BREEDING GOALS FOR PRODUCTION SYSTEMS UTILISING INDIGENOUS CHICKEN IN KENYA

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EGERTON UNIVERSITY

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DECLARATION AND APPROVAL

1. DECLARATION

This Thesis is my original work and has not, wholly or in part, been presented for an award of a degree in any other university.

Enock Ondeyo Menge

Signed: ______________________________

Date: ________________________________

2. APPROVAL

This thesis has been submitted for examination with my approval as the official University supervisor.

Prof. Dr. A. K. Kahi

Signed: ______________________________

Date: ________________________________

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DEDICATION

TO: My dear Wife Sophia Kemuma Ondeyo
And our Children
Sammy, Martha and Joshua
Who have put up with my unusual routines,
All the farmers and researchers who believe in the indigenous chicken,
and
My parents
Musa Menge and Naom Moraa
Who have always inspired me to try a little harder.

-*“Minds are like parachutes; they only function when wide open” (Sir James Dewar)*

ABSTRACT

Indigenous chicken are mainly kept in subsistence systems and constitute about 80% of Africa's poultry flock. Currently, there are no well-defined breeding goals and genetic improvement programmes for the indigenous chicken are rare. The overall aim of this study was to develop breeding goals for use in production systems utilising the indigenous chicken. The specific objectives were to construct a deterministic bio-economic model for the economic evaluation of production systems utilising indigenous chicken, to identify breeding goal traits and estimate their economic values under different production circumstances and to determine the influence of economic values on genetic gain in the breeding goal traits. To construct the bio-economic model, three production systems were identified based on the level of intensification and management regime, namely: confined full ration system (CFRS); semi-intensive system (SIS); and free range system (FRS). The model was able to predict live-weight on every subsequent day starting with the hatching weight as the initial weight and the average daily gains for the birds, and used these outputs to estimate feed intake. The outputs from the model included revenue, costs and profitability in the different production systems. The traits which influenced profitability were identified and considered as potential breeding goal traits. They included live weight (LW) of pullets (LWp) and cockerels (LWc), egg weight (EW), hatchability (HTC), fertility (FRT); chick survival rate (CSR), age at first egg (AFE) and number of eggs per clutch (NeCl). Economic values were derived for each of the traits above. The AFE and EW had negative economic values in all systems (-14.20, -1.142 and –0.757; -0.052, -0.045 and -0.045) in CFRS, SIS and FRS respectively. The rest of the traits had positive economic values in all production systems. In terms of magnitude, semi-intensive system had high values for FRT and HTC. CSR was the most valuable trait in FRS and SIS with economic values of +14.114 and +19.227 respectively. The influence of the estimated economic values on genetic improvement was also assessed using different selection indices. The first selection index (I) included information on LWc, LWp, EW and CSR whereas the second selection index (II) included information on AFE, HTC, FRT and NeCl. Economic response in index I was KSh. 133.31; 66.71 and 105.33 for CFRS, SIS and FRS respectively and was KSh. 155.95; 20.13 and 13.14 for CFRS, SIS and FRS respectively for the second index. The economic values were fairly stable to changes in prices of meat and eggs and can be used to set up improvement programmes for indigenous chicken in Kenya. There was a clear relationship between the economic values and genetic gain. This study came up with breeding goals appropriate for genetic improvement programmes for indigenous chicken in Kenya.

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LIST OF ABBREVIATIONS

AACMC	Australian Agricultural Consulting and Management Company
ADG	Average Daily Gain (g)
AFE	Age at First Egg (days)
ALWF	Asymptotic Liveweight of hens (kg)
ALWM	Asymptotic Liveweight of Cocks (kg)
BLUP	Best Linear Unbiased Prediction
BW16	Body Weight at 16 weeks (kg)
BW20	Body Weight at 20 weeks (kg)
CFI	Cumulative Feed Intake (h-hens, c-cockerels, p-pullets)
CFRS	Confined Full Ration System
CSR	Chick Survival Rate (%)
DM	Dry Matter
EBV	Estimated Breeding Value
EN	Egg Number
EW	Egg Weight (g)
FAO	Food and Agriculture Organisation of the United Nations
FRS	Free Range System
FRT	Fertility (%)
gp	Growth potential (%)
GSR	Grower Survival Rate (%)
H5N1	H5 Subtype of Influenza A Virus
HTC	Hatchability (%)
HW	Hatching Weight (g)
INCIP	Indigenous Chicken Improvement Project
KAPP	Kenya Agricultural Productivity Project
KARI	Kenya Agricultural Research Institute
KSh.	Kenya Shillings
LSR	Layer Survival Rate (%)
LW	Live Weight (subscript c-cockerels, p-pullets, m-cocks, f-hens)
MALDM	Ministry of Agriculture, Livestock Development and Marketing
MLD	Ministry of Livestock Development
NCl	Number of egg Clutches per year
NeCl	Number of eggs per Clutch
NPDP	National Poultry Development Programme
NRC	National Research Council
PROL	Prolificacy
SIS	Semi-Intensive System
SM	Sexual Maturity (days)
TME	Total Metabolizable Energy
WHO	World Health Organisation

CHAPTER ONE

GENERAL INTRODUCTION

1.1. Background information

The domestic fowl (*Gallus domesticus*) is widely represented in all parts of sub-Saharan Africa (Gueye, 1998). They belong to the order *Galliformes*, family *Phasianidae* and genus *Gallus*. The five closest feral kins of the chicken are the Red Jungle Fowl *(Gallus gallus),* Grey Jungle Fowl *(Gallus sonnerati)*, Ceylon Junge Fowl *(Gallus lafayettei)* and *Gallus varius*. Of these, *Gallus gallus* is the species comparatively closest to the chicken and is therefore thought to be their progenitor (Moiseyeva *et al.,* 2003). Chicken have a diploid number of 78 chromosomes of which ten pairs are macro-chromosomes including the sex chromosomes while 29 pairs are micro-chromosomes. The female is the heterogametic sex (ZW) whereas the male is homogametic (ZZ) and the microchromosomes have been found to be richer in chromatin material than macrochromosomes (Musa *et al.,* 2005).

Several terms, i.e., African chicken, bush chicken, village chicken or runner chicken, have been used to describe the indigenous fowl (Gueye, 1998; Safalaoh, 2001). However, distinct local varieties have been reported in some African countries, i.e., Egypt, Cameroon, Burkina Faso, Morocco and Sudan (Gueye, 1998). Indigenous chicken tend to be robust and are well adapted to harsh environmental conditions such as hot or cold weather, rain and periodic feed shortages (Mbugua, 1990; Gueye, 1998; Kolstad and Abdou, 2002). These birds have many advantages such as good egg and meat flavors, hard eggshells, high dressing percentages, low cost of production and require little special care (Tadelle *et al.,* 2000). They are also used during ceremonies and rituals.

Indigenous chicken *(Gallus domesticus)* have been kept in Africa for many generations. They currently constitute about 80% of the continent's poultry flock and are kept in subsistence systems (Gueye, 1998). Management interventions are limited or non-existent under most of these systems (Tadelle *et al.,* 2000). The indigenous chicken are very appropriate tools for poverty alleviation because they are widely accepted among various communities and religions and require very low start-up capital (Permin *et al.,* 2001). The economic strength of the indigenous chicken lies in the low cost of production when compared to the value of the outputs. This aspect has led to the use of the term low-input-low-output systems or balanced systems to describe the production systems under which indigenous chicken are kept (Tadelle *et al.,* 2000).

Indigenous chicken constitute about 73% of Kenya's poultry flock (MALDM, 2000). When compared to commercial layers and broilers, the indigenous chicken produce fewer eggs and have smaller bodies, respectively (French, 1942; Ebangi and Ibe 1994; Safalaoh, 2001) and tend to have lower feed efficiency (King'ori *et al.,* 2003; Tadelle *et al.*, 2003a). Attempts at their genetic improvement were made through the National Poultry Development Programme (NPDP), which was launched in 1976. The programme concentrated on the exchange of exotic breeds of chicken with the local types, the general aim being to improve egg production and body weight (Nyange, 1995). The programme did not succeed due to the inability of the commercial birds to survive in harsh environments, lack of continuous supply of exotic breeding stock and to the inability of farmers to select the indigenous chicken at the farm level (Nyange, 1995).

Breeding programmes need to be well organised to increase the productivity of indigenous chicken with respect to the ability to lay more eggs, grow faster and have high feed efficiency without losing the important genetic characteristics related to product qualities, disease resistance and adaptability. Setting up of breeding programmes for the indigenous chicken requires the definition of clear breeding goals, which address the needs of the production systems utilising them. Breeding goals are linear combinations of traits that have an influence on the profitability of a given domestic species, weighed with their respective economic values (Hazel, 1943). Traits in the breeding goal are usually chosen on the basis of their influence on the overall profitability of a livestock enterprise. The change in net profit as a result of the unit improvement in a trait is called the economic value. Deriving the economic values is an important step in the design of breeding goals (Ponzoni, 1988). Therefore, when emphasis is put on the wrong traits or when important traits are left out of the breeding goal, genetic change is likely to be in the wrong direction or probably to be worse than none at all (Ponzoni, 1984).

In Kenya, breeding programmes for indigenous chicken are lacking probably due to the absence of well defined breeding goals for these birds. As a result, performance of indigenous chicken in traits of economic importance has continued to be comparatively low. Farmers therefore, have to either wait longer to benefit from meat harvests or have many birds to harvest more eggs for consumption or sale. There is the need to develop sustainable breeding goals to be used in selection of indigenous chicken.

1.2. Objectives

The overall aim of this study was to develop breeding goals for use in production systems utilising the indigenous chicken. The specific objectives were:

1. To construct a deterministic bio-economic model for the economic evaluation of production systems utilising indigenous chicken.
2. To identify breeding goal traits and estimate their economic values under different production circumstances.
3. To determine the influence of economic values on genetic gain in the breeding goal traits.

1.3. Hypotheses

H_o: Utilisation of indigenous chicken is equally profitable in different production systems

H_o: The economic importance of different traits in the breeding goals is similar

H_o: Economic values have no influences on genetic gain in breeding goal traits.

CHAPTER TWO

LITERATURE REVIEW

2.1. Chicken production in Kenya

2.1.1. Exotic chicken

A substantial portion of the meat and eggs consumed in Kenya are derived from commercial broilers and layers respectively. The exotic chicken are kept under intensive production systems and provided with feeds, shelter and clean water and regularly vaccinated against common poultry diseases like New Castle Disease. The capital requirements for starting such production units are usually substantial and due to logistical challenges like transportation of products to markets and acquisition of feedstuffs, commercial chicken production tends to be popular in urban and peri-urban areas. The chicken are specialised for a single purpose of either meat or eggs.

2.1.2. Indigenous chicken

Indigenous chicken are more numerous than the exotic chicken in Kenya (73-74% of chicken flock) and therefore tend to supply more families with eggs and meat than the commercial chicken (MALDM, 2000). Chicken farmers in Kenya show no specific breed preferences however most households have a flock whose size expands and shrinks seasonally. They are mostly kept under subsistence production systems, which rely on simple and cost effective shelters, and given minimal management input. Here the chicken are utilised as dual-purpose birds producing both eggs and meat.

2.1.3. Chicken production systems

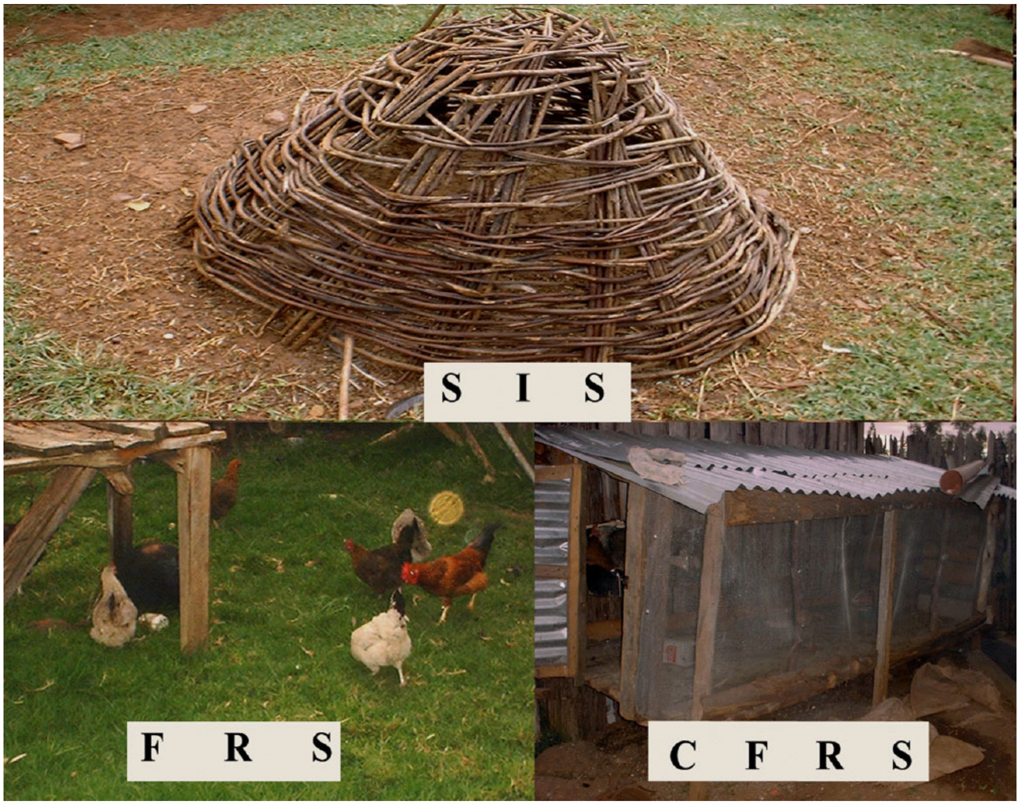
Chicken production systems can be broadly classified as subsistence and commercial based on the scale of operation, the way in which outputs are used and the level of management. Commercial production systems tend to be intensive and dependent on the product of interest and are either integrated or non-integrated (Groen *et al*., 1998). Jiang *et al.* (1999) demonstrated the importance of specifying whether the systems are integrated or not by obtaining different economic values for each case. Integration refers to the situation where the same company does the primary breeding, multiplication, hatchery and commercial level operations (Groen *et al*., 1998). Commercial systems are therefore capital and labour intensive undertakings with high-risk exposure.

Commercial broilers in Kenya are kept under deep litter systems, and charcoal burners are used for providing heat during brooding. Brooding is done for the first three weeks of life after which heating is withdrawn. The most advanced farmers use automatic drinkers to provide water and are able to monitor the maximum and minimum temperature for purposes of regulating brooding temperature. Farmers build shelters using iron sheets or other available materials and provide clean water; broiler starter and broiler finisher feeds to the chicken (Manual, 1990). Plate 1 shows one broiler house with the deep litter system while Plate 2 shows the structures used in indigenous chicken production systems.

In contrast, layers are kept in either the battery (cage) system or on deep litter floors and provided with nesting for laying eggs. Some are also kept on slatted floors which ensure the chicken droppings do not accumulate in the chicken shelter. The market supply of day old chicks is dominated by Kenchic Ltd., followed by others such as Kenbrid which is based in Naivasha, Muguku Poultry Farm based in Kikuyu, LakeChic and Ideal Poultry Farm (MALDM, 2000).

The subsistence production system is predominant in Africa, and supplies an estimated 80% of the rural population with food (Amer *et al.,* 1998). The chicken under subsistence systems, mostly indigenous chicken, have not only shown a remarkable ability to perform, albeit poorly, under constant disease and parasite challenge, but also to sustain their populations through natural incubation (Kitalyi, 1998). The farmer aims mainly at producing eggs and meat for home consumption but some may often be sold. The indigenous chicken are mainly kept as dual purpose birds, producing both meat and eggs for the family (Horst, 1988).

Plate 1. Intensive broiler production in deep litter system



Key: SIS-semi-intensive system; FRS-free range system; CFRS-confined full ration system

Plate 2. Indigenous chicken production systems

2.1.4. Marketing systems for chicken and their products

Commercial chicken farming is common in peri-urban and sub-urban areas where the market is fairly easily accessed. It is usually based on high yielding exotic varieties of chicken (Mbugua, 1994; MALDM, 2000). Marketing channels include local markets, which refer to the open markets nearest to the farmer, hotels and supermarkets. To a limited extent, broilers are grown on contract-farmer basis where the farmer is provided with credit in the form of inputs and some extension support and the chicken are bought at some agreed prices. The contractor recovers the credit after slaughtering and selling the meat (MALDM, 2000).

The market channels for the indigenous chicken are more informal (Figure 1) whereby middlemen buy village chicken in dozens and later resell them at the hotels or main urban centres at a profit. The buyers of indigenous chicken products range from the local shopkeepers, neighbours or itinerant traders who may barter some other types of goods for the chicken. The hotels have a dedicated clientele who prefer their products and pay a little more for indigenous chicken meat or eggs presumed to possess unique flavours (Gueye, 1998). Sometimes the farmers also carry their chicken or eggs to the nearest (local) market. In subsistence systems, the chicken are usually disposed off when there is need for cash or when there is surplus production (Tadelle *et al.,* 2003a).

Figure 1 illustrates the marketing structure depicting the various channels of associated with chicken trade in Kenya. The segment of the market served by the commercial broilers and layers is supported by advertising through various media (i.e., radio, television, billboards and promotional materials at agricultural fares). Currently, efforts at promotion have met with serious drawbacks from emerging diseases like Avian Influenza. Avian Influenza is a disease caused by type A strains of the influenza virus. There are 15 subtypes of the influenza virus that infect birds and recent outbreaks have been caused by subtypes H5 and H7 where transmission has usually been by direct contact with infected birds (WHO, 2004). Cooking of poultry (e.g. chicken, ducks, geese, turkeys and guinea-fowl) at or above 70°C throughout the product, leaving absolutely no meat raw or red is a safe measure to kill the H5N1 virus (FAO Press Release – 2005). However, about 100 people have died from avian influenza worldwide since 1997 (WHO, 2005).

