster and therefore reached marketable size much earlier. Considering the range of marketable size for hybrid broilers, the slaughtering age could be reduced. Raising hybrid broilers on bamboo slat floors – as practiced in the experiment – has proven to be suitable for small farmers, providing a favorable and hygienic environment for the chickens and making litter removal easy and less labor intensive. However, a main concern is the more frequent development of blisters on the breasts, knees and feet. This is due to the heavy body weight of the hybrids. These blisters affect the quality of carcass, and consequently customers may not buy them. This problem could be curtailed by shortening the rearing period and hastening supply to the local market.

The 3- and 4-line crossbreeds had a high market demand (live marketing) because of their similarity to the native chickens, especially their feather color. Crossbreeds at the age of 10 weeks reached a suitable size for home consumption and for traditional roasting, and rearing could continue easily until 12 weeks if the market required a larger size. The local market requires a type of chicken that is similar to the native chicken (Laopaiboon *et al.*., 1999). For this reason, according to Jeenduong *et al.* (2001) the 3-line crossbreeds are the most popular among crossbreed-raising farmers. Crossbreeds are normally slaughtered and sold as total carcass, including giblets. Body conformation would attract customers, who place importance on body length and length of shank and drumstick, etc. These characteristics were found in 3-line crossbreeds, being very similar to native chickens. Thus, the selling price would be the same as for native chickens. A body weight of 1,300 g/bird, the size requirement by consumers, is recommended; this is suitable for traditional Thai dishes. In this respect any native crossbreed is suitable such as 2- and 3-line crossbreeds.

Leotaragul and Pimkamlai (1999) and Chomchai *et al.* (1998b) reported that the marketable sizes of native chicken in Thailand ranged between about 1,200 and 1,500 g/bird. The marketable size of native chicken is one of the most important criteria for farmers to decide whether to raise native chickens for the market. The marketing systems are village level, sub-district level, and town level; middlemen sell the chickens. Normally, the price of native chickens could be 20-25% higher than hybrid broilers, and this could double during the Chinese New Year festival (Choprakarn, 2001). In Africa, live indigenous birds are on sale wherever there is a market. Many birds are transported in large wicker baskets, on lorries, from rural to urban areas. In Kenya, besides supplying poultry meat and eggs for human consumption, the scavenger chickens are sources of petty cash. They also fulfill a social function – a visitor may give a chicken as a gift on departure (Musiime, 2003).

5.8 Native chicken genetic improvement, conservation and utilization

Currently, native chickens are considered to be the least valuable farmers' asset, but they help to supplement incomes and the nutritional status of rural families. The rearing of village chickens requires little or no inputs; hence, it is less affected by the constraints of intensive farming. This is very important in developing countries. Improving the genetic disposition of native chickens might not exactly meet the needs of farmers. Native chicken genetic conservation is a necessary requirement for future generations. Crossbreeding programs of native chickens with exotic breeds has a positive aspect, production-wise, but this is offset by contamination from exotic genes or loss of genes that play important roles in the performance of native chickens. Earning cash may not compensate for the loss of genes that could lead to new disease outbreaks, loss of texture and palatability of meat. The key factor is to avoid inbreeding. There are 17 lines of native chicken in Thailand. The lines should be considered as the gene pool by all development agencies and stakeholders, i.e. governments, the private sector and farmers. The conservation of native chickens not only benefits a country but also has benefits globally by preserving genetic material. The commercial selection program over the last 50-60 years has led to a decrease in the genetic strength of poultry making them more susceptible to diseases. Balancing the development and conservation of native chicken genetic disposition could be key activities in the future (Phalarak, 2001). In Lesotho, people have kept village poultry for centuries. There have been attempts to improve the productivity of these chickens by crossbreeding with imported Plymouth Rock stocks in order to meet the increasing nutritional demands of rural people. Some farmers tried to rear them under management systems similar to those used for commercial hybrid chickens. The performance was poor, compared to those that were left to roam and scavenge but their progeny have better body mass than indigenous chickens and they are resistant to disease (Khomari, 2003).

6 SUMMARY AND CONCLUSIONS

Chickens are important economic livestock in Thailand. The technology for intensive chicken production is advanced. The country is one of the world's leading chicken producers, and the major producer in the region of both meat and eggs. About 86% of chicken products on the Thai market come from hybrid broilers; 13% are from indigenous chickens. The main production areas are the Eastern Region (40%) and the Central Region (35%). In the northern and northeastern regions, production is 12 and 13%, respectively. A large proportion is produced exclusively for export. About 80% of broilers are produced by large multinational companies. Because of the high quality requirements, chicken-meat production for export requires advanced technology. Small farmers do not have the investment capacity for this. Another increasingly important issue affecting the poultry industry is animal welfare. European countries especially require high animal welfare standards during production and maintenance of good health; this can only be ensured by large commercial-scale producers.

In Thailand, the consumption of chicken meat, especially in the urban areas, is high. Traditionally, native chickens have played an important role in the nutrition and protein supply of rural people. But because of slow growth and the relatively low productivity of native breeds, their share in local markets is insignificant. It is estimated that 90-120 millions indigenous chickens are produced annually. Forty-five percent of indigenous chickens in the country are raised in the northeastern region, the majority by rural households (80%) – mainly for home consumption but also for sale. Some chickens are kept as pets and as fighting cocks. The country has been quite successful in improving crossbreeds of native chickens for meat. But adoption by small farmers has been low and most crossbred native chickens are produced by medium-scale commercial raisers. Native chickens are still the major type of poultry on small farms. The market demand for native chickens is relatively high but the supply is rather limited because the current rearing system is problematic. Several attempts have been made over the past twenty years to improve native chicken production for small farmers. Native chickens are usually raised in extensive systems, often with supplementary feeding of rice by-products of low quality. An important part of their feed and vitamin supply is obtained from scavenging natural food. The major feed source for native poultry kept on small farms is based on crop by-products and residues.

This study considered improving the livelihoods of small farmers through better integration of livestock, in this case chickens, into the current farming system. Profitable niche opportunities could be developed for small farmers based on indigenous types of chicken, which are assumed to be better suited to the tropical climate and to the conditions on smallholder farms than high-performance hybrids, and the use of on-farm feed sources which are often not utilized efficiently. The chickens would be raised under largely natural conditions and in an animal-friendly way. Such a system would make the best use of already available resources, with an absolute minimum of external inputs and with no negative environmental impact as generated by many of the large-scale high-tech chicken production systems.

This study also aimed at identifying suitable feeding regimes for native chickens that reduce dependence on commercial feeds and make better use of on-farm feed resources. For this, the growth performance of different breeds of chickens was studied under different feeding regimes and with an emphasis on typical on-farm feed resources. Also, the effect of the feeding regimes on carcass quality was investigated.

The study was carried out on-station. Four breeds were tested: native chickens, commercial hybrid broilers, a 3-line crossbreed and a 4-line crossbreed. Two feeding systems were used; (i) commercial hybrid broiler feed (feeding system 1) and (ii) formulated feed (feeding system 2). Each experimental pen (block) had fifty birds, 2-3 days old. Feeding was *ad libitum* with supplements – via the drinking water - of vitamins and minerals.

The basic performance indicators measured were weight gain, feed intake and feed utilization efficiency, and carcass quality.

The results are summarized hereunder:

Hybrid broilers receiving feeding system 1 reached a body weight of 1,000-1,250 g at the age of 20-25 days; rearing continued until week 7 producing a body weight of 2,500 g, as required by local consumers. During this period, mortality was high thus reducing the economic return. Feed utilization efficiency was higher than with the other breeds, and also better than with feeding system 2. With feeding system 2, which was supplemented with ground maize at rates of 30% between the age of 0-3 weeks and 50% at the age of 4-6 weeks, the chickens reached the same size two weeks later. During the first eight weeks, the 4-line crossbreed had greater body weight gain when fed with commercial hybrid broiler feed. However, during the fattening period (8-12 weeks) it was beneficial to add 12% dietary protein (feeding system 2). For the 3-line crossbreed, growth performances with feeding system 1 and feeding system 2 were similar; but the trend was slightly steeper with feeding system 1. However, the overall growth performance was still lower than for the 4-line crossbreed. The feed intake rate of the 4-line crossbreed was clearly higher than the 3-line crossbreed, as was feed utilization efficiency. The 4-line crossbreed grew faster and reached a marketable size (1,200-1,400 g/bird) at the age of nine weeks, whereas the 3-line crossbreed required another 1-2 weeks to reach the same body weight.

Native chickens raised with feeding system 2 had good growth, feed utilization efficiency and carcass quality. The body weight of native chickens reached marketable size by week 15, 3-4 weeks later than the 3- and 4-line crossbreeds. The percentage of the total carcass of the native chickens was not significantly different from the crossbreeds, but the trend was higher and the carcass contained lower total fat. Locally available feed, such as maize, also provides a favorable alternative for small farmers to increase farm productivity and family income.

The study showed that the two feeding regimes tested had significant influences on growth, feed utilization efficiency and carcass quality for all four types of chickens. For each type of chicken, the response was different, sometimes significantly. The results show that there are feasible options for profitable chicken rearing for small-scale farmers without sophisticated and expensive pens or cages. Particularly, if the feed resources available on the farm (i.e., not purchased) can be integrated into the rearing system. This would certainly contribute to an enhancement of the livelihoods of small farmers.

With supplemented local feed, hybrid broilers reached marketable size at the age of 5-7 weeks. Crossbred native chickens (3- or 4-breed crossing) – depending on the type of crossbreed – reached marketable size at the age of 9-12 weeks. Native chickens reached marketable size at the age of 15-20 weeks.