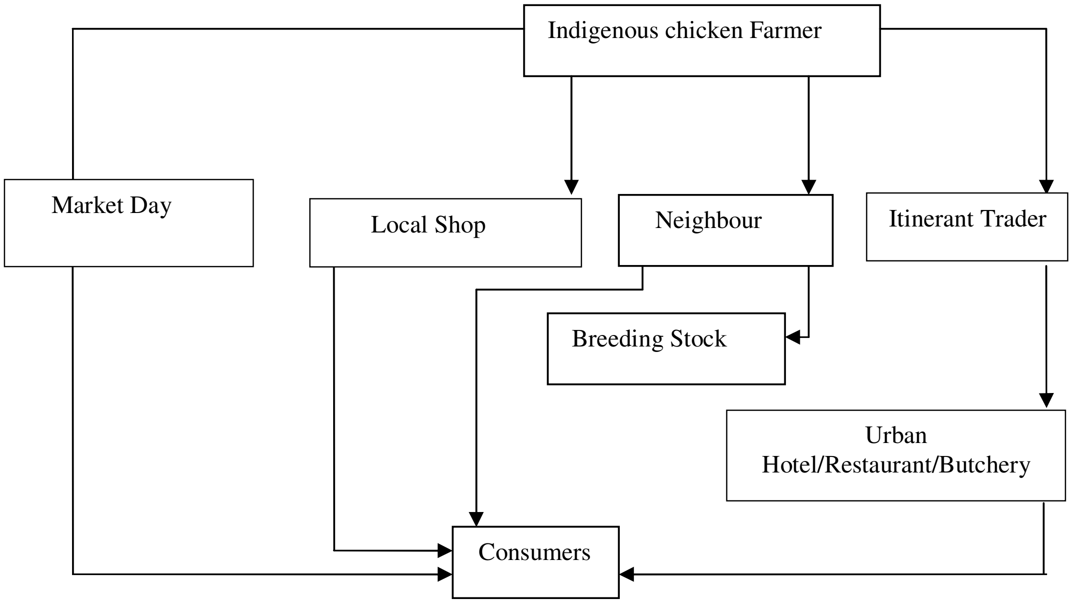


Figure 1. The marketing structure for indigenous chicken

2.1.5. Chicken breeding

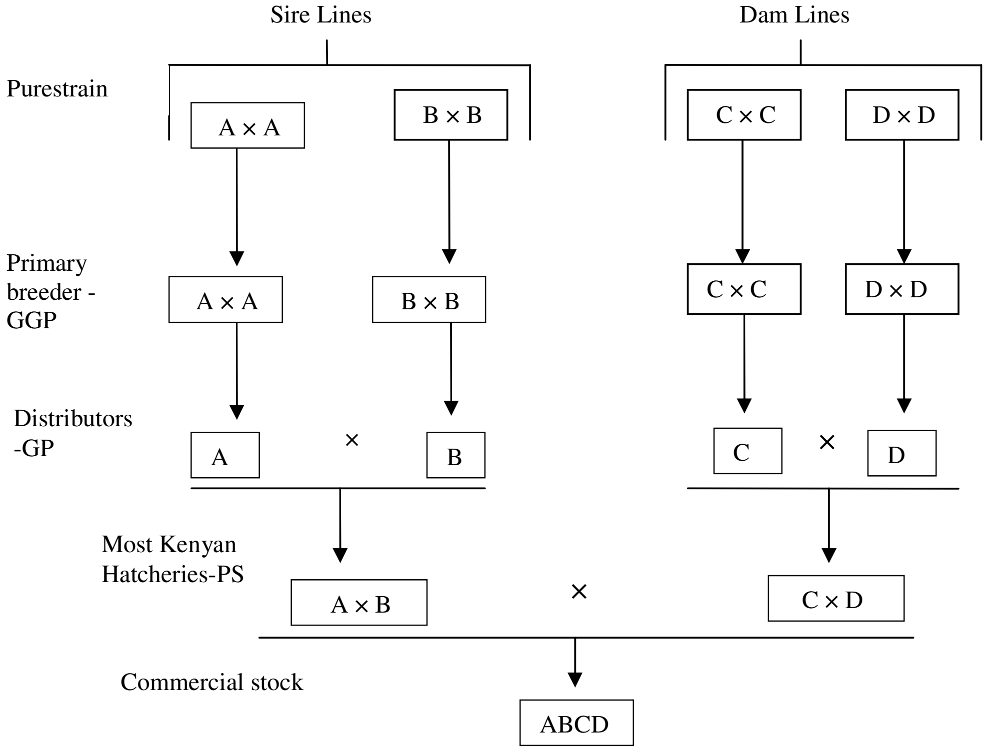
In Kenya, commercial chicken for both eggs and meat are supplied by a few hatcheries, which hold franchise for international breeding companies. For example, Kenchic supplies chicken to the local market for Arbor Acres (Kenchic, 2003), which is ultimately owned by the Aviagen group (USA). Kenbrid on the other hand supplies chicken from Nutreco (N.V.) Netherlands, bred by Euribrid. Before suspending operations, Rift Valley Hatcheries used to supply the local market with Yaffa layers and ANAK broilers from the Poultry Breeders' Union, Israel. The sources of breeding stock for other hatcheries like Muguku, LakeChic and Ideal farms are largely unknown.

Kenyan poultry enterprises have kept grandparent stock in the past, however the hatcheries mostly obtain parent stock directly from international breeders and rear them for purposes of producing fertile eggs (Mbugua, 1994). The fertile eggs are then hatched and day old chicks supplied to the farmers. The lead time for orders is usually three weeks to three months and the main producers of day old chicks have depots, in main towns in Kenya and in neighboring countries, which act as day old chick collection points. Both layer and broiler parent stock are kept on deep litter system (Plate 1), but provided with nests so as to avoid getting dirty or broken eggs.

During the growth of the parent stock, careful monitoring of live weight gain is done so as to prevent the parent stock from achieving their growth potential and thus create problems in fertility and hatchability. It has been shown that very heavy breeders tend to have low reproductive scores (Pigott, 1981; Eitan and Soller, 2002). Hatcheries receive mainly crosses and do not handle pure strains. The breeders also give their recommendations on a suitable mating ratio to ensure maximum fertility and hatchability. Generally, a substantial proportion of chicken meat is produced from specialized meat stock while eggs are also produced from specialized egg stock. At the end of their productive life, layers and broiler parent stock are sold to be slaughtered for meat. Figure 2 illustrates the structure of the commercial breeding industry. Traits, which have, negative correlations (i.e. body weight gain and egg number) are conveyed through sire lines and dam lines respectively as they cannot be improved satisfactorily within a single line (Moav and Hill, 1966). Liljedahl and Weyde (1979) reported that selection for egg weight causes a negative response in egg number and vice versa. However, excellent hybrid vigour is obtained if the lines are selected separately for the opposing traits and only crossed to produce the parent stock.

Indigenous chicken breeding in Kenya is a relatively individual affair and the farmer decides what characteristics to propagate. Some farmers have however indicated that they prefer colours that are not bright for purposes of camouflaging the chicken from airborne predators as they forage for feed and others have shown preference for prolific chicken among other characteristics (Gueye, 1998). Improvement programmes have been undertaken at the national level through the National Poultry Development Programme (NPDP). The NPDP was launched in 1976 to develop and improve small-scale commercial poultry production through extension and applied research (Wainaina, 1994). It was a bilateral project funded by the Kenyan and Netherlands Governments.

The programme was launched with several constraints in mind which included low productivity of local birds, poor skills in commercial poultry production among the small scale farmers, limited knowledge on poultry husbandry among extension staff and fluctuations in supply and prices (Wainaina, 1994). Phase I and II of the programme had six components, namely; the egg production pilot project, broiler production pilot project, the cockerel exchange pilot programme, training, research, and marketing surveys. The egg and broiler production pilot projects were supported by a credit programme administered through the Co-operative Bank (Wainaina, 1994). Co-operative Society members were targeted and it was hoped that they could start keeping 200 layers or 1000 broilers. The cockerel exchange pilot



GGP-great grandparents; GP-grandparents; PS-Parent stock

Figure 2. The structure of the international chicken breeding industry

programme was aimed at improving the ability of indigenous chicken to produce meat and eggs.

According to the report by Wainaina (1994), the egg and broiler production pilot projects were phased out after evaluation in 1983-84. The focus then shifted to increasing the production and consumption of poultry meat and eggs among subsistence farmers at low costs. The egg and broiler production pilot projects seem to have been premised on the assumption that one of the constraints to increased poultry production was lack of credit to obtain commercial stock. However, the particular reasons for phasing out these components have not been indicated. It can only be inferred that either the farmers incurred losses due to high mortality and many failed to repay the credit given or that it was felt that the production systems were not favored by the subsistence farmers. Since the evaluation missions made a major recommendation for training of the staff involved in the NPDP, it may also be concluded that the staff may have not initially had the skills that were necessary for the tasks. The situation was remedied as more staff was trained in poultry husbandry at the Barneveld College beginning from 1983. When phase III was launched, all other components were dropped except, the cockerel exchange programme and training.

The objective of phase III was broad and aimed at increasing production and consumption of cheap poultry meat and eggs among the mainly subsistent rural households. This is when the cockerel exchange programme was emphasized as a quick means of achieving the objective. The pullet exchange programme was later added to complement the cockerel exchange programme (Nyange, 1995). It was during phase III that it was proposed that Rhode Island Red chicken be introduced to the farmers. This was intended to by pass the need for breeding and especially selection at the farm level, but was not implemented until towards the end of 1993. Government farms were set up where the exotic varieties were raised for sixteen to twenty weeks before being supplied to farmers in exchange for their indigenous chicken. The programme was discontinued with time and now there are hardly any such crossbreeding activities going on. Initially, the project covered 6 districts but later expanded to cover 12 districts during phases III and IV, finally expanding to 26 districts by the end of the project (Wainaina, 1994).

Currently, it has been suggested that some of the types of indigenous chicken may be threatened with extinction (Maina *et al.,* 2002). There are attempts to maintain some indigenous chicken from various regions of Kenya within the framework of the Kenya Agricultural Productivity Project (KAPP) funded project on improvement of indigenous chicken. The indigenous chicken are being maintained at KARI's National Animal Husbandry Research Centre and at Egerton University. This project aims at increasing the productivity of indigenous chicken by identifying potential genotypes for different environments, raising their performances, promoting their utilisation and thus conserving these resources and systems associated with them. This will lead to raised household incomes, employment creation and assured food and nutrition security. To achieve this major objective, the project adopted an indigenous chicken value chain approach that incorporates the market demand component (A. K. Kahi, personal communication).

2.1.6. Constraints to chicken production

Chicken production in Kenya suffers from constraints such as lack of appropriate breeds, high cost of feeds, which are of irregular quality, recurrent disease out-breaks and lack of credit. Other constraints include low consumption of eggs and chicken meat due to their high cost (Itunga, 1994). Scarcity of appropriate breeds could be attributed to the lack of functional genetic improvement programmes, whereas high cost of feeds is as a result of competition for grains between man and animals. Due to the high cost of feeds, the products tend to be costly, especially from the systems that require intensive management.

In sessional Paper No. 2 of 1994, on National Food Policy, the Ministry of Agriculture, Livestock Development and Marketing identified the poultry industry's major problems as large fluctuations in the production of day-old chicks, inadequate disease control, high feed prices, insufficient credit facilities and inadequate market intelligence (Itunga, 1994). Other constraints include lack of capital, poor quality of feeds, lack of appropriate technical know how, lack of market organization and support and lack of institutional support (Mburu, 1994). Although among the programmes set up to achieve policy objectives, a programme on poultry breeding was proposed (Itunga, 1994), it would appear that not much has changed during the intervening period. Breeding is a long-term exercise, which requires the definition of clear breeding goals, the establishment of breeding structures, and the dissemination of genetic superiority generated at centres where selection is carried out.

2.2. Performance of indigenous chicken genotypes and their crosses

The traits that influence productivity include the annual egg number, live weight at sexual maturity, feed efficiency, and egg weight. Fertility and hatchability are also important because they influence the number of eggs spared for consumption or sale. Mothering instinct of the chicken plays a central role in the generation of replacement stock within the smallholder production systems but has a negative impact on egg production of the hen (Gueye, 1998).

Traits such as resistance to diseases like Mareks, incubation behaviour, foraging efficiency, naked necks, plumage colour and homing instinct are essential for suitability to particular environments. These traits are important for the extensive production systems where the chicken are left to search for feed resources. Table 1 shows the performance coefficients of local chicken in several countries. Kitalyi and Mayer (1998) in: Missohou *et al.* (2002) reported that on average local chicken in Tanzania laid 2.4 clutches each with about 15 eggs whereas Minga *et al.* (1989) in: Missohou *et al.* (2002) observed that the clutch size was between 6 and 20 eggs. Buldgen *et al.* (1992) in: Missohou *et al.* (2002) noted that Senegalese indigenous chicken produced 5 clutches in a year each with 8-10 eggs. Egg weights were also highly variable, ranging from 30g to 49g.

Table 1: Production coefficients of rural poultry in selected countries in Africa

Author(s)	Country	Clutches per year	Egg per clutch	Egg weight (g)	Hatchability (%)	Chick mortality (%)
Kitalyi and Mayer (1998)	Ethiopia	1.1	13	-	71	66
	Gambia	3.2	13	-	71	19
	Tanzania	2.4	15	-	78	32.5
Buldgen *et al.* (1992)	Senegal	5	8-10	40	80	66
Mourad *et al.* (1997)	Guinea	3.78	10	30.7	87.5	10.7
Shanawany and Banerjee (1991)	Ethiopia	-	-	44-49	39-42	-
Bourzat and Saunders (1990)	Burkina Faso	2.7-3	12-18	30-40	60-90	-
Minga *et al.* (1989)	Tanzania	-	6-20	41	50-100	>80
Van Veluw (1987)	Ghana	2.5	10	-	72	50
Wilson *et al.* (1987)	Mali	2.1	8.8	34.4	69.1	56
Wilson (1979)	Sudan	4.5	10.87	40.6	90	-

Source: Missohou *et al.* (2002)

This could be a clear indicator of the existence of variation for egg production traits. Hatchability and survival of the chicks also vary. Survival has been reported to be as high as 89.3% (Mourad *et al.,* 1989) and indigenous chicken in Africa tend to differ in productivity and disease resistance (Msoffe *et al.,* 2002). Indigenous chicken are relatively active and hardy thus have better ability to withstand the disease challenges associated with free-ranging and the tropical heat stress than chicken genotypes obtained from temperate areas.

Table 2 shows some growth characteristics of indigenous chicken. The weight of chicks is generally around 32g and by the third month there are clear differences between male and female growers. The body weights of indigenous chicken at maturity are in the range of 1 kg for females and around 1.8 kg for males. They lay 60-130 eggs per year (Hossary and Galal, 1995) and show high fertility and hatchability (Trail, 1961; Hossary and Galal, 1995; Kumar *et al.,* 2002). The Fayoumi chicken have been shown to have higher compensatory growth than the New Hampshire and White Leghorn breeds (Hossary and Galal, 1995). They attain sexual maturity later at between 24 and 36 weeks. Crossing with exotic stock however, improves sexual maturity to around 18-20 weeks (Gueye, 1998).

Table 2: Growth performance of indigenous chicken

	Mean ± SE
Reproductive cycle (days)	92±19
Weight of chicks (g) at 1 week of age	31.7±5.3
Weight growers at 3 months (g)	
Female	398 ±107
Male	558±152
Weight of mature birds(Kg)	
Female	1.02
Male	1.6

Sources: Missohou *et al.* (2002) and Kitalyi (1998).

Crossbreeding the indigenous chicken with the exotic breeds also improves the growth traits, such as live weights, daily gains and feed efficiency (Omeje and Nwosu, 1988; Katule, 1992; Asiedu and Weever, 1993) and egg production traits (Tadelle *et al.,* 2000; Safalaoh, 2001). Studies on the 'Tsabatha' chicken of Cameroon (Ngou Ngoupayou, 1990) showed that these indigenous varieties have large body weights and therefore can potentially be used for meat production. In Ethiopia, it was found that the male indigenous chicken attained 1.5 kg live weight at six months (AACMC, 1984). Teketel (1986) showed that under station conditions, the local Ethiopian chicken reached 61% and 85% of body weights attained by White Leghorns at six months of age and at maturity, respectively. Naked-neck chicken tend to attain heavier body weights and show better brooding characteristics than normal feathered birds (Gueye, 1998).

Indigenous chicken are known to be protective of their young ones from predators, to possess excellent foraging ability, and are tolerant to extreme temperatures (Gueye, 1998). Foraging ability may be estimated by the foraging range (the distance the hen is able to cover in search of feed). Currently, some of the commercial breeders have included livability in their breeding objectives which is an indirect way of increasing survival and therefore disease resistance within the commercial flocks (Preisinger and Flock, 2000).

2.3. Development of breeding goals

2.3.1. Specification of the breeding, production and marketing systems

A breeding system describes how genetic resources are brought together to achieve the breeding goal, by specifying the mating systems adopted and the breeds to be utilised. A production system is an association of a finite number of elements considered together with their interaction with the environment, other higher levels being the farm and the sector (Charfeddine, 2000). The way the chicken are managed, fed, and flock replacement practices describe the production system (Kitalyi, 1998). The description of a production system also includes sources of income and expenses. Within the chicken production systems, there are the subsistence and commercial producers. The subsistence system has minimal costs and exposes the keeper to minimal risk therefore risk aversion has been identified to be a central factor influencing farmers' decisions (Amer *et al.,* 1998; Tadelle *et al.,* 2000; Kahi and Nitter, 2004). Marketing systems specify channels for marketing products in relation to the costs involved as well as the prices of outputs.