The advantage of native chickens – and to a certain degree also of the crossbreeds – is their good adaptation to environmental conditions on smallholder farms, and their relatively high resistance to diseases.

The growth performance of the chickens was linked to their genetic potential and their adaptive capacity to the environment. Birds with high genetic potential (e.g. hybrid broilers) only showed a superior performance under suitable environmental conditions. Native chickens tolerate poor environments (such as on smallholder farms); they tend to respond positively to slight improvements in feed and the keeping system. This makes the raising of native chickens are an economically promising option for small farmers. In the study area, native chicken feeding is based on maize products. Feed quality can be improved significantly by supplementing maize with formulated feed from feed mills. To maintain the growth performance and feed utilization efficiency, the level of dietary protein is important.

All types of chickens had better rearing environment when they were raised on a bamboo slat floor covered with netting. The slat floor kept the chickens away from the feces, which improved hygiene; there was a certain amount of temperature control, and manure was easily collected. A roost inside the pen reduced the stress on the chickens caused by fighting for space and often cannibalism. The chickens could freely fly, jump, walk and run and rest inside the pen, which improved general animal health and welfare. The accumulated manure underneath the pen floor should be removed frequently, depending on the condition of the manure; broiler manure should be removed more frequently because it contains more moisture and creates ammonia gas. The manure of the crossbreeds and the native chicken was rather dry.

At a stocking density of 8.9 birds/m^2, the rearing period for hybrid broilers should not exceed five weeks by such stocking density. Because of the rapidly increasing body size, floor space and access to the drinking devices are limited after this period. Whereas, at the same stocking density, the crossbreeds and the native chickens could use the extra space provided by the roost inside the pen. For the hybrid broilers and the native chickens, the roosts improved space utilization, increasing the yield per unit area under the *ad libitum* feeding system.

Recommendations

- Other feed sources such as paddy rice for all types of chicken should be investigated for small-scale farmers.
- The quality of meat should be investigated in order to reveal customer preference.
- Strategies to utilize collected chicken manure should be investigated for use as crop fertilizer.
- Analyse the return of investment in terms of economic analysis to evaluate the system.
- Investigate the nutrient flow performance from feed to meat, manure and crop uptake and retention in the soil and loss to the atmosphere.
- Develop a marketing system for native chickens comprising several marketing channels with linkages among the consumers and producers, within the country and abroad. The current marketing system is based on middlemen involvement. A better marketing system would benefit small-scale farmers in rural areas.
- The availability of a large numbers of native chicks at the village level would promote the raising of native chickens. Chick production and reducing the cost of native chicks should be studied. Promoting the rearing of native chickens would support genetic conservation.
- A proper free-range system taking into account animal health welfare could be developed for better flock control and maintenance.
- Improving native chicken hygiene could be underscored to control disease outbreaks and parasite infections. Vaccination should be emphasized and a vaccine-supply network should also be developed.

7 สรุปผลการศึกษา

ไก่เป็นสัตว์เศรษฐกิจที่มีความสำคัญต่อประเทศไทย ทั้งเพื่อการบริโภคภายในประเทศและส่งออก จนนับได้ว่าเป็นประเทศหนึ่งที่มีบทบาทสำคัญต่อตลาดไก่เนื้อของโลก โดยใช้เทคโนโลยีที่ก้าวหน้าและเน้นการผลิตในเชิงอุตสาหกรรม สำหรับการผลิตในประเทศไทยนั้น ร้อยละ 86 เป็นไก่เนื้อลูกผสม และ ร้อยละ 13 เป็นไก่พันธุ์พื้นเมือง โดยมีพื้นที่เลี้ยงไก่ส่วนใหญ่ในภาคตะวันออก (40%) รองลงมาคือ ภาคกลาง (35 %) ภาคเหนือ(12%) และภาคตะวันออกเฉียงเหนือ (13%) สำหรับการเลี้ยงเพื่อการส่งออกนั้น ร้อยละ 80 เป็นผลผลิตจากไก่เนื้อลูกผสม และดำเนินการผลิตโดยบริษัทขนาดใหญ่ เนื่องจากการส่งออกเนื้อไก่นั้นต้องใช้เทคโนโลยีที่ก้าวหน้า และต้องการผลผลิตที่มีคุณภาพตามที่ตลาดต้องการ ในขณะที่เกษตรกรรายย่อยยังมีข้อจำกัดในการลงทุนและความสามารถในการจัดการด้านการผลิต ทำให้ไม่สามารถที่จะเป็นผู้ผลิตที่ยั่งยืนได้ นอกจากนี้ประเทศต่างๆในแถบยุโรปมีข้อกำหนดในการเลี้ยงไก่ที่มีมาตราฐาน และการดูแลสุขภาพที่ดี ซึ่งการจัดการที่ได้มาตรฐานต้องการการลงทุนและวิทยาการที่เหมาะสม ความละเอียดและการเอาใจใส่ในกระบวนการผลิตทุกขั้นตอน ซึ่งส่วนใหญ่จะดำเนินการโดยผู้ผลิตรายใหญ่เพื่อการค้า

การบริโภคเนื้อไก่ในประเทศไทยนั้น
พบว่าประชาชนในเขตเมืองนิยมบริโภคไก่เนื้อทางการค้าเป็นส่วนม
ากเนื่องจากหาซื้อได้ในท้องตลาดและราคาไม่สูงนัก
ในขณะที่ไก่พื้นเมืองนั้นเป็นนับว่าเป็นแหล่งโปรตีนที่ความสำคัญต่อ
ประชาชนในพื้นที่ชนบท
ซึ่งมักจะเลี้ยงกันอยู่ทั่วไปเกือบทุกครัวเรือน
มีจำนวนไม่มากและมีราคาค่อนข้างสูงเต่เป็นที่นิยมบริโภคกันทั่วไป
อย่างไรก็ดีเนื่องจากไก่พันธุ์พื้นเมืองเจริญเติบโตช้า
และมีปริมาณไม่มากและไม่แน่นอน
ส่วนใหญ่มีการซื้อขายในหมู่บ้านและในตลาดท้องถิ่น
ประมาณกันว่าในแต่ละปีประเทศไทยมีประชากรไก่ซึ่งผลิตได้ประม
าณ 90-120 ล้านตัว โดยที่ส่วใหญ่ ของประชากรไก่ที่
เลี้ยงในภาคตะวันออกเฉียงเหนือ (45%) โดยที่ประชากรส่วนใหญ่
(80%) เลี้ยงไว้เพื่อบริโภคในครัวเรือน และเพื่อขาย
ขณะที่เกษตรกรจำนวนมากเลี้ยงไก่เพื่อความสวยงามและเลี้ยงเพื่อ
การกีฬา
อย่างไรก็ตามประเทศไทยถือว่าเป็นประเทศที่ประสบความสำเร็จใน
การปรับปรุงและพัฒนาการผลิตของไก่พื้นเมืองโดยการผสมข้ามกั
บไก่พันธุ์เนื้อและพันธุ์ไข่จากต่างประเทศทั้งนี้เพื่อเพิ่มศักยภาพการ
ผลิตของไก่พื้นเมืองให้สูงขึ้นและยังได้รับการยอมรับจากเกษตรกร
ผู้เลี้ยงและผู้บริโภคส่วนหนึ่งถือเป็นทางเลือกอีกทางหนึ่งให้กับกษต
รกรผู้สนใจแต่อย่างไรก็ดีไก่พื้นเมืองลูกผสมก็ยังไม่เป็นที่ยอมรับขอ
งเกษตรกรในระดับรายย่อยทั่วไป
จึงมีผลไก่พื้นเมืองยังชนิดสัตว์ปีกที่เลี้ยงโดยทั่วไปของเกษตรรายย่
อย

ขณะเดียวกันความไก่พื้นเมืองยังเป็นที่ต้องการของตลาดผู้บริโภคเป็นอย่างมากแต่ปริมาณที่มีขายในตลาดยังไม่แนนอนและมีปริมาณที่จำกัดเนื่องเกษตรกรผู้เลี้ยงยังขาดการจัดการที่เป็นระบบ แต่ก็มีความพยายามอย่างมากจากหลายๆฝ่ายที่เกี่ยวข้องในระยะเวลากว่า 20 ปีที่ผ่านมา ในการพยายามหาแนวทางการผลิตที่เหมาะสมในการเลี้ยงไก่พื้นเมืองให้กับเกษตรกรรายย่อย ทำให้การเลี้ยงไก่พื้นเมืองยังเป็นการเลี้ยงแบบธรรมชาติเพื่อการยังชีพโดยการพึ่งพาทรัพยากรอาหารที่มีในระบบครัวเรือนเป็นหลัก โดยการนำใช้ผลพลอยได้จากผลผลิตข้าวซึ่งถือว่าเป็นอาหารหลักที่สำคัญขณะเดียวกันไก่พื้นเมืองได้รับอาหารอื่นๆ จากการหากินตามธรรมชาติ จึงทำให้การเลี้ยงไก่ของเกษตรกรขึ้นอยู่กับผลพลอยได้หรือเศษเหลือจากการเกษตร

การศึกษานี้มีเป้าประสงค์ในการที่จะปรับปรุงวิถีชีวิตของเกษตรกรรายย่อยโดยการผสมผสานการเลี้ยงการเลี้ยงไก่เข้ากับระบบไร่นาของเกษตรกร ในการหาทางเลือกให้กับเกษตรกรเพื่อการพัฒนาการเลี้ยงไก่ทั้งหก่เนื้อทางการค้า ไก่ลูกผสมพื้นเมือง และไก่พื้นเมืองที่มีในชนบท โดยเฉพาะอย่างยิ่งการเลี้ยงไก่พันธุ์พื้นเมืองนั้นถือว่าเป็นชนิดไก่ที่มีความเหมาะสมกับสภาพอากาศในเขตร้อน และปรับตัวเข้ากับสภาพความเป็นอยู่เละวิถีชีวิตของเกษตรกรรายย่อยได้เป็นอย่างดี ซึ่งน่าจะดีกว่าการเลี้ยงไก่เนื้อลูกผสมๆ ต่างเพื่อการค้า

นอกจากนี้การนำใช้วัตถุดิบอาหารสัตว์ที่มีในระบบการเกษตรซึ่งมีก
ารนำใช้อย่างไม่เหมาะสมและมีประสิทธิภาพเพียงพอ
การศึกษาวิจัยการเลี้ยงไก่ในครั้งนี้
จะเน้นการเลี้ยงไกภายใต้ระบบประยุกต์ธรรมชาติ
และให้ความสำคัญกับสวัสดิภาพความเป็นอยู่ตามพฤติกรรมของสัต
ว์เลี้ยง
ระบบนี้จะมีการนำใช้ประโยชน์สูงสุดของปัจจัยการผลิตที่หาได้
มีความพยายามในการนำใช้ปัจจัยการผลิตจากระบบภายนอกให้น้
อยที่สุด และมีผลกระทบต่อสิ่งแวดล้อมน้อยที่สุด
แตกต่างจากการผลิตเพื่อการค้า เช่น
การผลิตที่ครบวงจรของผู้เลี้ยงรายใหญ่ทั่วไป

การศึกษานี้ดำเนินการในสถานีวิจัยที่ทำการทดสอบไก่เนื้อชนิดต่าง
ๆ สายพันธุ์ คือ ไก่พื้นเมือง ไก่เพื่อการค้า ไก่พื้นเมืองลูกผสม 3
สาย และไก่พื้นเมืองลูกผสม 4 สาย
มีวัตถุประสงค์หลักในการที่ทดสอบสมรรถนะของไก่ทางด้านการเจิ
ญเติบโต ประสิทธิภาพการใช้อาหาร และคุณภาพซาก ของไก่ 4
ชนิด จากการให้อาหาร ทั้ง 2 รูปแบบการทดลองครั้งนี้ได้
โดยไก่ทั้ง 4 ชนิดในโรงเรือนยกพื้นสูง
และพื้นที่คอกเป็นพื้นปูด้วยไม้ไผ่ระแนง และคลุมทับด้วยเนื้ออวน
ไก่แต่ละชนิดจะถูกเลี้ยงจนได้อายุและน้ำหนักที่ตลาดต้องการ คือ
7, 12 และ 20 สัปดาห์ ตามลำดับ โดยได้รับอาหาร ได้รับอาหาร 2
แบบ คือ ระบบที่ 1) อาหารสำเร็จ รูปไก่เนื้อเพื่อการค้า และ ระบบที่
2) ได้ระดับอาหารผสมระหว่างข้าวโพดบด
และอาหารสำเร็จรูปไก่เพื่อการค้า

โดยที่แต่ละสูตรอาหารแบ่งระยะการให้อาหารแยกเป็น 0-3, 4-6, และ 7-20 สัปดาห์ขึ้นไป จะมีอัตราปล่อยเลี้ยง ที่ความหนาแน่น 8.9 ตัวต่อตารางเมตร (ลูกไก่อายุ 1-3 วัน) หรือ (คอกละ 50 ตัว แต่ละคอกจะมีพื้นที่ 2.25x2.5 ตารางเมตร) ซึ่งไก่แต่ละคอกจะได้กินอาหารตลอดเวลา และได้เสริมวิตามินและเกลือแร่ในน้ำช่วง 1-3 สัปดาห์แรก ตลอดช่วงการเลี้ยง ได้ทำการชั่งวัดไก่แต่ละตัวทุกคอกทุกๆ ต่อสัปดาห์และน้ำหนักสุดท้ายในสัปดาห์สุดท้าย ชั่งวัดอาหารที่ให้และอาหารเหลือทุกครั้งที่มีการชั่งวัดน้ำหนักตัวไก่ สุ่มอาหารเพื่อการวิเคราะห์คุณภาพ เมื่อสิ้นสุดการทดลองจะทำการสุ่มเพื่อชำแหละและชั่งวัดซากและตัดแยกส่วนต่างๆ ตลอดจนแยกเนื้อ กระดูกและหนัง ชั่งวัดเพื่อศึกษาซาก

ผลทีได้จากการศึกษาสามารถสรุปได้ดังนี้

- การเลี้ยงไก่ด้วอาหารสำเร็จรูปไก่เนื้อลูก(ระบบที่ 1) พบว่า ไก่ทั้ง 4 ชนิดมีการเจริญเติบโตตามลำดับจากมากไปหาน้อยดังนี้ ไก่เนื้อลูกผสมทางการค้า ไก่ลูกผสมพื้นเมือง 4 สายพันธุ์ 3 สายพันธุ์ ตามลำดับ ขณะที่เมื่อเลี้ยงด้วยอาหารผสมข้าวโพดและอาหารไก่เนื้อทางการค้า (ระบบที่ 2) ก็ยังพบว่ามีการเจริญเติบไปในรูปแบบเดียวกัน โดยที่ไก่พื้นเมืองมีการเจริญเติบโตช้าที่สุด อย่างไรก็ดีอัตราการเจริญเติบของไก่ทั้งสามชนิด

ที่ได้รับอาหารสำเร็จรูปทางการค้ามีการเจริญเติบโตดีกว่าอาหารผสมข้าวโพดบดและอาหารไก่เนื้อ แต่ก็พบว่าไก่ลูกผสมพื้นเมือง 4 สายพันธุ์และ 3 สายพันธุ์
ที่ได้รับอาหารทั้งสองชนิดในช่วงเวลา 8-12 สัปดาห์
มีการเจริญเติบโตได้ดีไม่แตกต่างกันจากเลี้ยงด้วยอาหารระบบที่ 1 จากการให้อาหารในระบบที่ 2 จะทำให้ไก่เนื้อลูกผสม
ไก่ลูกผสมพื้นเมือง 3 สายพันธุ์ และ 4 สายพันธุ์
ไก่พื้นเมืองมีการเพิ่มน้ำหนักตัวจนได้ขนาดที่ตลาดต้องการที่อายุ 5-7, 9-12 และ 15-20 สัปดาห์ ตามลำดับ

- การเลี้ยงไก่ด้วยอาหารระบบที่ 1 พบว่า ไก่ทั้ง 4 ชนิดมีประสิทธิภาพการใช้อาหารตามลำดับจากสูงจไปหาต่ำดังนี้ ไก่เนื้อลูกผสมทางการค้า ไก่ลูกผสมพื้นเมือง 4 สายพันธุ์ 3 สายพันธุ์ ตามลำดับ
  โดยไก่เนื้อลูกผสมทางการค้ามีอัตราการกินได้สูงกว่าไก่พื้นเมืองลูกผสมทั้งสองชนิดรวมทั้งมีอัตราแลกเนื้อต่ำกว่าไก่พื้นเมืองทั้งสองชนิดอย่างชัดเจน สำหรับอัตราการเปลี่ยนอาหารเป็นเนื้อ (FCR) ขณะที่เมื่อเลี้ยงด้วยอาหารระบบที่ 2
  ก็ยังพบว่ามีประสิทธิภาพในการใช้อาหารในรูปแนวเดียวกัน
  แม้ว่าไก่พื้นเมืองมีประสิทธิภาพในการใช้อาหารดีใกล้เคียงกันกับไก่ทั้งสามชนิดในช่วงเวลาเดียวกัน
  แต่ก็ยังเจริญโตช้ากว่ามากทั้งนี้เนื่องจากความสามารถในการกินได้ต่ำกว่าไก่เนื้อทั้งสามชนิด นอกจากนี้ไก่พื้นเมืองลูกผสมทั้ง 2 ชนิดยังมีอัตราแลกเนื้อใกล้เคียงกันมาก
  แต่พบว่าไก่พื้นเมืองลูกผสม 4

สายพันธุ์มีอัตราการกินได้สูงกว่าไก่พื้นเมือง 3 สายพันธุ์ ทำให้มีการเจิญเติบโตเร็วกว่า อย่างไรก็ดีประสิทธิภาพการใช้อาหารของไก่ทั้งสามชนิด ที่ได้รับอาหารระบบที่ 1ดีกว่าอาหารระบบที่ 2 แต่ก็พบว่าไก่ลูกผสมพื้นเมือง 4 สายพันธุ์และ 3 สายพันธุ์ ที่ได้รับอาหารทั้งสองชนิดในช่วงเวลา 8-12 สัปดาห์ มีการใช้อาหารประสิทธิภาพใกล้เคียงกัน