2.3.2. Identification of sources of income and expenses

The consideration of all sources of income and expenses in the definition of comprehensive breeding goals is necessary. This is because ignoring some costs may reduce the selection efficiency and result in a gross over-estimation of the economic worth of genetic improvement (Ponzoni, 1988). In commercial farming enterprises, inputs are the main contributors to expenses, whereas incomes are measured in terms of money that accrues from sales of the farm produce (Amer *et al.,* 1998). There are other costs that occur due to the presence of the enterprise. Usually costs which may not change even if the level of production of the flock rose, are classified as fixed costs whereas those that do change with the level of production are called variable costs (Charfeddine, 2000). Fixed costs may increase if the scale of the enterprise is increased. Models from several farm enterprises indicate that each system tends to have its own peculiar sources of costs and revenue (Charfeddine, 2000; Kristensen and Pedersen, 2003). It is therefore necessary to consider each production system separately due to the unique sources of costs that may not apply to another system or species (Mukherjee, 1990). For the subsistence system, there are several economic advantages, which may not be easily expressed in terms of money. Notably, costs resulting from losses of stock are important for consideration. In general, revenues and costs in animal production systems are influenced greatly by biological traits expressed by the animals.

2.3.3. Determination of biological traits influencing income and expenses

In order to arrive at a conclusion on the traits influencing the income and costs of an indigenous chicken farming enterprise, one has to understand the dynamics of the indigenous chicken; the population build-up and depletion. Other factors that need attention are those related to inputs and costs, as the inputs are usually related to the genotypes (i.e., a big animal will require a greater quantity of feed and vice-versa or an animal with poor resistance to diseases requires more vaccinations). In the subsistence systems, the traits that reduce the risk exposure, and increase survival will definitely influence incomes. If the costs are taken as the losses due to lower inputs then the conventional commercial traits of importance may become secondary when considered in the subsistence system (Amer *et al.,* 1998; Jensen, 2002; Kristensen and Pedersen, 2003).

For the commercial production system, which relies on the manipulation of the environment to maximize productivity, traits such as feed intake, feed conversion efficiency, growth and survival rates will be critical. Bio-economic models are useful in modelling biological traits that influence income and expenses (Jiang *et al.,* 1999). Modelling biological traits within profit functions is also useful in deriving their relative economic importance within the production system.

2.3.4. Derivation of economic values of traits

The economic value or weight of a trait is the marginal change in net profit per unit change in the trait (Hazel, 1943). The profit here is used as an indicator of economic efficiency of the livestock enterprise. Profit itself may be expressed as a difference between revenues and costs or as a ratio between revenue and costs, in which case the objective function is economic efficiency. In addition, it may also be expressed as a ratio of the energy of the product to the energy expended on production. Ponzoni (1988) identified two clear classes of costs (i.e., variable costs and fixed costs). Fixed costs ought to be spread over the useful life of the capital item whereas variable costs should be offset to the year they were incurred. Generally, if the component traits in a breeding goal are additive, monetary genetic progress based on linear selection indices is always greater than that based on non-linear indices (Smith *et al.,* 1986). It is therefore very important to obtain economic values that actually relate to the production circumstances in which the animal is to be kept.

A number of ways have been described for deriving economic values. The economic weights can be derived as partial derivatives with respect to the trait in a profit function. McArthur (1987) argued that it is important to take care of non-linearity effects especially when dealing with constraints either in quotas or facilities. The partial derivative is therefore useful when non-linearity effects are pronounced in a given production function. However, Gibson and Kennedy (1990) argued that when economic weights are linear and known, a standard selection index is optimal and that in cases where economic values are non-linear, use of a first order derived linear index gives fairly optimal genetic gains.

The economic weights may also be derived as regression coefficients of profit on traits. Forabosco *et al.* (2005) derived economic values for traits in Chianina beef cows using a multiple regression model. This approach depends on actual existing observations of trait and economic performances. A regression analysis of profits on traits measurements then seeks to identify how the trait performances explain the profitability of the livestock enterprise. In such a case, the regression coefficient of a trait becomes its economic value. This approach is not likely to be applicable in situations where there is inadequate existing data on profitability and traits performance. It is also inherently implied that the animals whose records are utilized in the regression analysis have optimum expression of the traits, but this may or may not be the case. However, Forabosco *et al.* (2005) censored data to reduce biases and the economic values from both normative and regression approaches were in good agreement.

Partial budgeting or accounting method can also be employed in deriving economic values of traits. In this method, profit is expressed as the difference between revenues and costs. Ponzoni (1988) proposed that a rigorous process of identifying sources of income and expenses will enable the development of partial budgets and such functions can then be used to derive economic values. Production systems are however complex and may be difficult to describe by simple profit functions. When such a situation arises, the biological and economic components of the production systems can be expressed as a system of equations.

A similar method was used by Jiang *et al.* (1999) to derive economic values for traits in commercial broilers. Models such as the one used by Jiang *et al.* (1999) however, require that the profit be described by revenues and cost sub-models all of which are subject to the same scaling factors. Scaling refers to the number of animals in the livestock enterprise, market conditions, and management systems (Forabosco *et al.,* 2005). Although McArthur (1987) argued against the use of linear production functions, the study indicated that when a society is food deficient and use of resources has not been maximised, it is feasible that the constraints in quotas and resources do not apply and the assumption of linearity in the production function is therefore valid in the medium term. Regardless of the method used, economic values are useful in quantifying the relative economic importance of traits in a given production system and therefore provide a good basis for the choice of breeding goals.

2.4. Genetic and phenotypic parameters in chicken breeding

Genetic and phenotypic parameters are essential as they determine eventual genetic progress when selecting for multiple traits (Hazel, 1943). Estimates of genetic and phenotypic parameters are based on several assumptions. The reliability of such estimates is often more sensitive to certain assumptions than to others. For example, parameters can be estimated on the assumptions that the population under study is unselected, that traits are polygenic and additive (no intra-loci interactions) (Muir, 1997), or with no inter-loci interactions (pleiotropic effects), that there is no correlation between genotype and environment and that selection itself does not introduce new variation (Sheridan, 1987). Although it has been observed that violation of certain assumptions can be tolerated without compromising too much the integrity of the estimates, caution must be observed as unrealistic assumptions result in biased estimation.

Genetic and phenotypic parameters such as heritability and correlations have been estimated on different populations of indigenous chicken and at different stages of selection. Heritability is the proportion of phenotypic variation that is due to the additive genetic effects. Therefore, half of that variation is expected to be inherited by the offspring. Heritability is considered to be low when less than 0.25, moderate at 0.26-0.5 and high above 0.5 (Sheridan, 1987). Table 3 shows some genetic and phenotypic parameters of traits in two domestic avian species of chicken and pigeons.

Parameter estimates from Preisinger and Flock (2000) were made on a population that had undergone selection for several generations and it is expected that populations that have not been selected should have similar or higher heritability estimates. Table 3 also shows that the parameter estimates even for the same trait are quite varied. The reasons for the variations observed may include the fact that the parameter estimates were made on populations with different variance structures. It has been shown that in the course of selection, the allelic frequencies shift and that even for the same population, the specific trait period of estimation (for instance early laying period, middle laying period or late laying period in layer chicken) is likely to influence parameter estimates (Sabri *et al.,* 1999).

Table 3:Genetic and phenotypic parameters of some production and reproduction traits in chicken and pigeons

[1]Trait 1	h^2	σ_p	Trait 2	h^2	σ_p	r_g	r_p	Source
EN	0.20	11.43	EW	0.59	4.91	-0.22	-0.18	Francesch *et al.* (1997)
BW16	0.14	150.31	ADG	0.44	6.00	-0.62	-0.74	Iraqi *et al.* (2002)
EN	0.20	10.00	EW	0.50	4.00	-0.30	-0.10	Kenji *et al.* (2002).
SM	0.55	12.01	EN	0.54	11.43	-0.36	-0.32	Khalil *et al.(* 2004)
EN	0.41	-	BW	0.69	-	0.12	-	Kiani-Manesh *et al.* (2002)
BW	0.50	9.76	[2]PROL	0.12	4.20	-0.82	-0.36	Mignon-Grasteau *et al.* (2000a)
SM	0.47	13.00	EW	0.61	3.22	0.11	0.15	Nirasawa *et al.* (1998).
EN	0.22	12.60	BW20	0.30	157.40	0.54	0.14	Oni *et al.* (1991)
EN	0.36	9.00	SM	0.54	12	-	-	Preisinger and Flock, (2000)

[1] EN-egg number/year; EW-egg weight (g); BW-body weight; BW16-body weight at 16 wks; ADG-average daily gain; SM-age at sexual maturity; PROL-prolificacy; h^2-heritability; σ_p-phenotypic standard deviation; r_g - genetic correlation; r_p -phenotypic correlation; [2] PROL-parameters estimated in pigeons.

Heritability estimates for egg number year^{-1} (EN) ranges from 0.2 - 0.54. Kiani-Manesh *et al.* (2002) found that body weight (BW) in chicken has high heritability (0.69) and this agrees fairly well with the heritability estimate for BW obtained by Mignon-Grasteau *et al.* (2000a) of 0.5 in pigeons. In the same study, Mignon-Grasteau *et al.* (2000a) reported a heritability estimate for number of weaned chicks (PROL) of 0.12. Nirasawa *et al.* (1998), Preisinger and Flock (2000) and Khalil *et al.* (2004) all report moderate to high heritability for age at sexual maturity (SM) (0.47, 0.55, and 0.54 respectively). Egg weight (EW), has high heritability (0.59, 0.61) and genetic progress should therefore be high (Francesch *et al.,* 1997; Nirasawa *et al.,* 1998).

Phenotypic correlations are associations between phenotypic values of traits which can be directly observed and which occur as a result of genetic and environmental causes. Genetic correlations on the other hand are associations between breeding values of two traits caused by pleiotropy and linkage. Phenotypic and genetic correlations are important because they will be used in connecting traits within the selection criterion with traits in the breeding goal. Generally, egg weight is positively correlated to body weight, whereas egg number is negatively correlated with age at sexual maturity and egg weight. This means that selection for body weight may result in higher egg weights and selection for egg number may result in earlier sexual maturity for instance. The trait EN has negative genetic and phenotypic correlations with EW and SM (Kenji *et al.,* 2002) and PROL is negatively correlated with BW

(Mignon-Grasteau *et al.*, 2000a). However, SM and EW are positively correlated both genetically and phenotypically (Nirasawa *et al.,* 1998).

Prolificacy is important in the indigenous chicken production systems. This is the number of chicks weaned into grower stage by a hen. Among the Abagusii community of Kenya for instance, prolificacy is popularly referred to as “Omosarara” and farmers favour animals possessing it. In sheep, Conington *et al.* (2004) identified prolificacy as a potentially valuable trait especially in hill sheep, which suffer high neonatal losses. In chicken, this trait could provide a useful indicator of the mothering ability of the hen, fertility and chick survival. Prolificacy has been studied in domestic pigeons and the parameters estimated (Mignon-Grasteau *et al.,* 2000a). Genetic and phenotypic parameters are used to combine the individual traits in an optimal way in the breeding goal through selection index methodology.

2.5. Selection index theory

Selection index methodology has been used to effectively combine several traits in an economically optimal way in a single individual. Hazel (1943) showed that selection for an index, which gives an appropriate economically meaningful weight to each trait, is more efficient than selection for one trait at a time or for several traits at a time using independent culling levels.

Breeding goals are linear combinations of traits, appropriately weighed with their economic values (McArthur, 1987). The economic selection index is also called the breeding goal or the aggregate genotype (Hazel, 1943). In order to select animals for use as parents of the future generations, there must be some record of performance for the traits in the economic selection index or some other measurable traits correlated to them (Hazel, 1943). Such a record is used to estimate the breeding value (EBV) of each individual. When proxy traits are used during evaluation then a new combination of traits called the selection criteria is created. The traits in the selection criteria are weighted with index weights derived as follows,

$$I = b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_nX_n. \qquad (1)$$

X_n is the phenotypic standard deviation for trait n from the contemporary group mean and b_n is the weight for the given trait. The b is obtained by setting up simultaneous equations relating phenotypic with genotypic variances. If P is the matrix with phenotypic (co)variances, G the matrix with genetic variances and b a vector with the index weights, then:

$$Pb = G \qquad (2)$$

and therefore:

$$b = P^{-1} G \qquad (3)$$

The concern of the breeder is that the EBV is as close to the true value as possible. The methods of estimating EBV rely on assumed linear relationships for information sources and therefore combine measures from various sources to give a prediction of the breeding value. Due to the spatial and physical diversity of areas covered by breeding programmes, environmental effects can seriously undermine the reliability of EBVs. To remove any bias due in estimates, procedures for the Best Linear Unbiased Prediction (BLUP) were designed (Henderson, 1973). The data available is analysed according to some suitable statistical model, chosen to explain the factors responsible for observed variation. The BLUP procedures take care of relationships between animals, uses all information sources available, and adjusts for the varied environments (Jones, 1981; Robinson, 1982).

In poultry breeding, multi-trait index selection and pure-line selection are the two main approaches that have often been utilised (Liljedhal and Weyde, 1979; Preisinger and Flock, 2000). In chicken, traditional emphases of commercial breeders have been on egg production and live weight gain (Flock, 1979; Preisinger and Flock, 2000). For example, the selection criteria used for the Fayoumi in Egypt includes egg number and body weight at 8 weeks of age (Hossary and Galal, 1995). Breeding may also concentrate on the creation of specialized lines, where the selection for certain traits is intensified for different lines and finally three-way or four way crosses are done to achieve the end result (Preisinger and Flock, 2000). Whichever method preferred, a breeding goal for indigenous chicken must take care of the harsh environment within which the chicken are expected to perform.

2.6. Chicken mating systems and breeding structures

Mating systems are designs that determine how genetic resources are used to produce animals for a given purpose. Mating may be random or assortative. Assortative mating is where the animals are matched according to some criteria, and it may be negative or positive assortative mating. Mating systems generally indicate whether line breeding or crossbreeding is used, the kinds of reproductive technologies applied. Current theory indicates that a mating system is expected to optimize reproductive characteristics in dam lines and production characteristics in sire lines (Muir, 1997). A mating system should normally be based on an already defined breeding goal.

Breeding structures on the other hand describe the system that is used to obtain records and the way genetic progress is generated and disseminated to the wider population (Cunningham, 1979). The structures also will reveal to what extent organizations are expected to come together to achieve certain well-defined goals for their herds or flocks. McPhee (1984) also mentions that the breeding structures would include the kind of crossbreeding designs included in the genetic improvement programmes. Crossbreeding may not only be used to come up with new breeds made from older breeds but it may also be used to improve traits that are known to be antagonistic in the same breed. Kosgey *et al.* (2002) on a study on village breeding schemes in sheep found that when selection is based on individual phenotype there is some merit in running a closed nucleus over a more open “ram cycle system” in terms of genetic gains. They pointed out that screening of the commercial populations for recruitment purposes may be useful to boost genetic response while retaining the interest of the participating communities in genetic improvement. These findings were deemed useful when considering genetic improvement for indigenous chicken in Kenya.

CHAPTER THREE

DEVELOPMENT OF THE DETERMINISTIC BIO-ECONOMIC MODEL

3.1. Introduction

Animal production systems are complex involving interactions between biological and economic variables. In order to describe the behavior of such systems, computer simulation and modeling are important for two main reasons. First, biological processes are costly or time consuming to study; secondly, models are useful in predicting the effects of planned interventions beforehand (Muir, 1997; Kitalyi, 1998; Rola-Rubzen *et al.,* 2004) due to their capacity to capture the relationships between animal traits, revenues and costs. In economic evaluation, animal traits are considered as input factors responsible for variations in revenues and costs in the production system (Kluyts *et al.,* 2003). Identifying animal traits affecting revenues and costs and estimating their economic values can be approached through modeling and simulation, especially the use of bio-economic profit functions (Roosen *et al.,* 2005). In this study, a deterministic bio-economic model was developed which was able to predict live weight at various stages and feed requirements for each class of chicken. This chapter covers the development of a bio-economic model for supporting breeding of indigenous chicken and an evaluation of biological and economic variables that characterise indigenous chicken production systems in Kenya.

3.2. Materials and methods

In Africa, a number of indigenous chicken production systems have been identified with variable management regimes (Gueye, 1998; Tadelle *et al.,* 2003b). Most of these systems are subsistent but some products (eggs or live animals) are sold to supplement family income while others are given out as gifts (Tadelle *et al.,* 2003b). Subsistence production systems supply an estimated 80% of the rural population with food (Amer *et al.,* 1998). Under these systems, management interventions are usually limited (Gueye, 1998). These systems, however, are expected to be relevant for livestock production in Africa for the foreseeable future, mainly due to competition for grains between livestock and man (Kristensen and Pedersen, 2003).

The indigenous chicken under subsistence systems have not only shown a remarkable ability to perform, albeit poorly, under constant disease and parasite challenge, but also to sustain their populations through natural incubation (Kitalyi, 1998). Most households combine all production activities in one set-up, i.e., they are not divided into distinct stages with different tiers. The chicken breed within the homestead, eggs are laid and incubated by broody hens, and chicks grow as they run around with the dam in search of feed resources (Gondwe and Wollny, 2002).

3.2.1. General descriptions of indigenous chicken production systems

Typically, based on types and levels of inputs and the various outputs, three indigenous chicken production systems can be identified:

- Free range system (FRS) or scavenging system (Kitalyi, 1998), where no feed is supplied at all. Both the chicks and the mature chicken are left to forage within the homestead. About 95% of the indigenous chicken are raised under the FRS by rural smallholder farmers (Tadelle *et al.,* 2003a).
- Semi-scavenging system (SIS) or semi-intensive system (Gunaratne, 1998), where the chicken are partly confined, especially in relation to the prevailing activities in arable agriculture, e.g., when crops are at a stage where foraging chicken could destroy them. Chicken are confined to avoid conflicts, but are provided with crop residues, grains and kitchen wastes to supplement their daily feed requirements. The flock is not vaccinated but given ethno-veterinary attention (Gueye, 1998).
- Confined full-ration system (CFRS) or intensive system (Gunaratne, 1998), where the flock is confined all the time and supplied with a balanced diet. Vaccination against endemic diseases is common under this system. This system is not common in most field situations because of the inputs required (Kitalyi, 1998; Maphosa *et al.,* 2004). It was included in this study since this would give an idea of the viability of the production system when unimproved indigenous chicken genetic resources are used. In addition, the relative economic importance of each trait is needed to ensure that genetic improvement is proportional to the overall objective of the production system. Improvement in genetic potential of the indigenous chicken should be accompanied by a concomitant improvement in the standard of management.