- การเลี้ยงไก่ด้วยอาหารระบบที่ 1 จะได้น้ำหนักตัวในช่วง 1,000-1,250 กรัม ที่อายุประมาณ 20-25 วัน ซึ่งเป็นน้ำหนักที่ตลาดไก่สดที่ท้องถิ่นต้องการ และเมื่อเลี้ยงจนถึงอายุ 7 สัปดาห์จะได้น้ำหนักเฉลี่ยที่ 2,500 กรัมต่อตัว ในช่วงหลังนี้มีการเติบโตอย่างรวดเร็ว แต่มีอัตราการตายสูง และทำให้มีผลต่อการความเสี่ยงต่อกำไรที่อาจลดลงและอาจขาดทุนได้ ในขณะเดียวกัน เมื่อเลี้ยงด้วยอาหารระบบที่ 2 พบว่าไก่มีการเจริญเติบโตได้ดีเช่นกันแต่ช้ากว่า เพราะที่น้ำหนักเดียวกันต้องใช้เวลาเลี้ยงนานกว่าเดิมประมาณ 2 สัปดาห์ นอกจากนี้ประสิทธิภาพการของไก่เนื้อลูกผสมเมื่อได้รับอาหารระบบที่ 1 จะสูงกว่าไก่ชนิดอื่นๆ และดีกว่าอาหารระบบที่ 2 ขณะที่ไก่พื้นเมืองลูกผสม 4 สายพันธุ์ที่ได้รับอาหารระบบที่ 1 มีการเจริญเติ บโตในช่วงแรก (0-8) สัปดาห์ สูงกว่าเมื่อได้รับอาหารระบบที่2 ขณะที่ในช่วงอายุ 8-12 สัปดาห์พบว่าไก่พื้นเมือง 4 สายพันธุ์ที่ได้รับอาหารระบบที่ 2

การเจริญเติบโตได้ดีและไม่แตกต่างกับการได้รับอาหารระบบที่ 1 ขณะที่ไก่พื้นเมืองลูกผสม 3 สายพันธุ์เจริญเติบโตได้ดี และไม่แตกต่างกันเมื่อได้รับอาหารระบบที่ 1 และ 2 แต่แนวโน้มการเจริญเติบโตของพื้นเมืองลูกผสม 3 สายพันธุ์ที่ได้รับอาหารระบบที่ 1 ดีกว่า และสมรรถนะของการเจริญเติบโต,ประสิทธิภาพการใช้อาหาร (ปริมาณการกินได้น้อยกว่า อัตราแลกเนื้อสูงกว่า) นั้นยังด้อยกว่าไก่พื้นเมืองลูกผสม 4 สายพันธุ์ ทำให้ไก่ลูกผสมพื้นเมือง 4 สายพันธุ์มีน้ำหนักตัวส่งตลาดได้ (1,200-1,400 กรัม) ที่อายุการลี้ยงตั้งแต่ 9 สัปดาห์ไก่ลูกผสมพื้นเมือง 3 สายพันธุ์ต้องใช้เวลาในการเลี้ยงอีก 1-2 สัปดาห์เพื่อจะให้น้ำหนักเดียวกัน

- การเลี้ยงไก่พื้นเมืองด้วยอาหารระบบที่ 2 มีการเจริญเติบโตได้ดี แต่ยังไม่ดีเท่ากับไก่พื้นเมืองลูกผสม ทั้ง 3 และ 4 สายพันธุ์ ทั้งทางด้านประสิทธิภาพการใช้อาหาร และคุณภาพซากของไก่พื้นเมืองเมื่อได้น้ำหนักเดียวกับลูกผสมที่ตลาดต้องการ (1,200-1,400 กรัม) ที่อายุ 15 สัปดาห์ ซึ่งต้องใช้เวลามากกว่าไก่พื้นเมืองลูกผสม 3-4 สัปดาห์ อย่างไรก็ตามเปอร์เซ็นต์ซากที่ได้ของไก่พื้นเมืองไม่แตกต่างกันที่ขนาดส่งตลาด แต่มีแนวโน้มของเปอร์เซ็นต์ซากสูงกว่า และยังมีเปอร์เซ็นต์ไขมันในช่องท้องต่ำกว่า จึงทำให้พบว่าวัตถุดิบอาหารสัตว์ที่มีในท้องถิ่น เช่น ข้าวโพด

สามารถที่จะเป็นทางเลือกสำหรับเกษตรกรในการนำใช้เพื่อเพิ่มผลผลิตในระบบการเกษตร และรายได้ในครัวเรือน

- ไก่เนื้อลูกผสมมีเปอร์เซ็นซากสูงกว่าไก่พื้นเมืองลูกผสมทั้งสองชนิดเมื่อเลี้ยงด้วยอาหารระบบที่ 1 ทางการค้า
  เปอร์เซ็นซากของไก่ทั้งสามชนิดก็ไม่แตกต่างกันเมื่อเลี้ยงด้วยอาหารระบบที่2
  นอกจากนี้ไก่เนื้อลูกผสมทางการค้ามีเปอร์เซ็นไขมันในช่องท้องและมีการสะสมไขมันที่ผิวหนังสูงกว่าไก่พื้นเมืองลูกผสมทั้งสองชนิด
  ไก่เนื้อลูกผสมมีเปอร์เซ็นเนื้ออกสูงกว่าและยังมีเปอร์เซ็นกระดูกรวมน้อยกว่าไก่ทั้งสองชนิดเมื่อเลี้ยงดวยอาหารทั้งสองชนิด*อย่างไรก็ตาม ไก่เนื้อลูกผสมมีปริมาณเนื้อรวมลดลง* 6 %
  และน้ำหนักกระดูกเพิ่มขึ้น 2% *เมื่อเลี้ยงด้วยอาหารระบบที่* 2
  แม้กระนั้นก็ตาม ไก่เนื้อลูกผสมยังมีเปอร์เซ็นเนื้ออกสูกว่า ไก่ชนิดอื่นๆ

- คุณภาพซากของไก่พื้นเมืองเมื่อชำแหละที่อายุ 20 สัปดาห์ดีกว่าคุณภาพซากของไก่เนื้อลูกผสมที่อายุ 7 สัปดาห์ ไก่พื้นเมืองลูกผสม 3 สายและ 4 สาย ที่อายุ 12 สัปดาห์
  นอกจากนี้ไก่พื้นเมืองเมื่อเลี้ยงด้วยอาหารระบบที่ 1
  มีเปอร์เซ็นซากสูงกว่าไก่ลูกผสมพื้นเมืองที่เลี้ยงด้วยอาหารระบบที่ 2 ที่อายุและน้ำหนักส่งตลาด
  อย่างไรก็ดีองค์ประกอบของซากของไก่เนื้อลูกผสมทางการค้าดีกว่าไก่พื้นเมืองเนื่องจากมีอัตราส่วนของเนื้อต่อกระดูกสูงกว่าซึ่งก็หมายความว่าไก่พื้นเมืองมีส่วนของกระดูกเป็นองค์ประกอบใน

ซากสูงกว่า
อย่างไรก็ดีไก่พื้นเมืองมีอัตราส่วนของเนื้อต่อไขมันในช่องท้องสูงกว่าไก่เนื้อลูกผสมซึ่งเป็นการชี้ให้เห็นว่าไก่พื้นเมืองมีไขมันเป็นองค์ประกอบในซากต่ำกว่า

- เปอร์เซ็นซากของไก่พื้นเมืองสูงกว่าแต่ไม่แตกต่างกับไก่ลูกผสมพื้นเมืองทั้งสองชนิดเมื่อเลี้ยงด้วยอาหารระบบที่ 2 และพบว่ามีคุณภาพซากดีกว่าทั้งปริมาณเนื้อรวมที่มากกว่าและไขมันในช่องท้องต่ำกว่าโดยไก่พื้นเมืองมีเนื้อรวม หนัง กระดูก ไขมันรวมและไขมันในช่องท้อง 36.11% 7.43% 20.13% 2.62% และ 1.76% ตามลำดับ นอกจากนี้ไก่พื้นเมืองและไก่พื้นเมืองลูกผสมมีเนื้อรวมไม่แตกต่างกันเมื่อเลี้ยงด้วยอาหารระบบที่ 2 ตามลำดับ ไก่พื้นเมืองจะตอบสนองต่ออาหารที่มีโปรตีนสูงได้ดีแต่ไม่ดีเท่าไก่พื้นเมืองลูกผสมทั้งสองชนิดเนื่องจากมีข้อจำกัดจากความสามารถทางพันธุกรรมต่ำกว่ามาก แม้กระนั้นก็ตามคุณภาพซากของไก่พื้นเมืองที่เลี้ยงด้วยอาหารระบบที่ 2 สูงใกล้เคียงกับคุณภาพซากของไก่พื้นเมืองลูกผสมที่เลี้ยงด้วยอาหารระบบที่ 1 ที่น้ำหนักและอายุตามที่ตลาดต้องการ ด้วยเหตุนี้การเลี้ยงไก่พื้นเมืองด้วยด้วยอาหารระบบที่ 2 จึงมีความเหมาะสมกว่า

- ที่อัตราการปล่อยเลี้ยง 8-9 ตัว ต่อตารางเมตร ถือว่าเป็นอัตราการปล่อยที่สูงมากสำหรับการเลี้ยงไก่พื้นเมืองและไก่พื้นเมืองลูกผสม

แต่อย่างไรก็ดีสามารถลดความหนาแน่นได้ด้วยการสร้างคอนนอนเพิ่มเติมในคอก
แต่สำหรับไก่เนื้อลูกผสมเพื่อการค้าถือว่าไม่หนาแน่นมาก
และแต่พบว่าพื้นที่จะลดลง รวมทั้งขนาดไก่ที่โตขึ้นอย่างรวดเร็ว
ทำให้พื้นที่คอกลดลงมากการเสียพื้นที่สำหรับแขวนถังอาหารและถังน้ำ
ดังนั้นการเลี้ยงไก่เนื้อในคอกขังมีความเหมาะสมที่อายุประมาณ
5 สัปดาห์ และให้กินอาหารเต็มที่ตลอดเวลา

- การเลี้ยงไก่บนพื้นไม้ไผ่คลุมด้วยอวน
จะช่วยลดปัญหาการแปดเปื้อนมูลที่มีการขับถ่ายออกมา
ซึ่งเป็นการช่วยปรับปรุงความสะอาด และสุขาภิบาล
ช่วยในถ่ายเทอากาศให้ดีขึ้น และช่วยลดอุณหภูมิของคอกลง
และช่วยให้มีการเก็บรวมรวมมูลได่ง่ายขึ้น
นอกจากการเพิ่มคอนนอนในคอกเป็นการช่วยเพิ่มพื้นที่การเลี้ยงไก่เพราะทำให้มีพื้นที่ในการเกาะยึดมากขึ้น
และลดความหนาแน่นลง ช่วยลดความเครียดที่เกิดจากการต่อสู้จิกตีกัน นอกจากนี้ไก่ยังมีอิสระในการบิน กระโดด เดิน และวิ่ง
หรือเกาะยึดเพื่อการพักผ่อนในคอกขัง
เป็นการเพิ่มสวัสดิภาพความเป็นอยู่ของสัตว์เลี้ยงให้ดีขึ้น
นอกจากนี้มูลไก่ที่สะสมอยู่ใต้คอกจะมีการเก็บรวมรวมออกได้ง่ายๆขึ้น
ทั้งนี้ความถี่ในการรวบรวมมูลไก่ออกจากพื้นคอกนั้นให้พิจารณาจากสภาพของมูลสัตว์ เช่น
มูลไก่เนื้อลูกผสมทางการค้าควรจะมีการเก็บรวบรวมบ่อยๆ

เนื่องจากมีความชื้นสูง
และมีกลิ่นเหม็นมากทำให้เกิดแกสแอมโมเนียได้ง่าย
และมีผลต่อการเจริญเติบโตของไก่ได้ ขณะที่มูลของไก่พื้นเมือง
และไก่ลูกผสมพื้นเมืองมีลักษณะค่อนข้างแห้ง
และไม่ค่อยมีกลิ่นเหม็นมากนัก
ปริมาณจะสะสมแต่ละวันจะไม่มาก
การเก็บรวบรวมทำได้เป็นช่วงๆตามความเหมาะสม

- ผลที่ได้จากการศึกษาแสดงให้เห็นว่าแผนการให้อาหารทั้งระบบ มีอิทธิพลแตกต่างกันระหว่างประสิทธิภาพการใช้อาหารและคุณ ภาพซาก
  ทำให้พบว่าความเป็นไปได้สูงสำหรับทางเลือกต่างๆสำหรับเกษต รรายย่อยในการสร้างรายได้จากการเลี้ยงไก่เนื้อพันธุ์ต่างๆ
  และมีโรงเรือนที่ไม่ซับซ้อนและมีการลงมีการทุนต่ำ
  ถ้ามีวัตถุดิบอาหารสัตว์ในระบบทำฟาร์มอยู่แล้วก็สามารถที่จะนำ ใช้หรือผสมผสานการผลิต
  ซึ่งจะช่วยยกระดับการผลิตและความเป็นอยู่ของเกษตรกรรายย่อ ยอย่างยั่งยืนโดยเฉพาะไก่พื้นเมือง
  และไก่ลูกผสมอื่นๆที่มีความสามารถในการตอบสนองของสิ่งแวด ล้อมในการเลี้ยงได้ดีระดับหนึ่ง
  แต่จะปรับตัวได้ดีโดยเฉพาะในระบบการทำฟาร์มของเกษตรกรร ายย่อย และทนทานต่อโรคและพยาธิ ทำให้มีอัตตราการรอดสูง
  และอยู่ได้ในระบบสิ่งแวดล้อมที่เป็นธรรมชาติ

- สมรรถนะการเจริญเติบโตของไก่เนื้อนั้นขึ้นอยู่กับพันธุกรรมและ ความสามารถในการปรับตัวกับสิ่งแวดล้อม

สำหรับสัตว์ปีกที่มีการคัดเลือกยีนที่มีความสามารถสูง (เช่นไก่เนื้อลูกผสมทางการค้า) สามารถที่จะเจริญเติบโตได้ดีเมื่ออยู่ในสภาพแวดล้อมที่ดีตามศักยภาพของพันธุกรรม เช่นไก่พื้นเมืองมีความทนทานต่อสิ่งแวดล้อมที่มีความแปรปรวนได้ดี (โดยเฉาะการเลี้ยงไก่ของเกษตรกรในชนบท) จากการศึกษาพบว่าไก่พื้นเมืองมีการตอบสนองที่ดีขึ้นอย่างชัดเจนเมื่อมีการปรับปรุงอาหารที่ใช้ในการเลี้ยงและอีกระดับหนึ่ง ทำให้การเลี้ยงไก่พื้นเมืองของเกษตรกร ในคอกขังเป็นทางเลือกที่ดีที่จะให้ผลตอบแทนที่เหมาะสมด้านเศรษฐกิจ โดยเฉพาะในพื้นที่ศึกษา เกษตรกรได้มีการนำใช้เมล็ดข้าวโพดอาหารสัตว์มาใช้อาหารไก่เป็นหลัก การเพิ่มคุณภาพอาหารสามารถทำได้โดยเพิ่มอาหารสำเร็จรูปไก่เพื่อทางการค้า โดยเพิ่มในระดับโปรตีนที่ไก่ต้องการตามช่วงอายุ ทั้งนี้เพื่อเพิ่มสมรรถนะการเจริญเติบโต และประสิทธิภาพของการใช้อาหาร และไก่เนื้อมีคุณภาพซากตามที่ผูบริโภคต้องการ

ข้อเสนอแนะสำหรับการศึกษาต่อไปในอนาคต

1. การศึกษาการนำวัตถุดิบอาหารสัตว์ชนิดอื่นๆในการเลี้ยงไก่ทุกกชนิดสำหรับเกษตรกรรายย่อยที่มีการเลี้ยงแบบขังคอก และบนระแนงไม้ไผ่

2. การศึกษาคุณภาพของเนื้อไก่แต่ละชนิดเพื่อทดสอบความชอบของผู้บริโภค
3. ศึกษาแนวทางการใช้มูลไก่สดที่เหมาะสมกับการปลูกพืชของเกษตรกร
4. การวิเคราะห์ผลตอบแทนทางเศรษฐกิจของการเลี้ยงไก่ทั้ง 4 ชนิดและการให้อาหารทั้ง 2 ระบบ
5. ศึกษาการหมุนเวียนของแร่ธาตุที่สำคัญในการผลิต เช่น จากอาหาร เนื้อไก่ มูลไก่ และการนำใช้ประโยชน์จากพืชตลอดจนปริมาณที่หลงเหลือในดิน และสูญหายในบรรยากาศ
6. แนวทางการพัฒนาระบบการตลาดของไก่พื้นเมือง และไก่ลูกผสมพื้นเมือง ซึ่งประกอบไปด้วยเครือข่ายการตลาดเพื่อเป็นทางเลือกให้กับเกษตรกร และผู้บริโภค ทั้งภายในและต่างประเทศ ขณะที่ปัจจุบันการตลาดของไก่พื้นเมืองในระดับท้องถิ่นจะขึ้นอยู่กับคนกลาง ระบบการตลาดที่ดีจะเป็นประโยชน์โดยตรงต่อเกษตรกรในชนบท
7. ความสามารถในการผลิตลูกไก่ ในระดับหมู่บ้านจะช่วยเสริมให้มีการเลี้ยงไก่ที่มากขึ้นโดยทางอ้อม การผลิตลูกไก่ได้อย่างเป็นระบบในระดับหมู่บ้านจะช่วยลดต้นทุนการผลิตลูกไก่ลง ควรมีการศึกษาและส่งเสริมให้มีการผลิตที่ชัดเจน

และจริงจังซึ่งจะช่วยส่งเสริมการเลี้ยงไก่ แล้วยังเป็นการอนุรักษ์พันธุกรรมไก่พื้นเมืองอีกด้วย

8. ศึกษาการเลี้ยงไก่แบบปล่อยแปลงอิสระให้มากขึ้น เพื่อส่งเสริมสวัสดิภาพของสัว์เลี้ยง โดยการเน้นการควบคุมฝูงและการจัดการที่ดีขึ้น
9. การปรับปรุงระบบสุขาภิบาลในการเลี้ยงไก่ ควรจะมีการเน้นหนัก ซึ่งจะช่วยให้ลดการเกิดโรคระบาดต่างๆ รวมทั้งพยาธิต่างๆที่อาจเกิดขึ้น นอกจากนี้การให้วัคซิน ควรมีการพัฒนาทางด้านการจัดทำเครือข่าย การจัดหา และจัดส่งวัคซินไปยังชุมชนที่อยู่ห่างไกลในชนบท

8 ZUSAMMENFASSUNG

Studie über Masthuhn Produktion für Kleinbauern im Nordosten von Thailand

Der weitaus größte Teil der Geflügelproduktion in Thailand, die vorwiegend exportorientiert ist, liegt in den Händen von Großbetrieben und bei Vertragsproduzenten. Über 85 % der Geflügelprodukte –insbesondere der Masthühner– stammen von Hybrid-Rassen. Etwa 13 % des Hühnerbestandes sind einheimische Rassen. Sie werden vorwiegend extensiv und auf Kleinbetrieben gehalten und dienen vor allem der Selbstversorgung. Wegen ihres langsamen Wachstums und der daraus resultierenden geringen Produktivität sind sie für eine kommerzielle Nutzung im größeren Rahmen uninteressant.