In SIS, wet seasons tend to be the times of maximum crop production activity and therefore will usually be the period of greatest confinement. During the dry seasons, the chicken are left to roam the homesteads picking crop residues and kitchen refuse. It has, however, been shown that inadequate amounts of critical minerals (Calcium and Phosphorus) are obtained from the foraging activities (Gunaratne, 1998). In FRS and SIS, indigenous chickens have limited foraging ranges, which keeps the feed resource base fixed.

Consequently, the fixed feed resource base results in a fixed carrying capacity and any extra chicken above the carrying capacity will lead to a reduction in average productivity (McArthur, 1987).

The three systems were modelled taking into account the production circumstances since these influenced their biological and economic performance. Generally, in all systems, the hens incubate the eggs naturally and each hen sits on twelve to fifteen eggs at a time (Roberts, 1995). In this study, it was assumed that hens sit on fifteen eggs during brooding and that they stay with the chicks until they are three months old. This means the hen spends a total of 112 days (including the incubation period of 22 days) for every batch of chicks raised. The average weight of indigenous chicken at 147 days of age (21 wks) has been reported to be 1.5 kg for cockerels and 1.1 kg for pullets (Chemjor, 1998; Birech, 2003). Table 4 presents the biological, managerial and nutritional variables for the three production systems based on various studies in the tropics.(Trail, 1961; Wickramaratne *et al.,* 1993; Gueye, 1998; Kitalyi, 1998; Mopate and Lony, 1998; MALDM, 2000 and Tadelle *et al.,* 2003a).

Generally, after the grower stage, the excess cockerels are finished and sold off for meat at a uniform age of 20 weeks (CTA, 1999). Maturing cockerels are recruited to replace cocks culled-for-age or dead ones through exchange of cockerels with other farmers. Pullets replace hens culled for age, low productivity or those that die during the year. In all systems, the hatching weight was set at 30.7g. In CFRS, from 0-6 weeks, the chicks are on chick starter mash *ad libitum.* From 7 weeks of age onwards, they are on growers' mash *ad libitum.*

Table 4: Biological, managemental and nutritional variables in indigenous chicken production systems

Variables	Abbreviation	Production system[1]		
		CFRS	SIS	FRS
Biological variables				
Age at first egg (days)	AFE	168	168	168
Asymptotic live weight in females (kg)	ALW_F	1.64	1.70	1.35
Asymptotic live weight in males (kg)	ALW_M	1.96	2.20	1.99
Chick survival rate (%)	CSR	85	60	50
Clutches/yr	NCl	3	3	3
Egg weight (g)	EW	44	44	44
Eggs/clutch	NeCl	50	33	20
Fertility (%)	FRT	91.60	91.60	91.60
Grower survival rate (%)	GSR	90	70	55
Growth potential attained (%)	Gp	84.50	75.00	74.50
Hatchability (%)	HTC	83	83	83
Hatching weight (g)	HW	30.70	30.70	30.70
Layer survival rate (%)	LSR	95	85	70
Laying percent (%)	Lpc	75	75	75
Productive lifetime (days)	PLT	730	730	730
Managemental variables				
Mothering period/ batch of chicks (days)	Brd	112	112	112
Sale age of surplus birds (days)	Sag	147	147	147
Nutritional variables				
Metabolisable energy content in chick mash (kCal/kg DM)	enc_C	2784	2784	2417
Metabolisable energy content in growers' mash (kCal/kg DM)	enc_G	2920		2417
Metabolisable energy content in layers' mash (kCal/kg DM)	enc_L	2500		2417
Metabolisable energy content in scavenged feed (kCal/kg DM)	enc_R	-	2417	2417

[1] CFRS-confined full ration system, FRS-free range system, SIS-semi-intensive system

To simplify the calculations, hatchability, laying per cent, number of settings, mothering period and sale age were assumed to be the same for all systems, although this may not always be true because management and production may differ from one system to another.

3.2.2. Flock dynamics

Defining the flock dynamics aids in identifying age and numerical distribution of the flock. The flock dynamics of indigenous chicken in FRS (base situation) are shown in Figure 3. The flock dynamics also apply for the other systems (SIS and CFRS) but with modifications on the parameters used in Table 1. The parameters used are based on flock averages. The number of chicken in a given flock can therefore easily be adjusted. The composition by sex of the chicks at day old was assumed to be 1:1. Various workers have reported a variety of mating ratios for the village production systems (Mwalusanya, 1998; Mopate and Lony, 1998; Kaudia and Kitalyi, 2002). For this study, a mating ratio of 1 cock to 5 hens was assumed for all production systems. The replacement policy was such that 50% of mature birds (old stock) were culled each year (MALDM, 2000). Excess cockerels and pullets were sold off when they reached sexual maturity. A pullet coming into lay replaced an old hen. The unimproved hen is able to lay 20-60, 30-100 and 80-150 eggs a year under the FRS, SIS and CFRS, respectively and usually in three clutches (Sonaiya *et al.,* 1999). Using proportions of chicken participating in various activities in the course of the year, the amounts and types of products generated from the family flock were computed.

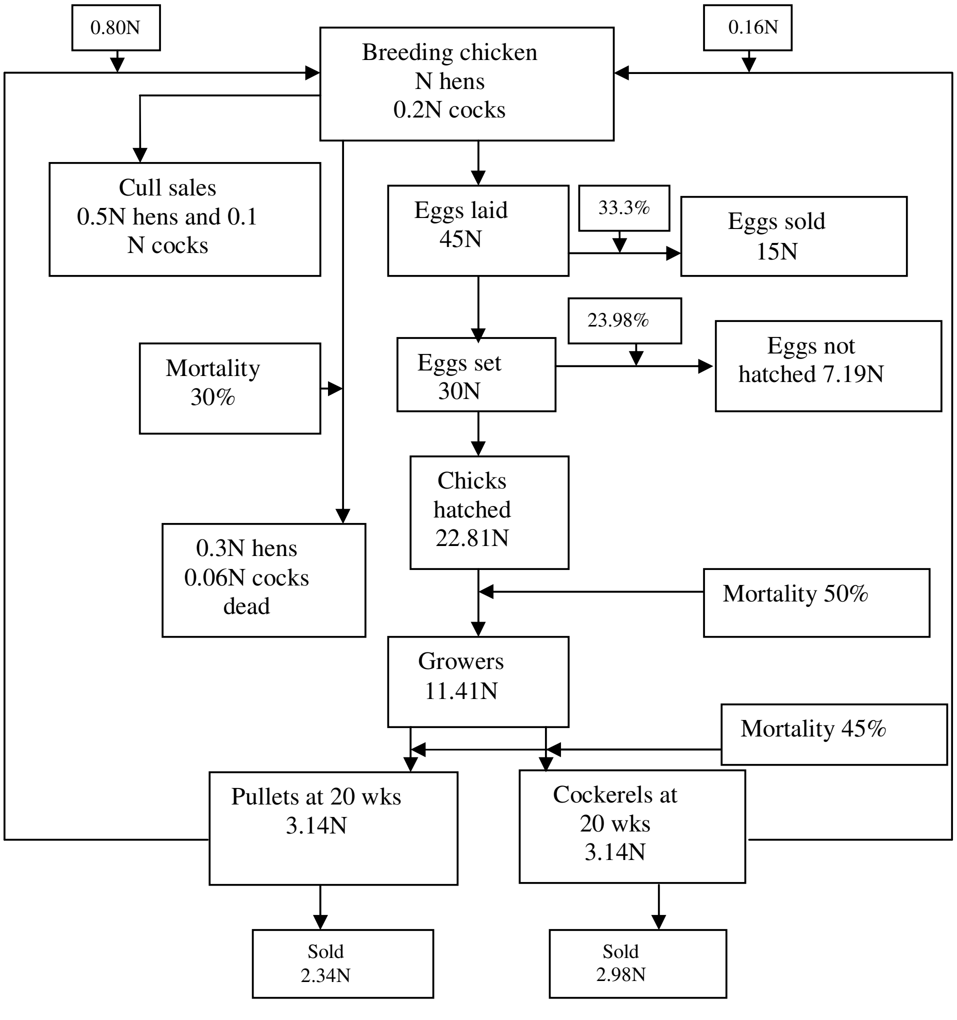


Figure 3. Structure of indigenous chicken production systems per year in a base situation (FRS)

3.2.3. Model description

The process of model development involved the description of outputs and inputs. Data deficiencies were apparent in village chicken production systems because of their subsistence nature. However, use of available data was maximized in the design of the current model. All outputs were valued at market levels. It was assumed that the expression of a trait follows the infinitesimal model (Bulmer, 1971). This means that additive genetic effects are entirely responsible for observed phenotypes (Muir, 1997). For simplicity, it was also assumed that there was no variation in the efficiency of feed utilisation among the birds. The model incorporates the biological traits that are to be genetically improved. The biological traits that influence revenues and costs for various categories of chicken are shown in Table 5.

Table 5: Biological traits influencing revenues and costs in indigenous chicken

Trait	Unit	Abbreviation
Age at first egg	Days	AFE
Chick survival rate	%	CSR
Feed intake of laying hens	kg DM	CFI_h
Feed intake to sale age (cockerels)	kg DM	CFI_c
Feed intake to sale age (pullets)	kg DM	CFI_p
Fertility	%	FRT
Grower survival rate	%	GSR
Hatchability	%	HTC
Hatching weight	G	HW
Layer survival rate	%	LSR
Live weight of cockerels at 21 weeks	Kg	LW_c
Mature live weight of cocks	Kg	LW_m
Mature live weight of hens	Kg	LW_f
Live weight of pullets at 21 weeks	”	LW_p
Number of eggs per clutch	-	NeCl
Egg weight	G	EW
Productive lifetime	Days	PLT

No carcass traits were included because, first, a large percentage of the indigenous chicken are sold live to the consumers, and secondly, the consumers have not shown discrimination between carcasses of different indigenous chicken. Indigenous chicken production systems were evaluated individually. The chicken kept under the FRS and SIS are exposed to open environmental stresses because they are not confined most of the time. Their nutritional, reproductive, disease status and ultimate productive performances are influenced by many factors.

Amongst specific groups of indigenous chicken, variation is observed for most of the traits. The model uses a modified Gompertz function to predict live weights at different ages for the different categories of chicken. A comparison of the suitability of the Gompertz and

Bertalanffy functions has been presented by Yakupoglu and Hulya (2001) for broilers. They recommended the Gompertz function for purposes of predicting the live-weight at a given age. The robustness of this growth model in estimation of growth in chicken has also been illustrated by Mignon-Grasteau *et al.* (2000b) and Novák *et al.* (2004). The basic Gompertz function is written as follows:

$$Y = A \times e^{-B} \times e^{-K \times t} \tag{4}$$

where Y = prediction of live-weight at age t (kg), A = asymptotic or predicted final weight (kg), B = integration constant or time scale parameter equivalent to ln(A/bwt_0) where bwt_0 is the hatching weight (kg), K = function of the ratio of maximum growth rate to mature size (maturing index) and t = the time in days. The Gompertz function, however assumes that there are no environmental factors limiting the performance of the animal, and therefore, there is need to modify the function to adjust for limiting growth conditions by adding a multiplier, gp (Amer *et al.,* 1997). A similar approach has been used by Conington *et al.* (2004). The equation used in this model is as follows:

$$W_t = ALW \times \exp\left\{-\exp\left[G - B\left(t_2 - t_1\right)\right]\right\} \tag{5}$$

where W_t = predicted bird live weight at time t (kg), ALW = asymptotic or expected mature live-weight (kg), G = ln[-ln(HW/ALW)], B = 0.0365/ALW $^{0.75}$ × gp, HW = hatching weight (kg), gp = proportion of growth potential achieved and t_2-t_1 = time in days from hatching to date of the prediction. For each sex, the daily gain (g) (DG) was calculated as $(W_{t+1} - W_t)\times 1000$ and the average daily gain (ADG) was calculated by getting the mean of all the daily gains generated. It was assumed that male and female attain maturity live weight when they are 24 weeks (168 days) old and maintain this weight to culling.

The model estimates feed intake using the energy requirements equation (NRC, 1994) and caloric density of the feed resources available within the three production systems. Total metabolisable energy (TME) requirements (kCal) per day for chicken are estimated as:

$$TME = \left(W_t^{0.75} \times \left[173 - \left(1.95 \times T\right)\right] + \left(5.5 \times DG\right) + \left(2.07 \times E\right)\right) \tag{6}$$

where W_t is the predicted live weight at time t (kg), T is the ambient temperature (ºC), DG is the daily gain (g) and E is the egg mass (g) laid per day estimated as:

$$E = \frac{\left(NeCl \times lpc \times NCl \times EW\right)}{365} \tag{7}$$

where NeCl is the number of eggs laid per hen per clutch, lpc is the laying percentage, NCl is the number of clutches per year, EW is the egg weight (g). For chicks, growers and cocks, the last term in equation 6 was zero since they do not lay eggs. Dry matter intake (FI) per day (kg) for animal category i (i = chicks, pullets, cockerels, hens or cocks) was computed as

$$FI_i = \frac{TME_i}{enc_{type}} \qquad (8)$$

where enc_{type} = energy content in the feed (kCal/kg DM) and subscript type represents the type of feed resources depending on the animal category and production system. Due to the variations in the types of feed resources utilised, it was necessary to test the sensitivity of the feed intake prediction equations to changes in feed quality. Under CFRS, the standard caloric density of commercial feeds for each age category was used.

In general, the model estimates profitability as follows:

$$P = R - C \qquad (9)$$

where P is the profit per hen per year (KSh), R is the revenue per hen per year (KSh) and C is the cost per hen per year (KSh). The revenues (R) were calculated using the equation:

$$R = R_{eggs} + R_{pullets} + R_{ecocks} + R_{ococks} + R_{ohens} \qquad 10)$$

where R_{eggs} is the revenue from the sale of eggs (KSh), $R_{pullets}$ is revenue from the sale of excess pullets (KSh), R_{ecocks} is the revenue from the sale of excess cockerels (KSh), R_{ococks} is revenue from the sale of old cocks (KSh) and R_{ohens} is the revenue from the sale of old hens (KSh). Costs (C) were derived from the following equation:

$$C = BC_{eggs} + FC_{chick} + FC_{pullets} + FC_{cockerels} + FC_{hens} + C_{lab} + C_{vet} + C_{fixed} \qquad (11)$$

where BC_{eggs} is the costs as a result of brooding activities of the hen (KSh), FC_{chick} is the feed costs for chick(KSh), $FC_{pullets}$ is the feed costs for pullets (KSh), $FC_{cockerels}$ is the feed costs for cockerels (KSh), FC_{hens} is the feed costs for laying hens also includes the feed costs for cocks (KSh), C_{lab} is the cost of labour (KSh), C_{vet} is the cost of health care (KSh) and C_{fixed} is fixed costs associated with shelter and equipment (KSh). Economic variables used in all the production systems are presented in Table 6. All the costs and prices are stated in Kenya Shillings (KSh). The study considered the 2005 prevailing market prices. Any fluctuations in costs and prices were ignored. The various components of R and C were calculated as shown below.

Table 6: Economic[1] variables in the three production systems

Variable	Abbreviation	Production system[2]		
		CFRS	SIS	FRS
Price per egg	p_{egg}	5.00	5.00	5.00
Meat price per kg live weight	p_{meat}	150.00	150.00	150.00
Price per kg DM of chick mash	p_{cmash}	19.60	19.60	
Price per kg DM of finishers' mash	p_{fmash}	17.40	-	-
Price per kg DM of growers' mash	p_{gmash}	17.40	-	-
Price per kg DM layers' mash	p_{lmash}	16.30	-	-
Price per kg DM of scavenged feed	p_{sfr}		2.20	2.20
Fixed costs	C_{fixed}	335.00	60.00	0

[1] All units in Kenya Shillings (1 US$=KSh. 75.00)

[2] CFRS-confined full ration system, FRS-free range system, SIS-semi-intensive system

Calculation of revenues

The sources of revenues in all production systems were eggs, surplus pullets, cockerels and cull- for-age cocks and hens. For simplicity, the set percentage (setpc), number of day-old chicks (Nchicks) and of pullets (Npullets) per hen per year were first calculated as:

$$\text{setpc} = \left(\frac{15}{\text{NeCl} \times \text{lpc}}\right) \times 100 \tag{12}$$

$$\text{Nchicks} = \sum_{i=1}^{\text{Nsett}} \left(\text{NeCl} \times \text{lpc} \times \text{setpc} \times \text{HTC} \times \text{FRT}\right)_i \tag{13}$$

and

$$\text{Npullets} = 0.5 \times \text{Nchicks} \times \text{CSR} \times \text{GSR} \tag{14}$$

where NeCl = number of eggs laid per hen per clutch, lpc = laying percentage, setpc = percentage of eggs set, Nsett = number of settings per year, HTC = hatchability (%), FRT = egg fertility (%), CSR = chick survival rate (%) and GSR =grower survival rate (%). With a sex ratio of 0.5, Npullets is equal to the number of cockerels per hen per year (Ncockerels).

Revenue from eggs (R_{egg})

Depending on the farmer's needs and the capability of the hens to incubate, a certain percentage of eggs were set each year. The remainder of the eggs was available for sale or consumption. Revenue from eggs (R_{egg}) was computed as:

$$R_{egg} = \left[\sum_{i=1}^{\text{Nsett}} \left[\text{NeCl} \times \text{lpc} \times \left(1 - \text{setpc}\right)\right]_i + \left[\text{NeCl} \times \text{lpc} \times \left(\text{NCl} - \text{Nsett}\right)\right]\right] \times p_{egg} \tag{15}$$

where NCl = number of clutches per year and p_{egg} = price per egg (KSh).

Revenue from pullets ($R_{pullets}$)

Revenue from pullets is attained from those not needed for replacement. The number of pullets not needed for replacement ($N^{culled}_{pullets}$) was estimated as:

$$N^{culled}_{pullets} = \text{Npullets} \times (1 - \text{HRr}) \quad (16)$$

where HRr = replacement rate (%) of hens estimated as:

$$\text{HRr} = \frac{365}{\text{PLT}} \quad (17)$$

where PLT = productive lifetime (days). The revenue from pullets ($R_{pullets}$) was therefore computed as;

$$R_{pullets} = N^{culled}_{pullets} \times LW_P \times p_{meat} \quad (18)$$

where LW_p = live-weight of a pullet at day 147 (week 21) (kg) and p_{meat} = price per kg live-weight (KSh).