Zur Verbesserung der Fleischleistung wurden Hochleistungsrassen mit einheimischen Rassen gekreuzt. Diese Kreuzungen werden von kleineren kommerziellen Betrieben gehalten. Bei den Kleinbauern fanden sie keinen Eingang. Auf Kleinbetrieben –oft sind dies Subsistenzbetriebe– sind die einheimischen Rassen dominierend. Sie erfordern ein Minimum and Haltungsaufwand. Sie laufen tagsüber frei herum. Einen Teil ihres Futters suchen sich die Tiere selbst; zugefüttert werden Ernterückstände und Küchenabfälle. Die Stallungen beschränken sich i.a. auf ein einfaches Nachtquartier unter oder neben dem Haus, das die Tiere schützt. Die Tiere haben im allgemeinen eine gute Resistenz gegen Geflügelkrankheiten.

Die Nachfrage, insbesondere nach Fleisch von einheimischen Rassen, steigt. Verbraucher, insbesondere in den größeren Städten, sind bereit für höherwertige Produkte auch höhere Preise zu zahlen. Doch trotz der höheren Preise, die für Produkte einheimischer Rassen erzielt werden, ist das Angebot beschränkt. Die Haltung und Mast dieser einheimischen Rassen ist für die kommerzielle Haltung in größerem Maßstab nicht möglich. Die geringe Futterverwertung, die extensiven Haltungsansprüche (Platzbedarf) und das nicht regulierbare Nachzuchtverhalten dieser Rassen erschweren eine groß angelegte kommerzielle Nutzung.

Diese Bedingungen eröffnen attraktive Produktionsnischen für Kleinbauern. Auf den Betrieben anfallende Ernterückstände und Rohprodukte, wie z.B. von Reis und Mais, sind wertvolle Futterressourcen für einheimische Rassen, die oft nicht optimal genutzt werden. Daraus ließen sich für Kleinbauern wesentliche Einkommenssteigerungen erzielen, unter tierfreundlichen –d.h. weitgehend natürlichen– Haltungsbedingungen.

Das engere Ziel dieser Arbeit war, die Verwertung von Futterressourcen, wie sie für viele Kleinbetriebe in Thailand typisch sind, von verschiedenen Hühnerrassen und im Vergleich zu kommerziellem Futter zu erfassen. Wichtig war sowohl die Entwicklung des Körpergewichtes der Tiere als auch die Qualität des Fleisches.

Vier Rassen wurden in die Studien einbezogen: (i) eine einheimische Rasse, (ii) Hybrid-Masthühner, (iii) eine Dreilinien-Kreuzung und (iv) eine Vierlinien-Kreuzung. Zwei beiden einbezogenen Futter-Regime waren: (i) kommerziell produziertes Mastfutter [Futter 1] und (ii) Futtermischung typischem Futtermaterial, das auf Kleinbetrieben anfällt (z.B. Reis, Mais, Mungbohnen) [Futter 2].
Die Futter-Regime wurden für drei Wachstumsphasen (Altersstufen) eingestellt, (i) 0-3 Wochen, (ii) 4-6 Wochen) und (iii) 7 Wochen bis Schlachtalter. Das Schlachtalter variierte, je nach Rasse, zwischen 7 Wochen (Hybriden), 12 Wochen (Kreuzungen) und 20 Wochen (einheimische Rasse).
Die Hühner wurden in Volieren (statistischer Block) mit jeweils 50 Tieren besetzt im Alter von 2-3 Tagen besetzt. Futteraufnahme war *ad libitum* mit Vitamin- und Mineralstoffzusätzen über das Trinkwasser.

Die wesentlichen Ergebnisse können wie folgt zusammengefasst werden:

Die Hybriden erbrachten mit Futter 1 nach 20-25 Tagen ein Gewicht von 1000-1250 g. Nach 7 Wochen wurde das Schlachtgewicht von 2500 g erreicht. Die Mortalität war hoch. Die Futternutzungseffizienz war höher als bei den anderen Rassen, und auch höher als mit Futter 2. Mit Futter 2, das Mais enthielt (30 % zwischen Woche 3-5; 50% zwischen Woche 4-6), erreichten die Tiere das Schlachtgewicht 2 Wochen später. Während der ersten 8 Wochen hatte die Vierlinien-Kreuzung größere Zunahmen mit Futter 1. Allerdings waren die Zunahmen zwischen Woche 8-12 besser mit Futter 2. Bei der Dreilinien-Kreuzung waren die Unterschiede in der Gewichtszunahme zwischen Futter 1 und Futter 2 insignifikant, obwohl Futter 1 bessere Ergebnisse zeigte.

Insgesamt zeigte die Vierlinien-Kreuzung bessere Gewichtszunahmen. Entsprechend war die Futteraufnahme bei der Vierlinien-Kreuzung wesentlich höher als bei der Dreilinien-Kreuzung. Die Vierlinien-Kreuzung erreichte das typische Schlachtgewicht (1200-1400 g) im Alter von 9 Wochen, während die Dreilinien-Kreuzung 1-2 Wochen länger brauchte.

Die einheimische Rasse (Futter 2) zeigte gutes Wachstum, Futternutzungseffizienz und gute Fleischqualität. Die typische Schlachtreife wurde nach 15 Wochen erreicht, also 3-4 Wochen nach den Kreuzungen. Der Anteil des Schlachtkörpers am Lebendgewicht der einheimischen Rasse war nicht signifikant unterschiedlich zu den beiden Kreuzungen, obwohl absolut höhere Werte erreicht wurden. Der Fettgehalt des Schlachtkörpers war bei der einheimischen Rasse insgesamt niedriger. Dies zeigt, dass lokale, d.h. auf dem Betrieb erzeugte, Futtermittel eine echte Alternative zu gekauftem Futter darstellt.

Die Untersuchungen zeigten, dass die beiden Futter-Regime, je nach Hühnerrasse, unterschiedlichen Einfluss auf Gewichtszunahme, Futtereffizient und Schlachtkörperqualität hatten. Die Ergebnisse zeigen machbare Alternativen

für eine profitable Haltung einheimischer Hühner auf Kleinbetrieben auf, ohne den Einsatz teurer Produktionsmittel. Insbesondere, wenn der Betrieb eigene Futterressourcen besitzt, die eingesetzt werden können. Dies kann die Einkommen von Kleinbauern wesentlich verbessern.
Mit lokalem Futter erreichten Hybriden das Schlachtgewicht in 5-7 Wochen, die beiden Kreuzungen in 9-12 Wochen und die einheimische Rasse in 15-20 Wochen. Ein großer Vorteil der einheimischen Rasse –teilweise auch der Kreuzungen- ist ihre gute Anpassung an die einfachen Haltungsbedingungen in Kleinbetrieben und ihre gute Resistenz gegen Krankheiten.

Das Wachstumspotential der Hühner war geprägt durch ihr genetisches Potential und ihre Anpassungsfähigkeit an die Umwelt- und Fütterungsbedingungen. Tiere mit hohem genetischem Potential zeigten hohe Leistungen nur unter spezifischen, für sie günstigen, Umweltbedingungen. Einheimische Rassen tolerieren ungünstigere Umweltbedingungen –wie z.B. auf Kleinbetrieben– und reagieren eher positiv auf schon geringe Verbesserungen in den Haltungs- und Fütterungsbedingungen. Diese Eigenschaften machen die Haltung einheimischer Hühner zu einer ökonomisch attraktiven Alternative für Kleinbauern. Entsprechend der verfügbaren Futterressourcen –hier sind eiweißreiche Futterstoffe besonders wichtig– kann durch gezielte Zugabe von zugekauften Futtermitteln und essentiellen Mineralstoffen und Vitaminen Futter erzeugt werden, das eine profitable Haltung einheimischer Hühner für die Kleinbauern ermöglicht.

Bei der Aufstallung der Hühner ist es wichtig, darauf zu achten, dass die Hygiene nicht durch feuchte Fäkalien beeinträchtigt wird. Hier bietet sich für Kleinbauern z.B. ein einfacher Spaltenboden aus Bambus in der Kotecke an. Das allgemeine Wohlbefinden der Tiere hat insgesamt positive Auswirkungen auf die Leistung, wie z.B. ausreichend Auslauf, Schatten und Rückzugs- und Ruhemöglichleiten in der Voliere.

Weiterer Forschungsbedarf besteht bei der Entwicklung von Volieren für den kleinbäuerlichen Betrieb, die sowohl die Erfordernisse der Bauern als auch der Tiere besser erfüllen. Wegen des besonderen Lege- und Brutverhaltens der einheimischen Rassen ist die Nachzucht der Tiere in ausreichender Zahl und zu den gewünschten Zeiten schwierig. Weitere Forschungen auf diesem Gebiet, unter Einbezug der sozioökonomischen Bedingungen, sind für eine weitere Verbesserung der kleinbäuerlichen Haltung einheimischer Hühnerrassen erforderlich.