Revenue from cockerels ($R_{ecockerels}$)

Revenue from cockerels is from those not needed for replacement. The number of cockerels not needed for replacement ($N^{culled}_{cockerels}$) was estimated as:

$$N^{culled}_{cockerels} = \text{Ncockerels} \times (1 - \text{CRr}) \quad (19)$$

where CRr = replacement rate of cocks (%). Assuming a cock to hen ratio of 1:5, CRr was estimated as:

$$\text{CRr} = \left(\frac{365}{\text{PLT}}\right) \times \frac{1}{5} \quad (20)$$

The revenue from cockerels ($R_{ecockerels}$) was therefore computed as;

$$R_{ecockerels} = N^{culled}_{cockerels} \times LW_c \times p_{meat} \quad (21)$$

where LW_c = live-weight of a cockerel at day 147 (21 weeks) (kg).

Revenue from culled hens (R_{ohens})

This is the revenue from the number of hens that are culled (N^{old}_{hens}) due to age or lowered productivity estimated as:

$$N^{old}_{hens} = \frac{365 \times \text{LSR}}{\text{PLT}} \quad (22)$$

where LSR = survival rate of layers (%). The revenue from culled hens (R_{ohens}) was therefore computed as; $R_{ohens} = N^{old}_{hens} \times LW_f \times p_{meat}$ (23)

where LW_f is the mature live-weight of a hen at day 168 (24 weeks) (kg).

Revenue from culled cocks (R_{ococks})

Besides the cocks that die in the course of the year, a proportion of cocks were culled because their daughters attained sexual maturity. Therefore, the number of cocks culled (N_{cocks}^{old}) was derived as:

$$N_{cocks}^{old} = \frac{1}{5} \times N_{hens}^{old} \qquad (24)$$

The revenue from culled cocks (R_{ococks}) was therefore computed as;

$$R_{ococks} = N_{cocks}^{old} \times LW_m \times p_{meat} \qquad (25)$$

where LW_m is the mature live-weight of a cock at day 168 (24 weeks) (kg).

Calculation of costs

Costs arose from brooding activities of the hen, husbandry, feeds and fixed assets. No marketing costs were included for all systems as all the products were assumed consumed at home and incase there was any surplus, marketing was done on-farm.

Cost of brooding (BC_{egg})

The cost of brooding was equivalent to the value of eggs lost due to brooding activities. This was as a result of failure of eggs to hatch and the number of days spent by the hen brooding. In this study, it was assumed that hens spend a total of 112 days (including the incubation period of 22 days) for every batch of chicks raised. The cost of brooding was:

$$BC_{egg} = \left[\sum_{i=1}^{Nsett} \left[(NeCl \times lpc \times setpc) \times (1 - (HTC \times FRT)) \right]_i + \frac{(NeCl \times NCl \times lpc \times Nsett \times brd)}{365} \right] \times p_{egg} \qquad (26)$$

where brd = mothering period per batch of chicks (days).

Feed costs for chicks from day 0 to day 42 (FC_{chick})

Chicks in the SIS and CFRS are fed chick mash from day 0 to day 42 whereas those in FRS are fed on scavenged feed resources. The feed costs (FC_{chicks}) were computed as follows:

$$FC_{chicks} = \left[Nchicks \times CFI_{chick} \right] \times p_{cmash} \qquad (27)$$

where CFI_{chick} is the cumulative feed intake per chick (kg DM) and p_{cmash} is the price per kg DM of chick mash (KSh). For the FRS, the price per kg DM of scavenged feed (p_{sfr}) was used instead of the $p_{cmash.}$ The cumulative feed intake (DM) per chick was computed as:

$$CFI_{chick} = \sum_{i=1}^{42} (FI_{chick})_i \qquad (28)$$

whereby FI_{chick} is the feed intake per chick per day (kg DM).

Feed costs for pullets and cockerels from day 43 to sale age (day 147)

The model assumes selection of replacement pullets and cockerels occurs at day 126. The cockerels are used for breeding when they are 148 days old while pullets lay their first egg at day 168. Pullets and cockerels in CFRS are fed growers and finishers' mash from day 43 to day 147 whereas those in SIS and FRS are fed on scavenged feed resources. In CFRS, pullets and cockerels to be culled are fed on finisher mash until attaining the sale age of 147 days. For the replacement pullets and cockerels, they continue being fed growers' mash until day 147. For simplicity, three feeding costs and intake are simulated for three periods: for all pullets and cockerels from day 43 to day 126, for culled pullets and cockerels from day 127 to day 147 and for replacement pullets and cockerels from day 127 to day 147. In CFRS, the feed costs from day 43 to day 126 for pullets ($FC_{pullets1}$) were estimated as:

$$FC_{pullets1} = \left(Npullets \text{ x } CFI_{pullets1}\right) \text{ x } p_{gmash} \qquad (29)$$

where $CFI_{pullets1}$ is the cumulative feed intake of a pullet from day 43 to day 126 (kg DM) and p_{gmash} is the price per kg DM of growers' mash. The cumulative feed intake of a pullet from day 43 to day 126 ($CFI_{pullets1}$) was calculated as:

$$CFI_{pullets1} = \sum_{i=43}^{126} \left(FI_{pullets}\right)_i \qquad (30)$$

The feed costs ($FC_{cockerels1}$) and cumulative feed intake ($CFI_{cockerels1}$) from day 43 to day 126 for cockerels were estimated using equations (29) and (30), respectively. In SIS and FRS, p_{gmash} was substituted with p_{sfr}. In CFRS, the feed costs for culled pullets from day 127 to day 147 ($FC_{pullets2}$) were estimated as:

$$FC_{pullets2} = \left(N_{pullets}^{culled} \text{ x } CFI_{pullets2}\right) \text{ x } p_{fmash} \qquad (31)$$

where $CFI_{pullets2}$ is the cumulative feed intake of a culled pullet from day 127 to day 147 (kg DM) calculated using equation (30) but summation was done from day 127 to day 147 and the type of feed used changed to finishers mash in equation (8) and p_{fmash} is the price per kg DM of finishers' mash (KSh). Similarly, the feed costs ($FC_{cockerels2}$) and the cumulative feed intake for culled cockerels from day 127 to day 147 ($CFI_{cockerels2}$) and were estimated as $FC_{pullets2}$ and $CFI_{pullets2}$ above, respectively, but substituting $N_{pullets}^{culled}$ with $N_{cockerels}^{culled}$ in equation (31). In SIS and FRS, the feed costs and intake for culled pullets and cockerels from day 127 to day 147 were estimated as above but p_{fmash} was substituted with p_{sfr} in equation (31) and the type of feed used changed to scavenged feed resources in equation (8). In CFRS, the feed costs from day 127 to day 147 for replacement pullets ($FC_{pullets3}$) were estimated using equation (29) but substituting Npullets with the number of replacement pullets ($N^{rep}_{pullets}$) and $CFI_{pullets1}$ with the cumulative feed intake of a replacement pullet from day 127 to day 147 ($CFI_{pullets3}$). A similar approach was used to calculate the feed costs ($FC_{cockerels3}$) and cumulative feed intake ($CFI_{cockerels3}$) of replacement cockerels. The number of replacement pullets ($N^{rep}_{pullets}$) was calculated as:

$$N^{rep}_{pullets} = \text{Npullets x HRr} \qquad (32)$$

In SIS and FRS, the feed costs and intake for replacement pullets and cockerels from day 127 to day 147 were estimated as above but p_{sfr} instead of p_{fmash} was used in equation (31) and the metabolizable energy content in scavenged feed (enc_R) used instead of the metabolizable energy content in growers' mash (enc_G) in equation (8).

Feed costs of replacement pullets from day 148 to age at first egg (day 168).

In CFRS, the feed costs of replacement pullets from day 148 to age at first egg (AFE) ($FC_{pullets4}$) were estimated using equation (32) but substituting $N^{rep}_{pullets}$ and $CFI_{pullets1}$ with the cumulative feed intake of a replacement pullet from day 148 to day 168 ($CFI_{pullets4}$). In SIS and FRS, $FC_{pullets4}$ and $CFI_{pullets4}$ were estimated using parameters (p_{sfr} and enc_R) for the available feed resource.

Total feed costs of pullets ($FC_{pullets}$) and cockerels ($FC_{cockerels}$)

The total feed costs of pullets ($FC_{pullets}$) and cockerels ($FC_{cockerels}$) were calculated as:

$$FC_{pullets} = FC_{pullets1} + FC_{pullets2} + FC_{pullets3} + FC_{pullets4} \qquad (33)$$

and

$$FC_{cockerels} = FC_{cockerels1} + FC_{cockerels2} + FC_{cockerels3} \qquad (34)$$

Cumulative feed intake of pullets ($CFI_{pullets}$) and cockerels ($CFI_{cockerels}$)

The cumulative feed intake of pullets ($CFI_{pullets}$) and cockerels ($CFI_{cockerels}$) were calculated as:

$$CFI_{pullets} = CFI_{pullets1} + CFI_{pullets2} + CFI_{pullets3} + CFI_{pullets4} \qquad (35)$$

and

$$CFI_{cockerels} = CFI_{cockerels1} + CFI_{cockerels2} + CFI_{cockerels3} \qquad (36)$$

Feed cost of hens and cocks (FC_{hens})

The feed cost of hens and cocks in the flock (FC_{hens}) were estimated as:

$$FC_{hens} = \left[\left(\text{LSR x } CFI_{hens1} \right) + \left(\frac{\text{LSR}}{5} \text{ x } CFI_{cocks1} \right) \right] \text{ x } p_{lmash} \qquad (37)$$

where CFI_{hens1} and CFI_{cocks1} are the cumulative feed intake per hen and cock, respectively (kg DM) and p_{cmash} is the price per kg DM of chick mash (KSh). For the SIS and FRS, p_{sfr} was used instead of the $p_{lmash.}$ The cumulative feed intake (kg DM) per hen (CFI_{hens}) was computed as:

$$CFI_{hens} = \sum_{i=1}^{365} (FI_{hens})_i \qquad (38)$$

where FI_{hens} is the feed intake per hen per day (kg DM). The cumulative feed intake (kg DM) per cock (CFI_{cocks}) was computed using equation (38).

Total feed intake of hens and cocks

The total feed intake of hens and cocks (CFI_{hen}) was estimated as;

$$CFI_{hen} = (LSR \text{ x } CFI_{hens1}) + \left(\frac{LSR}{5} \text{ x } CFI_{cocks1}\right) \qquad (39)$$

Labour costs (C_{lab})

Under CFRS, time is needed to feed and water the birds. In a typical family flock of five hens, the time needed to do these chores each day is 50 minutes. Under SIS, this time was reduced by 50% and under the FRS, it was assumed that a person needed 10% of that time to collect eggs or do other relevant and necessary tasks related to the free-range chicken (Gueye, 1998). This time was valued using the current official payment rates per day (KSh. 228.40) for unskilled agricultural labour in Kenya (Chune, 2003). The government payment rates are computed based on an eight-hour working day. Labour costs per year were computed as:

$$C_{lab} = \left(\frac{50}{60} \text{ x } 365 \text{ x } \frac{228.40}{8} \times \text{time}\right) \times \frac{1}{5} \qquad (40)$$

where time = 1 for CFRS, 0.5 for SIS and 0.10 for FRS.

Healthcare costs (C_{vet})

This includes money spent on purchasing and administration of medication. Under CFRS, there is vaccination against New Castle disease/Infectious bronchitis (at KSh 2/= $bird^{-1}$) for all chicks and mature chicken, Infectious bursal disease (at KSh 1/= $bird^{-1}yr^{-1}$) for all chicks and Fowl pox (at KSh 1/= $bird^{-1}$) for all chicks and adult birds. In addition, there is treatment against coccidiosis (at KSh 0.50 $bird^{-1}yr^{-1}$) for all birds in the family flock. Under FRS and SIS, the birds are only given herbal preparations, which are commonly known among members of the communities (Gueye, 1998). Veterinary costs were therefore not included in the total costs for these two systems.

Fixed costs (C_{fixed})

Fixed costs relate to the structures built and equipment obtained for the purpose of keeping the chicken. For CFRS, the owner will build a small shelter, usually with locally available materials with feeders and drinkers provided together with laying nests. Under, FRS no shelter is built but birds shelter in kitchens or other perching. In SIS, the farmer buys coops in which the birds are confined. Under FRS, no fixed costs are incurred. The fixed costs per year in CFRS and SIS are presented in Table 6.

3.3. Results

The deterministic bio-economic model developed was able to predict the live weight of chicken during the growth period. The growth parameters obtained were used to estimate feed intake. To deal with the performance limiting conditions within the various production systems, the growth equations were internally adjusted. Some field data on live weight could not be obtained; consequently, it was not possible to validate the model by comparing estimated values with actual observations from experimental results. The other outputs of this model included feed intake of various chicken categories, revenue, costs and profitability of the three production systems, which are very difficult to collect under field conditions. However, the model was executed under the base situation and the simulated outputs checked to determine whether they were reasonable or not.

Table 7 shows the simulated live-weight changes and feed intake of various chicken categories for each production system. The three systems showed marked differences in average daily gains. The average daily gain for males was 9.96g, 9.24g and 9.07g in CFRS, SIS and FRS, respectively. The corresponding daily gain in females was 9.14g, 8.61g and 7.68g. The live weight of cockerels and pullets at 21 weeks of age and of mature live weight of cocks and hens followed a similar trend to that observed for daily gain with chicken in CFRS being heavier than in the other production systems. Feed intake patterns revealed that on average, the chick feed intake per bird was lowest in SIS and highest in FRS. On the other hand, the feed consumption of growers (pullets and cockerels) was higher in the SIS than in the other systems whereas layer feed consumption was highest in the CFRS.

Simulated relationships between daily gain and feed intake in cockerels are presented in Figure 5 for CFRS since this system utilises commercial feeds whose composition is well known. An increase in daily gain was associated with an increase in feed intake up to week 12.

Table 7: Simulated live weight changes and feed intake of various chicken categories in each production system

Model Outputs	Abbreviation	Production system[1]		
		CFRS	SIS	FRS
Live weight changes				
Average daily gain (0 to day 147) in males (g/d)	ADG_m	9.96	9.24	9.07
Average daily gain (0 to day 147) in females (g/d)	ADG_f	9.14	8.61	7.68
Live weight of cockerels at 21 weeks (kg)	LW_c	1.50	1.39	1.36
Live weight of pullets at 21 weeks (kg)	LW_P	1.38	1.30	1.16
Mature live weight of cocks (kg)	LW_m	1.63	1.57	1.51
Mature live weight of hens (kg)	LW_f	1.47	1.42	1.22
Feed intake of various categories				
Cumulative feed intake of chicks (kg DM)	CFI_{chick}	1.01	0.83	1.13
Cumulative feed intake of pullets (kg DM)	$CFI_{pullets}$	8.27	11.11	8.64
Cumulative feed intake of cockerels (kg DM)	$CFI_{cockerels}$	7.06	9.65	7.70
Cumulative feed intake/hen/yr (kg)	CFI_{hen}	47.71	32.72	29.00

[1] CFRS -confined full ration system, FRS -free range system, SIS- semi-intensive system.

Thereafter, daily gain increased gradually probably as a result of a reduction in feed intake. From week 0 to 22, chicken pass through different development stages that require feeds with different energy contents. Therefore an assessment of the influence of energy content of the feeds utilised in various stages on feed intake is important. Figure 6 shows the simulated changes in feed intake of growers and layers when there is an increase in the energy content in feed. These changes were simulated for CFRS.