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Appendix

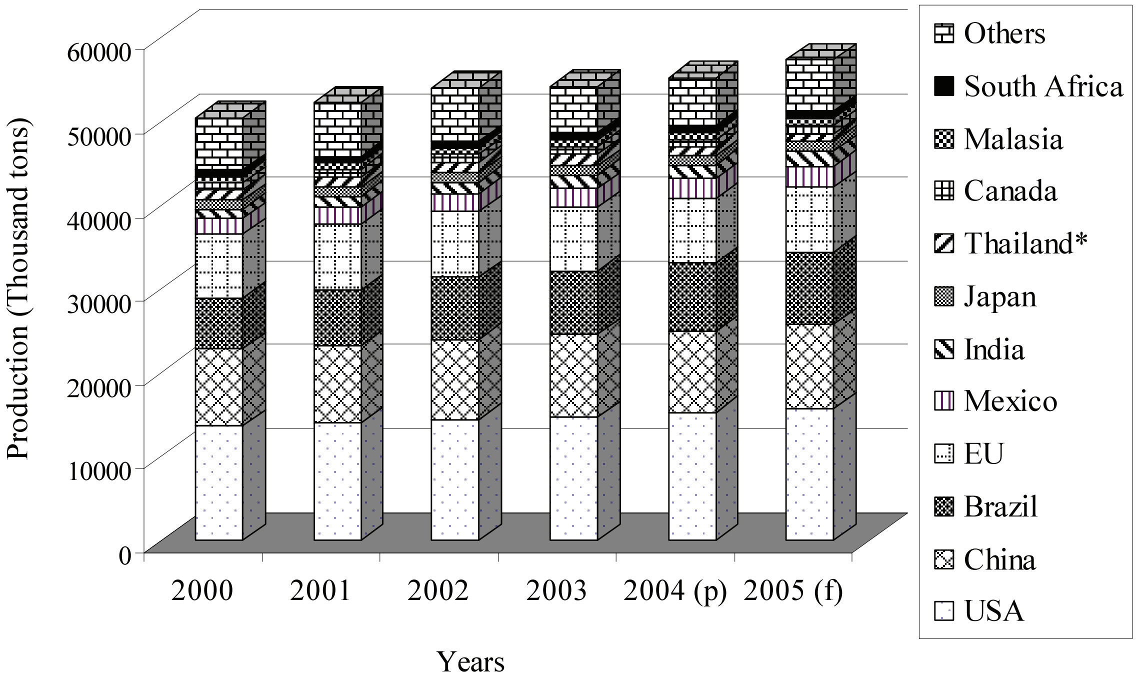

Figure A-1 World poultry production of major country during 2000 to 2005
*Sources: USDA, * Thai Broiler Processing Exporters Association cited by Animal Feed Business Journal, 2005. (2004 preliminary; 2005: forecast)*

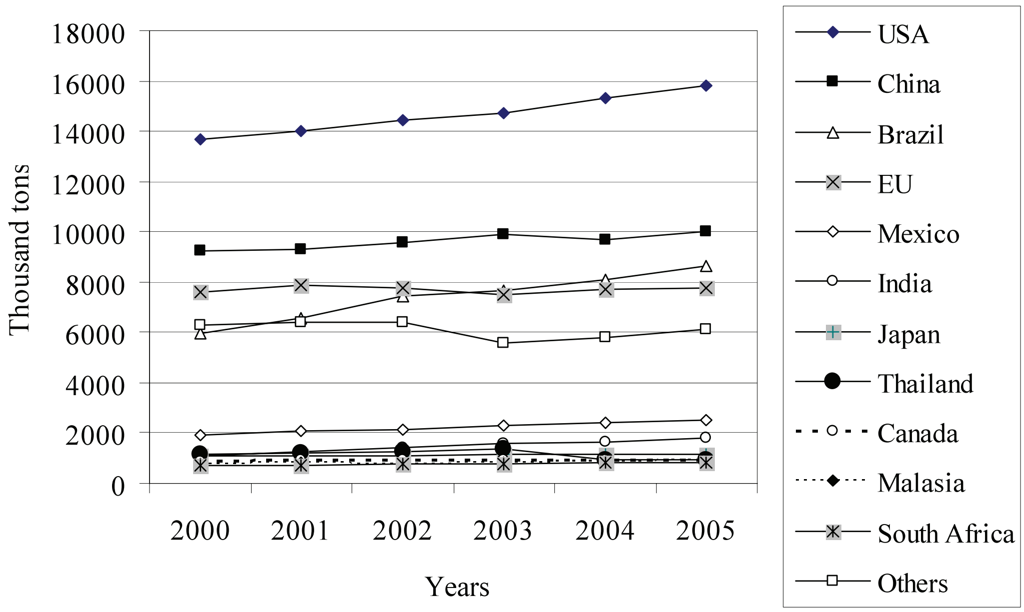

Figure A-2 Trend of poultry production of major country producers during 2000 to 2005
*Sources: USDA, * Thai Broiler Processing Exporters Association cited by Animal Feed Business Journal, 2005. (2004: preliminary; 2005: forecast)*

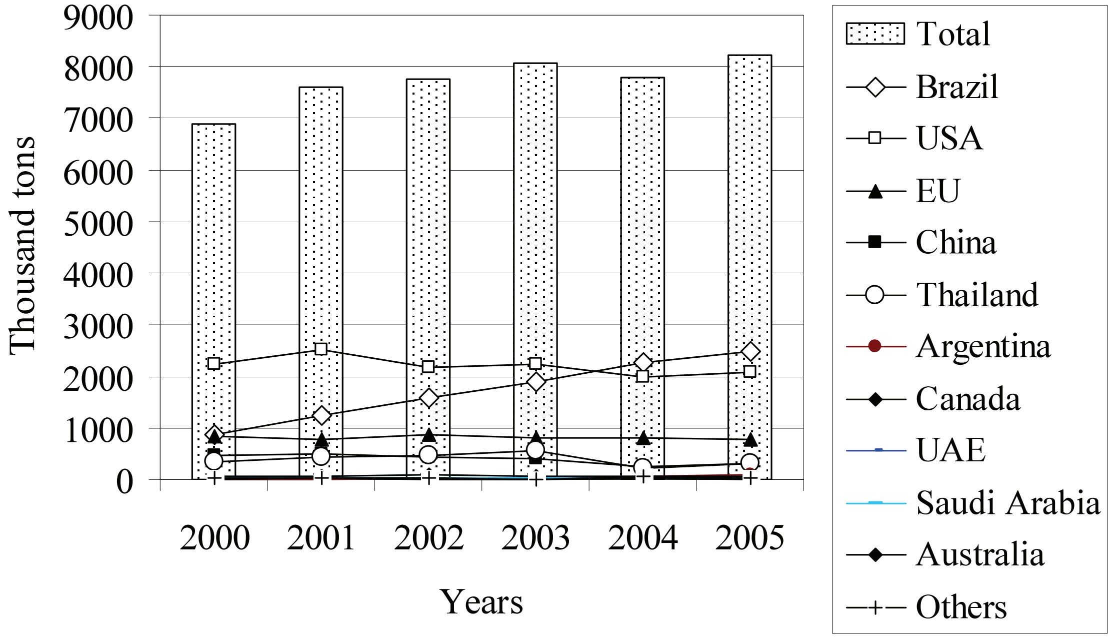

Figure A-3 Trend of export volume of poultry meat of major country exporter during 2000 to 2005 *Sources: USDA, * Thai Broiler Processing Exporters Association cited by Animal Feed Business Journal, 2005. (2004: preliminary; 2005: forecast)*

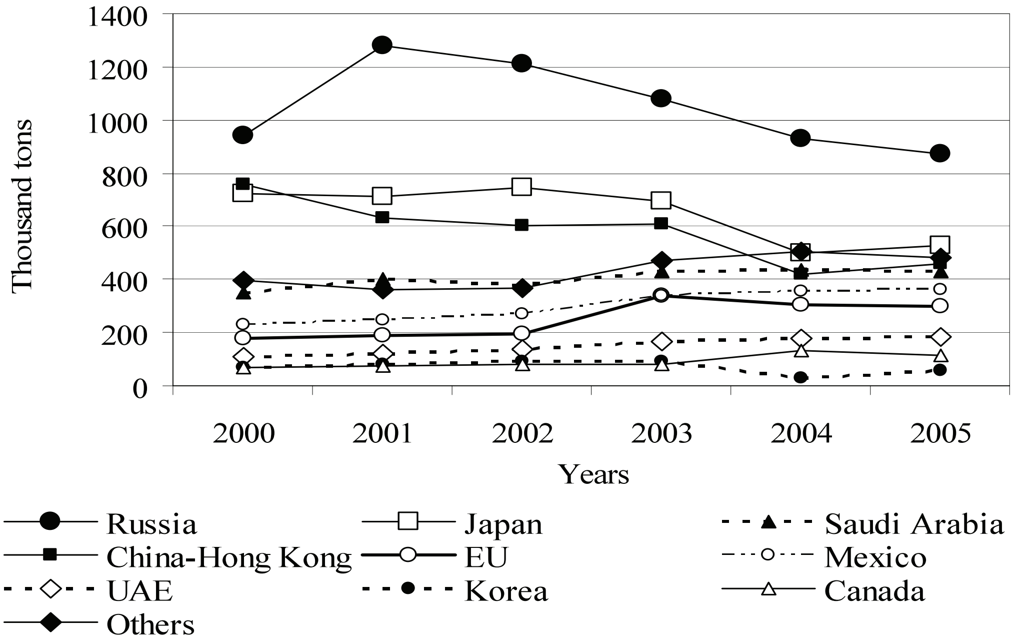

Figure A-4 Trend of poultry meat imported by major countries importer during 2000 to 2005 *Sources: USDA, * Thai Broiler Processing Exporters Association cited by Animal Feed Business Journal, 2005. (2004: preliminary; 2005: forecast)*