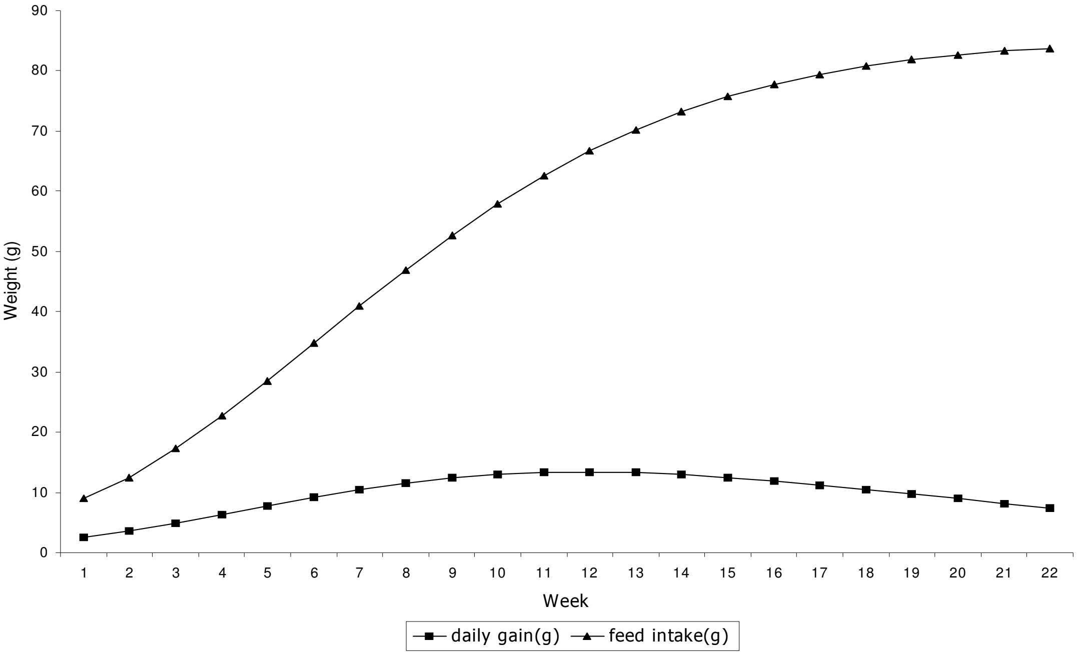


Figure 4. Simulated curves for daily gain and feed intake of cockerels from week 1 to 21 in CFRS

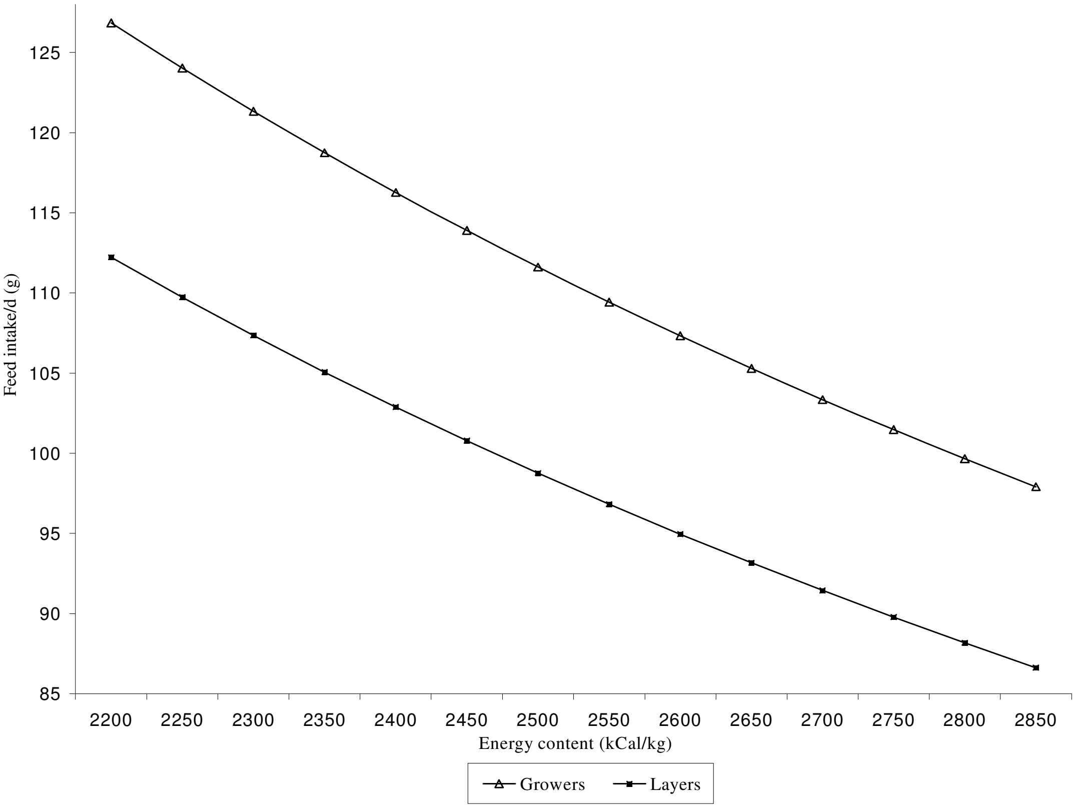


Figure 5. Simulated changes in feed intake of male growers and layers as a result of changes in the energy content of feed in CFRS

When the caloric density of the feed increased, the amount of feed consumed reduced. This behaviour in CFRS might also indicate that the energy content of the feed resources influences feed intake of the birds in SIS and FRS.

Simulated revenues, costs and profits for each of the production systems are presented in Table 8. The values obtained for each system depend on the flock structure used since the three systems had different flock composition. Most of the revenue in all systems came from the sale of cockerels, which had higher body weights, and fewer cockerels than pullets were required for replacement (Figure 3). Eggs contributed to revenues in all production systems (17.46% in CFRS, 8.52% in SIS and 6.67% in FRS) indicating that egg production traits are also important in these production systems. Labour contributed significantly to the total costs in all systems (34.91% in CFRS, 52.92% in SIS and 28.12% in the FRS). Profits were simulated using two evaluation bases; with fixed costs and without fixed costs. This was done since inclusion of all fixed costs in a single year can cause distortion of the economic performance and mask the actual merit of a production system.

Table 8: Simulated revenues, costs and profitability of the indigenous chicken production systems[1]

Description	Production system[2]		
	CFRS	SIS	FRS
Revenues			
Eggs	450.00	137.50	82.50
Pullets	677.22	467.00	345.60
Cockerels	1322.34	898.80	729.34
Culled hens	104.52	90.53	64.05
Culled Cocks	23.28	20.02	15.86
Total (a)	2577.37	1613.85	1237.35
Costs			
Brooding activity	350.60	180.40	155.16
Feed costs for chicks	338.64	341.17	71.72
Feed costs for pullets	852.17	98.21	92.84
Feed costs for cockerels	803.79	80.72	67.29
Feed costs for hens	777.67	72.00	63.80
Labour	1736.79	868.40	173.68
Fixed Cost (f)	670.00	60.00	0.00
Profit without f [a-b]	-2398.27	-27.00	612.86
Profit [a-(b+f)]	-3068.27	-87.04	612.86

[1]All units in Kenya Shillings (1US$ = KSh. 75.00). [2]CFRS - confined full ration system, FRS - free range system, SIS - semi-intensive system.

In both evaluation bases, CFRS was least and FRS the most profitable (Table 8). On average per hen per year, the use of indigenous chicken was profitable in FRS and not in CFRS and SIS.

3.4. Discussion and conclusions

In this chapter, a deterministic bio-economic model for use in the biological and economic evaluation of production systems utilising the indigenous chicken in Kenya was developed. The bio-economic model was assumed to be linear and the outcomes were completely determined by the initial input parameters. The input parameters used (Table 4) were based on flock averages and may be adjusted to suit specific situations. With slight modifications, the model can be used to assess the biological and economic performance of various production systems of other domestic avian species. Bio-economic models have been used to represent livestock production systems for purposes of economic evaluation in broiler (Groen *et al.,* 1998), dairy (Kahi and Nitter, 2004), sheep (Kosgey *et al.,* 2004), goat (Bett *et al.,* 2007) and beef (Rewe *et al.,* 2006) production systems.

Feed intake peaked at week 12 and reduced thereafter (Figure 5). Indigenous chicken tend to have high feed conversion ratios as a result of either the poor type of feeds usually available especially in extensive systems or low genetic potential for feed conversion efficiency or both (Roberts, 1999; Tadelle *et al.,* 2003a). However, high conversion ratios in indigenous chicken have also been reported in cases where they were provided with commercial feeds (Kingori *et al.,* 2003). Genetic variation has been observed for feed conversion efficiency among strains of indigenous chicken implying that selective breeding can be used to improve feed efficiency (Tadelle *et al.,* 2003a).

Several factors are known to influence the actual feed intake of chicken on extensive production systems. These factors include the energy content of the feed material (Wickramaratne *et al.,* 1993; Roberts, 1999) and the actual ability to scavenge (forage) (Gueye, 1998). In this study, the feed intake trends within the CFRS were taken to be indicative of the feed intake under the SIS and the FRS. It was difficult to attach a specific value to the feed consumed under the FRS and SIS, yet it was necessary to represent the cost associated with feed intake in the model for the two systems. Therefore, a marginal value of KSh.1.00 kg^{-1} for fresh (not DM) free range feed resources was used. Attempts at estimating feed costs are better than no attempts at all (Kahi *et al.,* 1998). Ponzoni and Newman (1989) showed that excluding feed costs has the effect of exaggerating profitability of the production system because feed costs constitute a large percentage of overall production costs.

The average daily gains obtained from the model were higher than those reported by Mwalusanya (1998) but comparable to those reported by Tadelle *et al,* (2003a). This was probably because of among other factors, the hatching weight (HW) used as an input in the model which was higher than that reported by Mwalusanya (1998) but similar to that reported in Tadelle *et al* (2003a). This observation suggests that hatching weight may have a significant influence on the subsequent growth performance of the indigenous chicken.

The production variables included in the model (e.g., LW, HW, NeCl, NCl CFI, CSR, GSR, LSR) were partly influenced by the genetics of the birds and had direct effects on profit. These variables represent potential breeding goal traits. The inclusion of traits such as fertility, hatchability and chick survival was justifiable as these traits determined the bird off-take. Carcass quality traits were left out because consumers generally do not discriminate amongst indigenous chicken products although many prefer eggs and meat from indigenous chicken over those from the commercial birds (Gueye, 1998). In most village production systems in sub-Saharan Africa, farmers use more eggs for hatching chicks than for sale or consumption (Kitalyi, 1998; Maphosa *et al.,* 2004). Therefore, in this study it was assumed that farmers obtain all their supplies of day-old chicks by natural incubation using broody hens. The number of day old chicks obtained was not only dependent on eggs available, hatchability and fertility but also on the settings. The input parameter settings represented the perceived need for chicks by the farmer and this was the number of times the hen was allowed to incubate eggs. In order to evaluate all systems using the same criteria, a uniform figure of two settings was used in this study. In the commercial production systems, the purchase of day-old chicks constitutes a major item of expenditure (Groen *et al.,* 1998), which implies that appropriate adjustments must be made if this model were to be used for evaluating systems where day-old chicks are sourced from outside.

In chicken production systems, disease resistance is important. However, it was not included in the bio-economic model. Resistance has multifold influences on inputs and outputs, which in turn affect profit. It is further complicated by environmental factors, nonlinearity effects and interactions (Sivarajasingam 1995). This makes it difficult to incorporate measures of disease resistance into a bio-economic model. Indigenous chicken in Africa have been reported to be resistant to some tropical poultry diseases (Gueye, 1998; Msoffe *et al.,* 2002). Disease resistance is difficult to measure *per se* but indicator traits for resistance are available. For example, resistance to Marek's and other diseases, general fitness and productivity have been associated with the B system haplotype of the Major Histocompatibility Complexes which has enabled gene assisted selection to be done (CTA 1999; Msoffe *et al.,* 2002). Recently, a new system in addition to the above, which correlates with reduced incidence of tumour formation upon exposure to Marek’s disease virus, has been identified. The system has been called the Rfp-Y (Restriction fragment polymorphism-Y) and is thought to be due to additive genetic effects (Miller *et al.,* 1994).

The results show that the model can be applied to the smallholder poultry production systems in Kenya and in other tropical countries with similar production conditions. Profitability trends suggest that the chicken can be utilised profitably in FRS. Although CFRS showed negative profitability under both evaluation bases, it cannot be ignored because the transition from subsistence to commercial production is desirable and requires that management levels get better as the genetic potential of the birds is also improved. The profitability in SIS was also negative. However, this could be an underestimate. The negative profitability may indicate a rise in labour cost since a cost was assigned to family labour. The cost for labour is absent when children and sometimes adults provide labour. Studies in small ruminants have shown that inclusion of own labour cost in economic evaluation largely inflates the total costs with negative effects on profitability (Hamadeh *et al.,* 2001). The potential of chicken to act as a viable source of income for the rural households has been reported before (Gueye, 1998; Roberts, 1999; Permin *et al.,* 2001; Sonaiya, 2001). An indigenous chicken enterprise's initial capital requirements are modest and many poor families may find it the only manageable alternative. There are other roles, which add to the worth of the indigenous chicken to the smallholder farmers. For example, the poultry flocks are reported to have enabled faster recovery for smallholder farmers from disasters like droughts and disease outbreaks in Southern Africa in which case they acted as a form of insurance (Songolo and Katongo, 2001).

The primary objective of indigenous chicken farmers usually, is to improve the profitability of their indigenous chicken flocks by producing more meat and eggs. The farmers are also interested in traits that make the birds easily manageable such as disease resistance and broodiness. Defining a breeding goal involves the identification of animal characteristics that contribute to changes in profit and the relative worth of the animal (Barlow, 1987). The breeding goals should relate positively with the needs and aspirations of the farmers to be sustainable (Kahi and Nitter, 2004). In a breeding goal, breeding values of traits are weighted by their respective economic weights to come up with a total index, which is expressed in monetary terms. Economic weights are an indication of the relative importance of traits in a given system. The bio-economic model developed in this chapter can be used to derive economic weights for breeding goal traits for the indigenous chicken production systems. The following chapter presents the economic values of breeding goal traits in indigenous chicken and their influence on genetic gain.

CHAPTER FOUR

ECONOMIC VALUES FOR TRAITS OF INDIGENOUS CHICKEN AND THEIR EFFECTS ON GENETIC GAIN IN THREE PRODUCTION SYSTEMS

4.1. Introduction

Economic values show the relative importance of a trait within a production system when viewed against the overall profitability of a livestock enterprise. They are used to optimize genetic improvement of a combination of traits by weighting each trait with its anticipated contribution to the increased revenue of the enterprise (Hazel, 1943). The linear combination of the breeding values of economically important traits weighted by their respective economic values forms the breeding goal. Economic values therefore enable the breeder to express breeding goals in economic terms. However, the traits may not necessarily be expressed at the same rate in which case, the contribution to enhanced revenue will be affected positively or negatively by the lag period (McClintock and Cunningham, 1974). This chapter presents estimated economic values for indigenous chicken (low input) production systems and determines their influence on genetic progress within the context of an indigenous chicken breeding programme.

4.2. Materials and Methods

Economic values were derived using the bio-economic model presented in Chapter 3. The model was parameterized using biological (Table 4) and economic (Table 6) variables, which typify the indigenous chicken production systems. Three indigenous chicken production systems were identified based on input levels, while biological and economic information were from the literature on chicken production in tropical environments (Trail, 1961; Wickramaratne *et al.,* 1993; Gueye, 1998; Kitalyi, 1998; Mopate and Lony, 1998; MALDM, 2000, Tadelle *et al.,* 2003a) and by spot checks in poultry markets. The bio-economic model was able to predict daily gain, feed intake and final performance of the chicken as well as the profitability of the chicken production systems. Similar methods have also been used to estimate economic values for sheep (Kosgey *et al.,* 2003), dairy cattle (Kahi and Nitter, 2004), Boran cattle (Rewe *et al.,* 2006) and broilers (Groen *et al.,* 1998; Jiang *et al.,* 1999).

4.2.1. Derivation of economic values

Economic values of traits can be estimated using three methods; partial differentiation of the profit function with respect to the trait of interest, by partial budgeting i.e. accounting for unit changes in marginal returns and costs arising from the improvement in the trait of interest and regression coefficients of profit on trait performances. In this study, economic values were derived by partial budgeting. The performance in a trait was increased by one metric unit or percentage point and the accompanying change in profit observed while keeping all other traits constant. Economic values for traits of indigenous chicken (Table 5) were estimated for three production systems described in section 3.2. Accurate calculation of economic values in relation to production system is necessary. This may lead to a diversification of the breeding goal. Economic values were estimated using the equation:

$$EV = \frac{\delta TR - \delta TC}{\delta t} \qquad (41)$$

where EV represents the economic value, δTR the change in total revenue, δTC is change in total costs and δt is the unit change in a trait.

4.2.2. Sensitivity of economic values to changes in prices of inputs and outputs

Additional analyses were carried out to investigate whether the economic values would remain stable as production circumstances vary in the long term. The likely scenarios during the practical breeding programmes can be anticipated and planned for before hand. The sensitivity of the economic values to changes in meat and egg prices was tested for all production systems. Changes of ±15% with respect to the prices of meat and eggs were considered. The changes were performed one at a time, keeping all other parameters constant. The behaviour of economic values as a consequence of changes in prices gives information on the likely direction of future genetic progress and production systems, which have important applications in practical breeding programmes (Groen, 2000).

4.2.3. Assessment of the influence of economic values on genetic improvement

Due to the different reproduction rates in male and female animals and the need to test sires before they are used widely, the timing and frequency of expression of a certain improved genotype as a result of the use of selected parents may take longer. Secondly, the traits in the breeding goal may not all be expressed at the same time. To account for such delays, the gene flow methodology was used to adjust the economic values for time and frequency of expression.

Cumulative discounted expressions were derived using the discounted gene flow methodology (McClintock and Cunningham, 1974; Jiang *et al.,* 1999) with a ten-year time horizon to account for time lag and frequency of expression of a given gene from the time the parents are mated. Two discount rates were used, 0% and 5%. The cumulative discounted expressions were calculated as (Brascamp, 1978):

$$\text{CDE} = \sum_{i=0}^{t} h' m_{li} \delta^{i} \tag{42}$$

where CDE is the cumulative discounted expression; t is time horizon; h is the incidence vector that specifies frequencies by which age classes contribute to actual expression of traits; m_{li} represents the relative contribution of the initial set of genes in selected animals in selection pathway l to the genes of animals in an age class at time i and δ^{i} is the discount rate. For a trait with economic value *v* per unit, the discounted economic value was obtained for the selection pathway *l* as:

$$a_l = v \times (\text{CDE})_l \tag{43}$$

where a_l is the discounted economic value for the trait in selection pathway *l*, and v is the undiscounted economic value. Four selection pathways of genetic improvement were assumed; Sires to breed sires (SS), dams to breed sires (DS), sires to breed dams (SD) and dams to breed dams (DD). The selection pathways SS and DS (sire line) conveyed production traits while SD and DD (dam line) conveyed reproduction traits.

4.2.4. Phenotypic and genetic parameters

Selection requires that certain measurements be done on candidates for specific characters which are targeted for improvement or related to those targeted for improvement. The traits targeted for improvement have to be heritable, possess some variation within the animal population and be correlated with the characters referred to above. Efforts were made to identify any relationships between the traits in the selection criteria and those in the breeding goal. Estimates from the literature were obtained biased as much as possible towards tropical chicken (Oni *et al.,* 1991; Iraqi *et al.,* 2002; Kiani-Manesh *et al.,* 2002; Sabri *et al.,* 2004; Khalil *et al.,* 2004). It was necessary to consult a wide variety of sources because estimates of genetic and phenotypic parameters for local chicken are scarce. The genetic and phenotypic parameters used in this study are presented in Table 9.

4.2.5. Selection indices and criteria

The breeding goal traits were grouped and improved through different selection pathways, with the ultimate aim of crossing at the point of multiplication so as to obtain all round improvement according to the method described by Pigott, (1981). This approach ensures that the commercial chicken express vigour for all the breeding goal traits while at the same time achieving fast genetic improvement.

The selection index (I) was for the sire lines (SS and DS) and included traits such as EW, LW_c or LW_P and CSR. Information on EW and $LW_{c/P,}$ was available on the individuals, its dam, sire, 5 daughters and 5 sons. In addition, information on CSR was also available on the dams. For the dam lines (SD and DD), the selection index (II) included traits such as FRT, HTC, AFE,NeCl and CSR. The dam provided information on FRT, HTC, NeCl and CSR whereas the sire provided information on FRT and HTC. The daughters were measured on AFE. The dams to breed dams (DD) had the traits AFE, FRT, HTC, CSR and NeCl. Information sources were individuals and daughters for AFE, sire and dam for FRT and HTC additionally dams were measured for CSR and NeCl.

Table 9. Assumed heritabilities, phenotypic standard deviation, phenotypic (above) and genetic (below diagonal) correlations among selection criteria and breeding objective traits.

Trait[2]	AFE	PLT	LSR	LWc	LWp	LWf	LWm	HTC	FRT	CSR	GSR	NeCl	EW	CFIc	CFIp	CFIh
Units	Days	Days	%	Kg	Kg	Kg	Kg	%	%	%	%	eggs	g	kg	kg	kg
h^2	0.55	0.20	0.20	0.30	0.14	0.69	0.69	0.35	0.25	0.40	0.45	0.54	0.61	0.20	0.20	0.20
Σp	12.01	17.9	0.07	157.4	150.3	157.4	157.4	1.61	1.51	0.09	0.08	11.43	3.22	0.27	0.27	0.27
AFE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.32	0.15	0.00	0.00	0.00
PLT	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSR	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LWc	0.00	0.00	0.00		0.00	0.00	0.88	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00
LWp	0.00	0.00	0.00	0.00		0.88	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00
LWf	0.00	0.00	0.00	0.00	0.77		0.00	0.00	0.00	0.00	0.00	-0.77	0.30	0.00	0.00	0.00
LWm	0.00	0.00	0.00	0.77	0.00	0.00		0.00	0.00	0.00	0.00	-0.77	0.00	0.00	0.00	0.00
HTC	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00			
FRT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00			
CSR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00			
GSR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00			
Necl	-0.36	0.00	0.00	0.54	0.00	0.12	0.00	0.00	0.00	0.00	0.00		-0.18			
EW	0.11	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00				
CFIc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
CFIp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
CFIh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

[2]See Table 14 for trait descriptions and Chapter 3 for description of production systems

In cases like the current one where selection is for several traits at a time, the economic values are used as weights (Hazel, 1943). The selection index coefficients were derived as follows;

$$b = P^{-1}G\mathbf{a} \tag{44}$$

where b is a vector of the selection coefficients of the index traits, P is a phenotypic variance – covariance matrix of the characters in the selection index, G is a genetic variance - covariance matrix between the characters in the index and traits in the breeding objective and **a** a vector of economic values of the traits in the breeding objective. The response to selection (ER) was calculated using the equation:

$$ER = i \times r_{IH} \times \sigma_H \tag{45}$$

where i is selection intensity, r_{IH} is the accuracy of selection and σ_H is the standard deviation of the breeding goal. When the economic values are used in equation (44), the final units will be in the currency of the economic values, in our case Kenya Shillings.

To investigate the long-term effects of the economic values on genetic gain, stabilised genetic gain (R) per year was calculated as:

$$R = \frac{\sum_{s=1}^{4} ER_s}{\sum_{s=1}^{4} L_s} \tag{46}$$

where ER is the response to selection (see equation 45) in traits in the breeding goal. ER is summed across selection pathways (l) (s=1…4) and L is the generation interval across the selection pathways (Vargas, 2000).

4.3. Results and discussion

4.3.1. Estimates of economic values

The undiscounted economic values for traits of indigenous chicken are presented in Table 10. The AFE and EW had negative economic values suggesting that costs associated with improvements in these traits would out weigh the benefits. The economic values LWf, LWm, CFIc, CFIp and CFIh were also negative for all production systems considered. This implies that increasing the weight of mature males and females impacts on feed costs more than revenue due to their low numbers. This is also related to the fact that they stay longer in the system while being used for reproduction. This situation was reflected within the bio-economic model since live weight and survival rates were used to calculate feed intake throughout the production systems. Although it would be expected that a heavier breeder at the salvage stage would help reduce costs of keeping breeding stock (Jiang' *et al.,* 1999), it is apparent here that the costs out weigh the revenue thus resulting in marginal negative economic values. The economic values for the rest of the traits were positive in CFRS. As mentioned before, the economic values for LSR were negative in SIS and FRS probably due to the lower egg production expected from a layer within these two production systems.

Hatching weight (HW) was not included in the breeding goals because it is positively correlated with EW (Halbersleben and Mussehl, 1922) and by selecting for EW, the correlated trait HW would also be improved. The weight of the newly hatched chick is correlated with post-hatch growth and possibly chick mortality and feed conversion (Wilson, 1991) and therefore this trait seems important in chicken breeding. It should also be mentioned that among the egg production traits, the Kenyan market does not pay a premium for higher egg weight, so no obvious benefit accrued as a result of increasing EW yet it is associated with lower feed efficiency (Pigott, 1981).

The influence of the cost of feed type used was reflected in the magnitude of some of the economic values (i.e., CFIc, CFIp, CFIh), which were more negative for the CFRS than in the other two systems. This observation agrees with that of Jiang' *et al.* (1999). The HTC and FRT had positive economic values, which were highest in the SIS. The same trend was observed for early survival traits of the chicken. This is likely due to the lower costs of inputs utilized in the SIS coupled with better productivity associated with the medium input system when compared with the FRS. NeCl had positive economic values as would be expected because fewer breeding hens could be needed to produce a given number of hatching eggs.

Table 10. Undiscounted economic values for traits of indigenous chicken in Kenya

		Economic value (KSh.)		
Trait[1]	Units	CFRS	SIS	FRS
AFE	Days	-14.20	-1.142	-0.757
PLT	Days	+1.014	+0.322	+0.157
LSR	%	+0.168	-2.161	-2.388
LWc	Kg	+9.573	+4.987	+2.810
LWp	Kg	+4.447	+2.219	+1.134
LWf	Kg	-1.718	-0.706	-0.366
LWm	Kg	-1.673	-1.425	-1.339
HTC	%	+4.636	+12.057	+9.233
FRT	%	+4.074	+10.589	+7.906
CSR	%	+5.343	+19.227	+14.114
GSR	%	+4.949	+16.295	+12.736
NeCl	Eggs	+0.044	+0.045	+0.047
EW	g	-0.052	-0.045	-0.045
CFIc	Kg	-0.071	-0.027	-0.007
CFIp	Kg	-0.051	-0.020	-0.005
CFIh	Kg	-0.003	-0.001	-0.001

[1] NeCl-Number of eggs per clutch, EW-Egg weight (g), LW-Body weight (Kg) (f-hens, m-cocks, p-pullets, c-cockerels), AFE-Age at First Egg (days), CFI-cumulative feed intake (c-cockerels, p-pullets, h-hens), HTC-hatchability, FRT-fertility, PLT-productive lifetime, LSR-layer survival rate, CSR-chick survival rate, GSR-grower survival rate.

4.3.2. Sensitivity of economic values to changes in prices of meat and eggs

Table 11 shows the sensitivity of economic values to changes in the prices of eggs and meat in all production systems. In general, economic values for AFE and EW were not sensitive to changes in price of eggs or meat in all production systems. The economic values of HTC and FRT increased with increases in egg and meat prices. This is probably because the traits are related to egg utilisation and chick numbers. The economic value of NeCl increased with price of eggs across production systems. The implication of this outcome is that a hen producing more eggs (i.e. higher NeCl) would become more valuable as the price of eggs increases. An increase in the economic values of HTC and FRT with increase in price of eggs is not surprising because a higher HTC or FRT means that fewer fertile eggs are needed for hatching the same number of chicks, due to lower wastage of incubated eggs, thus resulting in improved revenue.

Increases in the price of meat boosted the economic values of LWc, LWp, and CSR whereby the trends were similar across the production systems. All three were used as inputs in calculating the revenue from sales of live chicken and would be expected to respond to changes in the price of meat. The HTC, FRT and CSR are all related to the number of finished chicken available for sale at the end of the growing period. Indigenous chicken incubate their eggs and HTC and FRT therefore determine the number of chicks hatched and reared. The CSR influences the number of chicken alive at the beginning of the grower stage.

4.3.3. Assessment of the influence of economic values on genetic improvement

The economic values were discounted for all systems studied and their influence on genetic improvement assessed. Each selection pathway had a unique discounting factor. The discounting factors and the discounted economic values are given in Table 12. Only one age class of 0.5 years related to a six month attainment of sexual maturity in the chicken was used. Jiang *et al.* (1999) noted that age class definition might not have drastic effects on the overall results in such a calculation. The influence of economic values on genetic improvement was assessed by comparing the genetic gains achieved in the breeding goal traits. The response in the breeding goal traits and stabilized ER achieved assuming selection intensity of 1.755 (Top 10%) for SS and DS and of 1.4 (Top 15%) for SD and DD pathways are shown in Table 13. The ER for production traits was obtained as the sum of the responses for SS and DS selection pathways whereas response for reproduction traits was the sum for SD and DD.

Economic responses for production traits were KSh 133.31, KSh 66.71 and KSh 105.33 for CFRS, SIS and FRS, respectively. The corresponding response for reproduction traits were KSh 155.95, KSh 20.13 and KSh 13.14. Generally, the overall response was highest for CFRS where management was better. This supports the assertion that improvement in genetic merit should be accompanied with improvement in management standards and that intensification would be advantageous for the improved indigenous chicken. The difference in overall response between SIS and FRS was KShs. 31.63.

In SIS and FRS, reproduction traits had a lesser economic impact than production traits. The traits CSR, HTC and FRT contributed minimally to economic response in SD and DD selection pathways for all the production systems. This observation agrees with Shalev and Pasternak (1983) who found that selection for fertility, hatchability and lower mortality accounted for less than 1% of potential economic savings in the production costs of a broiler enterprise. Smallholder farmers prefer to use eggs for hatching to consuming them (Gueye, 1998). Although traits like FRT, HTC, NeCl had lower overall genetic superiority than traits like LWc and LWp they have to be monitored because it has been shown that intense selection for body weight alone introduces fertility problems among chicken (Pym, 1979). The predicted genetic superiority in production traits demonstrates that farmers who use a greater proportion of fertile eggs for hatching than for consumption gain more by emphasizing meat over eggs. In economic terms, an improvement in meat production traits would be expected to have a greater positive impact on the livelihoods of the farmers than a similar improvement in egg traits. Overall, the breeding goals were economically viable and worthwhile as they would have a huge economic impact on the rural households where millions of indigenous chicken are kept.

4.3.4. General

Adaptation traits are critical for indigenous chicken and some traits like chick survival were included to take care of adaptation. This is due to the fact that the inability of the exotic genotypes to survive and produce in new environments is now well known considering other experiences of exotic x indigenous chicken crossbreeding programmes. Indigenous livestock in various countries have been subjected to crossbreeding programmes with exotic genotypes, which in general has resulted in varying consequences (Valle Zárate, 1996; Wollny *et al.,* 2002; Ayalew *et al.,* 2003; Sonaiya and Swan, 2004; Katinka *et al.,* 2005). In Bangladesh and Ethiopia for instance, exotic birds were reported to have better performance in extensive systems but suffered very high mortalities (Mahfuzar *et al.,* 1997; Tadelle *et al.,* 2000). Sustainable genetic improvement can be obtained if the indigenous chicken are selected for the existing production systems where stressors like predation, poor feed resources, and disease prevalence are common and thereafter deliberate crossing with exotic chicken done to improve on some other aspects (Sonaiya and Swan, 2004). Marks (1993) showed that birds selected to perform well under low protein diets performed well under both low and high protein diets. This is significant due to its possible role in conferring adaptability to both low and high quality diets.

Poultry are likely the most widely kept species among smallholder farmers worldwide and could play a much broader role in poverty alleviation than bigger species. Perry *et al.* (2003) ranked poultry as the most important species in hierarchy in peri-urban and landless systems. In the same study, Perry *et al.* (2003) also reported that there exists a livestock ladder which operates between species and within species. The poorest people usually keep poultry and the less poor keep improved breeds or bigger species.

Table 11. Sensitivity of economic values to changes in prices1 of meat and eggs in the three production systems

		AFE	PLT	LSR	LWc	LWp	LWf	LWm	HTC	FRT	CSR	GSR	NeCl	EW	CFIc	CFIp	CFIh
System										**CFRS**							
	15%	-	-	-	-	-	-	-	4.833	4.252	-	-	0.051	-	-	-	-
Peggs	Base	-	-	-	-	-	-	-	4.636	4.074	-	-	0.044	-	-	-	-
	-15%	-	-	-	-	-	-	-	4.427	3.886	-	-	0.038	-	-	-	-
	15%	-	1.111	-0.051	11.329	5.422	-1.602	-	9.384	8.358	9.980	9.328	-	-	-	-	-
Pmeat	Base	-	1.014	0.168	9.573	4.447	-1.718	-	4.636	4.074	5.343	4.949	-	-	-	-	-
	-15%	-	0.917	0.387	7.817	3.472	-1.834	-	-0.113	-0.210	0.707	0.570	-	-	-	-	-
System										**SIS**							
	15%	-	-	-	-	-	-	-	12.251	10.764	-	-	0.052	-	-	-	-
Peggs	Base	-	-	-	-	-	-	-	12.057	10.589	-	-	0.045	-	-	-	-
	-15%	-	-	-	-	-	-	-	11.850	10.402	-	-	0.039	-	-	-	-
	15%	-	0.364	-2.429	5.948	2.751	-0.579	-1.402	14.481	12.776	22.580	19.169	-	-	-	-	-
Pmeat	Base	-	0.322	-2.161	4.987	2.219	-0.706	-1.425	12.057	10.589	19.227	16.295	-	-	-	-	-
	-15%	-	0.280	-1.905	4.019	1.680	-0.841	-1.454	9.621	8.391	15.857	13.406	-	-	-	-	-
System										**FRS**							
	15%	-	-	-	-	-	-	-	9.436	8.089	-	-	0.054	-	-	-	-
Peggs	Base	-	-	-	-	-	-	-	9.233	7.906	-	-	0.047	-	-	-	-
	-15%	-	-	-	-	-	-	-	9.029	7.722	-	-	0.040	-	-	-	-
	15%	-	0.174	-2.723	3.444	1.487	-0.205	-1.305	10.746	9.271	16.627	15.020	-	-	-	-	-
Pmeat	Base	-	0.157	-2.388	2.810	1.134	-0.366	-1.339	9.233	7.906	14.114	12.736	-	-	-	-	-
	-15%	-	0.139	-2.039	2.184	0.789	-0.520	-1.366	7.731	6.551	11.621	10.469	-	-	-	-	-

[1]Peggs-price of an egg; Pmeat-price of a kg of meat; [2]For trait descriptions see Table 13 and for description of production systems see Chapter 3. A dash represents no change.

Table 12. Discounted economic values for breeding goal traits in each selection pathway and production system

Pathway	Index traits		Discounted Expression		Discounted economic values (KSh.) (at 5% interest rate)		
	Trait[1]	Units	0%	5%	CFRS	SIS	FRS
SS	LWc	Kg	0.201	0.130	+1.244	+0.648	+0.365
	LWp	Kg	0.201	0.130	+0.578	+0.289	+0.147
	CSR	%	0.201	0.130	+0.695	+2.500	+1.835
	EW	g	0.201	0.130	-0.007	-0.006	-0.006
DS	LWc	Kg	0.749	0.525	+5.206	+2.618	+1.475
	LWp	Kg	0.749	0.525	+2.335	+1.165	+0.595
	CSR	%	0.749	0.525			
	EW	g	0.749	0.525	-0.027	-0.024	-0.023
SD	NeCl	eggs/clutch	1.096	0.790	+0.035	+0.036	+0.019
	AFE	Days	1.096	0.790	-11.218	-0.902	-0.598
	HTC	%	1.096	0.790	+3.662	+9.525	+7.294
	FRT	%	1.096	0.790	+3.219	+8.365	+6.246
	CSR	%	0.548	0.395	+2.111	+7.595	+5.575
DD	NeCl	eggs/clutch	1.498	1.050	+0.047	+0.048	+0.049
	AFE	Days	1.498	1.050	-14.91	-1.199	-0.795
	HTC	%	1.498	1.050	+4.868	+12.659	+9.694
	FRT	%	1.498	1.050	+4.278	+11.118	+8.301
	CSR	%	0.749	0.525	+2.805	+10.094	+7.410

[1] NeCl-Number of eggs per clutch, EW-Egg weight (g), LW-live weight at 21 weeks (Kg) (subscript p-pullets, c-cockerels), AFE-Age at First Egg (days), HTC-hatchability, FRT-fertility, CSR-chick survival rate.

Table 13. Genetic superiority in the breeding goal traits and economic responses for production systems[1]

Path	σ_I	σ_H	R_{IH}	*i*	Genetic superiority								ER
					AFE	LWc	LWp	HTC	FRT	CSR	NeCl	EW	
								CFRS					
SS	26.180	77.140	0.340	1.755	-	21.040	0	-	-	0	-	0	46.030
DS	49.700	320.870	0.155	1.755		0	21.280			0		0	87.280
SD	2.390	100.110	0.024	1.400	0	-	-	0.490	0.190	0	0	-	3.360
DD	108.770	132.920	0.820	1.400	-7.300	-	-	0	0	0	0	-	152.590
R													209.260
								SIS					
SS	13.700	36.320	0.380	1.755	-	21.230	21.230	-	-	-0.020	-	0.313	24.220
DS	24.370	65.440	0.370	1.755	-	-0.880	23.030	-	-	-0.010	-	0.93	42.490
SD	6.230	13.730	0.450	1.400	0	-	-	0.490	0.190	0	0	-	8.650
DD	8.280	18.230	0.450	1.400	0			0.490	0.190	0	0	-	11.480
R													86.840
								FRS					
SS	11.900	20.530	0.580	1.755	-	21.230	21.230	-	-	-0.020	-	0.313	20.900
DS	48.090	82.950	0.580	1.755	-	-0.870	22.990	-	-	-0.020	-	0.91	84.430
SD	4.740	9.980	0.470	1.400	0	-	-	0.490	0.190	0	0	-	6.570
DD	4.740	9.980	0.470	1.400	0	-	-	0.490	0.190	0	0	-	6.570
R													118.470

[1] ER-response to selection per generation; R-stabilized response per year (see equations 45 and 46 for details)

4.4. Conclusions

Currently, indigenous chicken are used profitably in the FRS. The chicken are marginally unprofitable in SIS probably due to higher labour cost component. However, the chicken are unprofitable when utilised within the CFRS. The results showed that various traits had different economic values and the economic values were fairly stable vis a vis changes in prices of the major products (eggs and meat). There were relationships between the economic values and genetic gain in the breeding goal traits, which supports the view that economic values influenced genetic improvement. Information on economic evaluation of indigenous chicken production in Eastern Africa is scarce. It is important to make every effort to include all the biological variables that influence the profitability of each production system and derive their economic values. The economic values derived for production and functional traits of indigenous chicken in this study imply that genetic improvement of the traits will have a positive impact on profitability of the indigenous chicken kept in all three systems. In all systems, genetic improvement of age at first egg will have a negative impact on profitability.