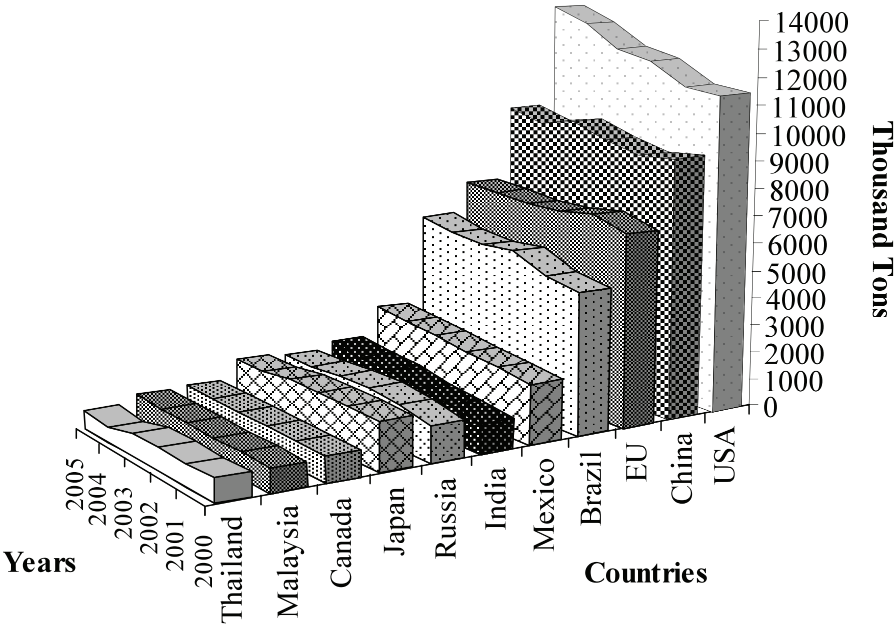

Figure A-5 Trend of poultry meat consumption by countries during 2000 to 2005
*Sources: USDA, * Thai Broiler Processing Exporters Association cited by Animal Feed Business Journal, 2005. 2004:)preliminary; 2005 forecast)*

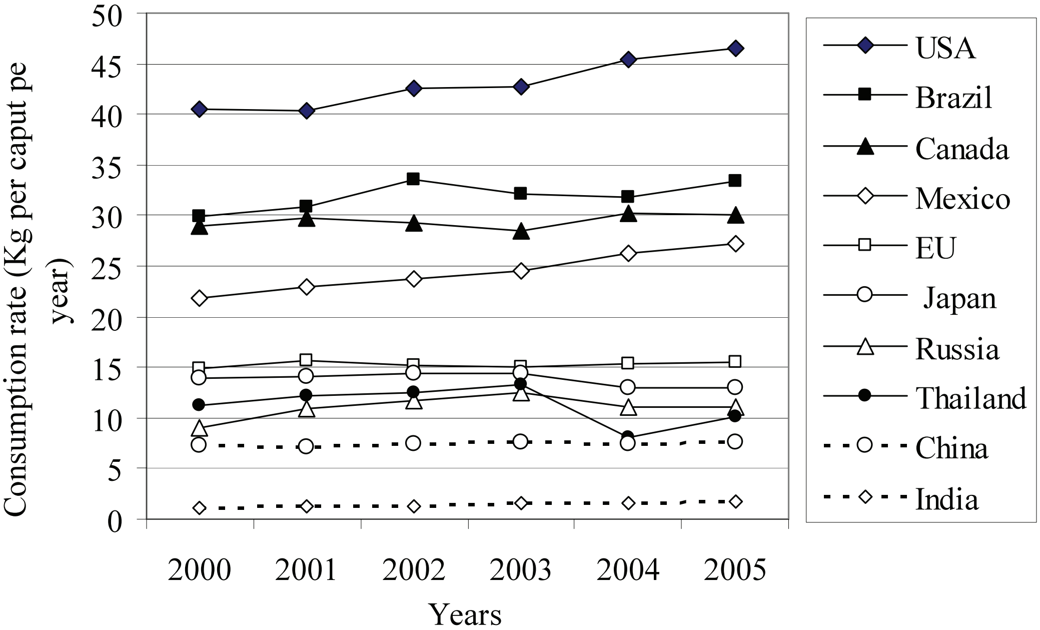

Figure A-6 Trend of poultry meat consumption rate (kg/person/year) by countries during 2000 to 2005 *Sources: USDA, * Thai Broiler Processing Exporters Association cited by Animal Feed Business Journal, 2005. (2004: preliminary; 2005: forecast)*

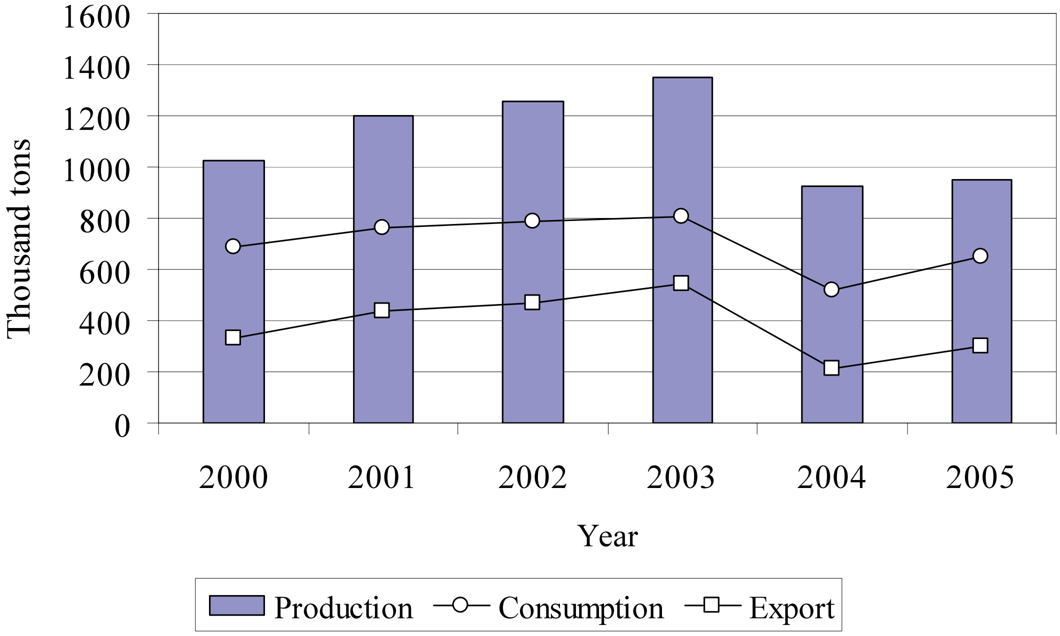

Figure A-7 Trend of poultry meat production and proportion of exporting and consumption of Thailand during 2001 to 2005. *Sources: USDA, * Thai Broiler Processing Exporters Association cited by Animal Feed Business Journal, 2005. (p)preliminary; (f) forecast*

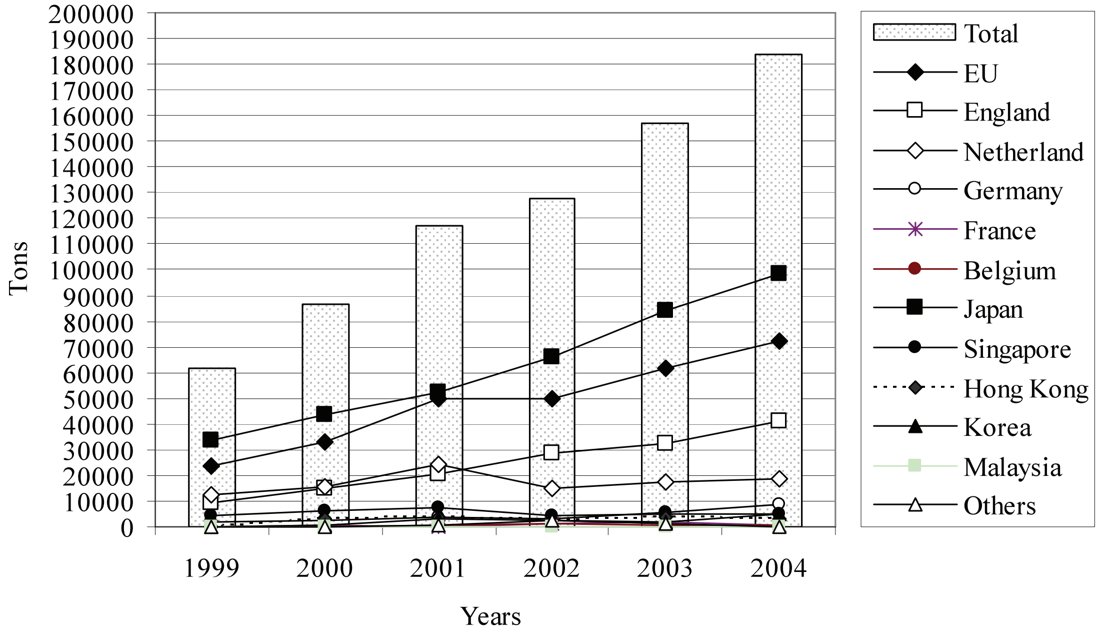

Figure A-8 Total processed poultry meat from Thailand imported by major countries during 1999 to 2004. *Sources: USDA, * Thai Broiler Processing Exporters Association cited by Animal Feed Business Journal, 2005.*

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