CHAPTER FIVE

GENERAL DISCUSSION AND CONCLUSIONS

5.1. Aim of the study

In most of the tropics, indigenous chicken keeping is considered a side activity, better left to the women and children presumably because of low economic returns. However, because the chicken are ubiquitous and widely accepted, there is need to establish the socio-economic potential of chicken in the overall effort to alleviate poverty. This need was identified in the first part of this study based on biological and economic factors that affect performance and thus influence the profitability of the production systems. This was achieved by constructing bio-economic models, which were as representative as possible of all the three identified production systems. It was then possible to carry out an assessment of profitability and identify the biological characters, which had an influence on the overall profitability of indigenous chicken farming.

Relative economic importance of each character termed as the economic values were derived and used to explore the impact of genetic improvement on biological and economic performance through both enhanced management and improved genetic merit (Sonaiya and Swan, 2004) with a view to making recommendations for the future. The study was therefore conceived to answer three null hypotheses; namely, i). Utilisation of indigenous chicken is equally profitable in different production systems ii). The economic importance of different traits in the breeding goals is similar iii) Economic values have no influences on genetic improvement in breeding goal traits.

5.2. Study methodology

Data collection was achieved by a thorough review of the literature, performance records from various studies and carrying out spot checks in various markets in Kenya. A bio-economic modeling approach was then used to estimate profitability and marginal returns of the production systems. The model was deterministic and the parameters represented flock averages. The deterministic bio-economic model was able to predict live weights of chicken during growth, and then using the outputs of the first component, predict the feed intake in the second. Each status in the production cycle had certain distinctive features in terms of (inputs) costs and (outputs) revenues. The model could not be validated due to lack of adequate data. To define a breeding goal, selection index methodology (Hazel, 1943) was applied in this study. The production variables were representative of the production circumstances in Kenya and many are applicable to other areas in the tropics. The production systems identified included confined full ration (CFRS), semi-intensive (SIS) and free-range systems (FRS). Bio-economic models were designed using mathematical representation of the biological and economic parameters for each system. Partial budgeting was applied to investigate the effect on profitability of increasing specific traits by a unit to derive their economic values (Ponzoni, 1988), which were later discounted. To test the viability of the breeding goals, stabilized genetic gains were predicted and the influence of economic values on genetic gains assessed.

5.2.1. Study limitations

The study used a deterministic approach to capture the features of production systems, which are highly dynamic and apt to change frequently. It is possible that some sections of the production systems behave randomly (i.e., in mating where dams mate with any sires within range) and such sections may require stochastic approaches to be more accurately represented (Kristensen and Pedersen, 2003). The deterministic approach used in this study however, was sufficiently robust to serve the purposes of this study. It was also important to be able to attribute changes in profitability to specific causal factors. There was a dearth of information on the phenotypic and genetic parameters for indigenous chicken in the tropics and therefore some parameters estimated in commercial chicken populations were adopted (Ebangi and Ibe, 1994). Prado-González *et al.* (2003) concluded that parameters estimated for chicken under an enclosed artificial environment might be different under scavenging, free-run environment conditions when genotype x environment interactions are important. They recommended that parameters should be estimated for chicken if genetic improvement programmes are planned for chicken under scavenging conditions. The need still remains for estimation of genetic parameters for indigenous chicken under extensive low-input systems.

5.3. Implementation of a breeding programme

Simple breeding goals were defined in this study, which could be applied in the genetic improvement programmes for indigenous chicken taking into account the nature of the production systems and the background of the smallholder farmers. The number of traits to be selected for was reduced by assuming a line breeding approach whereby few characters are selected for within a line and cross breeding done to get the commercial stock. The traits proposed for inclusion in the breeding goal were egg weight (EW), number of eggs per clutch

(NeCl), live-weight of cockerels (LWc) and pullets (LWp) at 21 weeks , age at first egg (AFE), hatchability (HTC), fertility (FRT) and chick survival rate (CSR).

Traits expressed in the hens such as NeCl, AFE, CSR, HTC and FRT should be improved through the dam lines while all production traits namely EW, LWc and LWp, should be improved through the sire lines in a breeding programme. It is also critical to take into account socio-cultural value systems (i.e., colour preferences) of the small-holder communities so as to package the product in colours that communities could find acceptable. It has been observed that development programmes that combine local knowledge with conventional scientific technologies are culturally more acceptable and therefore likely to succeed (Sonaiya and Swan, 2004). Such a programme would need a multi-sectoral approach, where the government, local institutions of higher learning, non-governmental organisations and individual farmers could have controlling stakes to avoid donor driven objectives which may sometimes change mid-stream (Solkner *et al.*, 1998).

5.3.1. Breeding structures

The indigenous chicken breeding industry in Kenya is unstructured such that each farmer follows his or her own objectives without technical considerations. However, in a possible breeding structure depicted as Figure 6, farmers can obtain improved chicken from the nucleus which will be able to lay more eggs, grow faster and will have a higher survival rate as they will have retained adaptation characteristics. Currently, there is no such a nucleus flock but this can be started in institutions of higher learning or in the Kenya Agricultural Research Institute where it may be easier to keep the flock running for long periods. A collaborative initiative such as the Indigenous Chicken Improvement Project (INCIP) is a step in the right direction. There are various multiplication centers formerly used for the National Poultry Development Project (generally idle now), which should take up the multiplication, limited recording and dissemination functions (B). In the nucleus breeding system illustrated in Figure 6, the first tier (A) generates genetic improvement and parent stock chicks are sent to the rearing centres (B) formerly used for the NPDP. In B, their LWc, LWp and AFE are measured (i); they are then sold to the smallholder farmers (C) at sexual maturity who use them for breeding (ii); and through occasional screening, eggs from exceptional performers in the commercial are collected and sent to the nucleus (iii); where they are hatched, the chicks evaluated and if they meet the criteria are recruited into the nucleus. This should be strategically timed at intervals to inject some variation and minimize inbreeding in the nucleus. Records kept in B could be used back in A to select sires and dams for the future.

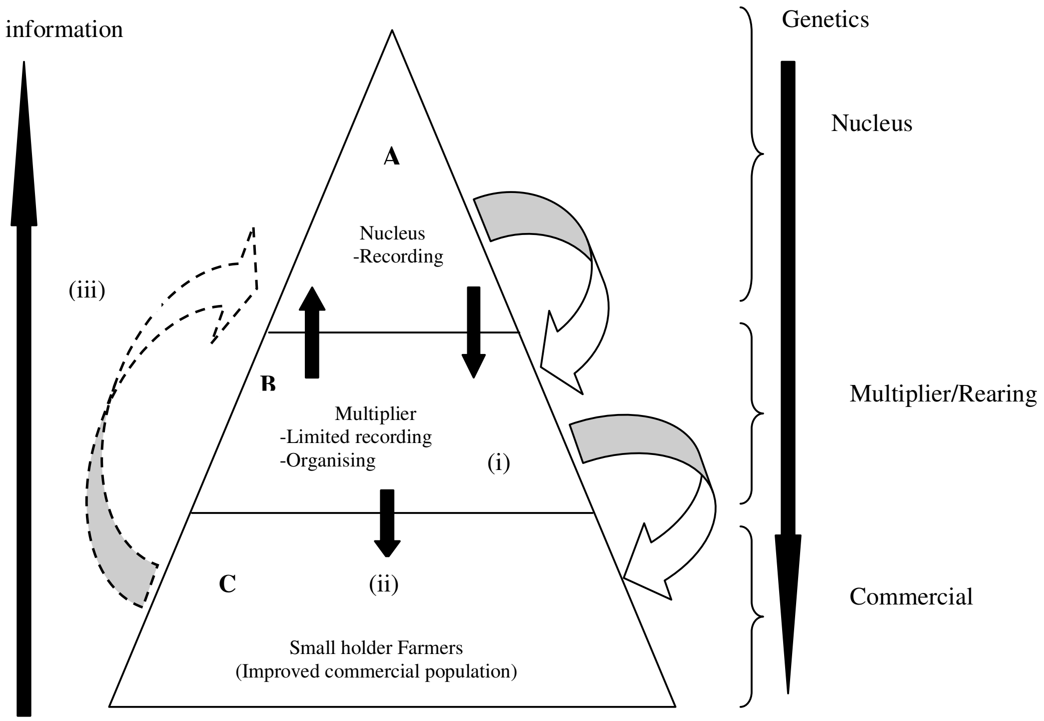


Figure 6. A possible breeding structure for indigenous chicken

5.3.2. Selection criteria and schemes

The high costs and skills required in breeding programme operations, demand that improvement efforts be concentrated on one nucleus flock with two lines, one selected for NeCl, AFE, CSR, HTC and FRT while the other is selected for EW, LWc LWp. The regional centres mentioned before can also over time be used to extend recording to the commercial populations in their areas of jurisdiction. Such records can then be used to select sires and dams in the nucleus. This would serve to reduce the generation interval (Hicks *et al.,* 1998) and improve bio-security so that the nucleus is protected from endemic diseases. Farmers should be encouraged gradually to participate in genetic evaluation so that they share in the benefits of genetic improvement. EW can be measured at weekly intervals while LWc, LWp, AFE and CSR can be measured once per lifetime. NeCl, HTC and FRT can be recorded for the first year of production. All these traits are very simple to measure and in the long run, the farmers can be organized into groups with the responsibility of recording given to the more literate members of the groups.

Whereas indigenous chicken breeders will have to anticipate that with better productivity, the consumption of chicken products will increase, it is not wise to assume output restrictions for production systems of developing countries (Jiang *et al.,* 1999). There also may be evolution of production systems to take advantage of the improved breeds and this may necessitate responding to market requirements already shaped by established players where for example the broiler breeding industry has the age-for-weight market with slaughter at a fixed target weight (Emmerson, 1997). Many farmers use indigenous chicken in a dual-purpose role and this cannot be ruled out in the breeding programme. Crossbreeding of lines selected for production and reproduction traits would provide the compromise bird for the random mating systems that exist for indigenous chicken (Jensen, 2002).

It is important to consider carefully where the need for crossing indigenous chicken with exotic types could arise, for instance where feather sexing may be required for purposes of separating males and females at an early age, the sex linked recessive gene for rapid feathering (k) is fixed in male lines and the female line carries the dominant allele for slow feathering (K). Since females are the heterogametic sex in chicken, males will be slow feathering while females are fast feathering (Pym, 1979) and early sexing can be done. Already, commercial breeders have fixed these genes and it would be unnecessary to go through the process of selecting for these traits. Crossbreeding could be required at some point during the process of genetic improvement. For crossbreeding to be effective, there is need to estimate the crossbreeding components for the various traits in indigenous chicken. In Kenya, studies on the estimation of genetic and phenotypic parameters for traits of indigenous chicken are lacking. Also lacking are crossbreeding parameter estimates for traits of various crosses between indigenous chicken and exotic breeds. A good understanding of the crossbreeding components through test crossing will aid in the design of an appropriate crossbreeding strategies.

5.3.3. Adaptability component

Indigenous chicken have to be hardy, well adapted to the sub-optimal conditions but yet improve in productivity. Genetic improvement should not lead to reduction in adaptability of the chicken because even among the exotic chicken, intensive selection for production alone has brought about problems such as leg deformities, poor reproductive scores and lack of adaptability among layers and broilers, respectively (Pym, 1979; Fairfull *et al.,* 1998; Siegel and Wolford, 2003).

A trait such as broodiness plays an important role in the overall performance of the production systems but was not included in the breeding goals considered in this study. Broodiness as a biological trait has been investigated extensively using reciprocal crosses between White Leghorns (which do not exhibit incubation behaviour) and various broody lines (Väisänen *et al.,* 2005). It is known that cocks do not show broodiness in domestic chicken. Working on the hypothesis that sex linked genes play a major role in the inheritance of this trait, Romanov *et al.* (2002) concluded that major genes on the Z chromosome (which is the sex chromosome in domestic chicken) did not control incubation behaviour, This question still needs to be answered in view of the important positive and negative roles played by this trait in the indigenous chicken production systems. More research is required in this area to clarify the mode of its inheritance. Other traits that may be used to confer greater adaptability include comb type and wattles for heat dissipation, naked necks, frizzled feathers, and slow feathering (**Appendix I and II**).

5.3.4. Constraints to tropical breeding programmes

One of the constraints that need to be anticipated is financial limitation. An indigenous chicken breeding programme is anticipated to start generating funds as the chicken gain wider acceptance. Other limitations of the breeding programme include the fact that controlled breeding necessitates some level of confinement. This may push some farmers to continue keeping their chicken in random breeding populations thus presenting an initial set-back to efforts aimed at improvement. Farmers can be encouraged to as much as possible confine the breeding hens and cocks together and ensure that all other cocks are sold or slaughtered as soon as they reach puberty. This could help restrict breeding activities to hens and cocks that are already improved.

Kosgey *et al.* (2006) also identified other constraints in tropical breeding programmes to include small flock sizes, single sire flocks, low level of literacy, lack of performance and pedigree records, lack of animal identification and organizational shortcomings. Since breeding stock will continuously be made available from the multiplication centres, the flock sizes do not have to be big, but the cocks can be exchanged after a period between villages to avoid inbreeding. Levels of literacy are improving and within villages, the most literate members of the communities can be given the responsibility of keeping the records. To provide the organizational framework for mobilising the local communities, non-governmental organizations could be invited to participate.

5.4. General remarks and conclusions

This study was conceived to address some of the constraints facing indigenous chicken production in Kenya although the results of this study might be applicable to countries in the region with similar production systems. The deterministic model used in estimating economic values for breeding objective traits is versatile and could be extended to analyze production systems with similar circumstances. The economic values were derived per breeding hen for each production system. Changes in the phenotypes were related to changes in revenues. The model uses flock averages and variations in flocks are neglected. This did not have adverse effects on the estimation of economic values as the approach has been used in the past (Jiang *et al.,* 1999). The model would have to undergo certain modifications depending on the nature of the production systems and performance indices of the species under consideration if it is to be used to assess other domestic avian species or production systems. The prices of the products and inputs would also need to be reviewed to fit into the relevant economic environment.

Traits, which could be included in breeding goals, were identified and their economic values derived (Table 10). Some of the economic values had moderate sensitivity to changes in prices of eggs and meat while others were not sensitive at all (Table 11). It was observed that discounting of the economic values had a noticeable effect on their magnitude (Table 12) and that it was important to utilize cumulative discounted expressions to avoid overestimating the economic influence of each trait on genetic gain. It was observed that most of the economic benefit came from improvement in live weight of male lines. This suggests that although the indigenous birds are kept in a dual-purpose role, more is to be gained from their meat than the eggs. The structure of the breeding programme should therefore be modeled along the development of specialized lines (Jiang *et al.,* 1999); accompanied by crossbreeding probably with the aim of obtaining birds fit for various purposes.

The results obtained in this study showed that indigenous chicken, at their current genetic merit were profitable in the FRS. The difference in genetic gains between FRS and SIS was (KSh. 31.63) suggesting that SIS had an advantage over FRS thus justifying the slightly higher level of inputs expended in SIS. In the short to medium term, it may therefore be better to promote the use of the FRS (Table 8) so that as the genetic merit of indigenous chicken for the breeding goal traits improves, intensification can follow (Perry *et al.,* 2003).

The breeding goals defined in this study need to be converted into actual material and monetary gain for the smallholder farmers who keep indigenous chicken. To make that progress, ways must be identified to obtain as fast as possible future generations of birds that will produce more efficiently under future production circumstances. There is need to identify chicken with the best genetic qualities relative to the breeding goals. This can only be achieved if trait recording, performance testing and breeding value estimation are undertaken. Due to cost considerations, it may not be feasible to carry out field recording for chicken but a more economical approach would be to establish flocks in performance testing stations and nuclei. This would allow progeny testing to be done and even pedigree registration. From the foregoing activities, selection indices or BLUP can be used to estimate breeding values.

In the case of the indigenous chicken, there are existing breeding practices which should be evaluated and adopted if found adequate. These include stock sharing, and giving out animals as gifts. Further work is also needed to identify optimum breeding strategies that can be used to achieve these breeding goals. There is need to determine the right number of birds to be kept within the nucleus flocks so as to minimize inbreeding and to identify appropriate mating systems. The chicken have high reproductive rates and the use of novel reproductive technologies like artificial insemination may not be quite necessary. The need to come up with innovative dissemination systems for the superior genes to get into the commercial population through the use of multipliers cannot be overemphasized. Finally, the mating or crossbreeding system adopted should optimize the combination of genetic material in the commercial bird, so that the potential of the chicken for various purposes is utilized.

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APPENDIX 1

Types of Combs


Buttercup

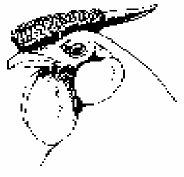

Strawberry


Cushion


V-shaped


Pea


Single


Rose


Silkis

Acknowledgements: University of Illinois Extension (www.urbanext.uiuc.edu)

APPENDIX II

Potentially useful major genes in chicken

Na	Naked neck (Autosomal-A)
Dw	Dwarf (Sex-linked-S)
K	Slow feathering (S)
Fa	Fayoumi (A)
F	Frizzle (A)
H	Silky (A)
Fm	Fibro-melanosis