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Characterisation of local chicken in low input - low output production systems: Is there scope for appropriate production and breeding strategies in Malawi?

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Characterisation of local chicken in low input – low output production systems: Is there scope for appropriate production and breeding strategies in Malawi?

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by

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DEDICATION

To my beloved mum and dad
for kick-starting my life to success

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List of Abbreviations

ADB	African Development Bank
ADD	Agricultural Development Division
AIDS	Acquired Immune Deficiency syndrome
AIREML	Average Information Restricted Maximum Likelihood
BA	Black Australorp
BAHS	Basic Animal Health Services
BCA	Bunda College of Agriculture
BW	Body weight
CP	Crude protein
CRD	Chronic respiratory disease
DAHI	Department of Animal Health and Industry
DANIDA	Danish International Development Agency
DMI	Dry matter intake as percentage of bodyweight
dw	Dwarf
EGR	Exponential growth rate
EMP	Efficiency of protein metabolism
EPA	Extension Planning Area
F	Frizzled
FAO	Food and Agricultural Organisation
FC	Feed cost
FI	Feed intake
G x E	Genotype by Environment Interaction
GMOFC	Gross margin over feed cost
FCR	Feed conversion ratio
FEWSNET	Famine Early Warning Systems Network
GDP	Gross Domestic Product
GE	Growth efficiency
H	Heritabilities
HDI	Human Development Index
HI	Hatching interval
HIV	Human Immunodeficiency Virus
LADD	Lilongwe Agricultural Development Division
LC	Local chickens
LSD	Least significant difference
LW	Live weight
ME	Metabolisable energy
MK	Malawi Kwacha
Na	Naked neck
NCD	Newcastle disease
N_e	Effective population size
NID	Normally and Independently distributed
NORAD	Norwegian Agency for International Development
NSO	National Statistical Office
PER	Protein efficiency ratio
POH	Point of hatch
PPP	Purchasing Power Parity
R	Rate of return
RI	Reproductive Index
SAS	Statistical Analytical System
SAU	Small Animal Unit

SD	Standard deviation
SFRB	Scavenging feed resource base
SGR	Specific growth rate
SPIP	Smallholder Poultry Improvement Programme
TC	Transaction cost
UNDP	United Nation Development Programme
USAID	United States Agency for International Development
WG	Weight gain
WT	Live weight

1. General introduction

Poultry production constitutes of smallholder rural and commercial urban production in Malawi. In 1998 the poultry population was estimated as 11.5 million (Malawi Government, 1999a). The rural poultry sector forms the largest component with more than 80 % of the poultry population. Chickens constitute the majority (83 %) followed by pigeons (14 %) and ducks (2 %). Other species include turkeys, geese and, currently into domestication, guinea fowls. Most of these are indigenous[1] except in chickens where traces of the Black Australorp (BA) breed can be found. These BA chickens were introduced to cross breed with local chickens (LC), a program that has been in practice for over 40 years, with a goal to improve productivity of the LC (Malawi Government, 1999). In most households, women and children are caretakers of traditional poultry kept on free-range extensive system, a practice common in most African and Asian countries (Aini, 1990; Dessie and Ogle, 1996, Kitalyi, 1997; Aganga et al., 2000). Rural poultry (chickens in particular) is widely and equitably distributed among households that even the more poor and marginalized in societies own them. The urban sector, on the other hand, comprises of commercial chicken production, mainly for egg and broiler production, raised under intensive system and using exotic layer and broiler strains. Because of high cost of production due to feeding and capital inputs, urban poultry sector constitutes less than 20 % in Malawi and other developing countries (Safalaoh, 1997; Gueye, 1998).

Corresponding with human population and status, rural poultry sector forms an important component of human livelihood and contributes significantly to food security. LC offer broad spectrum of uses to the majority of Malawians. They are an inexpensive animal food (meat and eggs) and income to most resource poor rural people. Socio-cultural contribution includes slaughters to a welcomed guest, in marriage and funeral ceremonies, and in settling disputes in traditional courts presided by chiefs (Gondwe et al., 1999a). Their small size and fast reproductive rates allow easy conversion into food and money that, for example, women in households can manage without waiting for decisions from husbands. Rural poultry can therefore be used to empower women and marginalized groups socially and economically. LC production is an important component of livestock in the rural societies.

As in most developing countries, LC, interchangeably called village, traditional or rural chickens, are generally considered to be genetically producing low quantities of meat and eggs, are raised under free-range and survive on scavenging. LC are usually sidelined and considered a secondary occupation to other agricultural activities in households. This makes LC to be raised with minimal input and thus produce the output cost effectively (Aini, 1990). In Malawi, this generalisation led to introduction of exotic dual purpose BA chicken to cross breed with the LC as a breeding strategy to improve their performance (Upindi, 1990). The primary goal was to improve meat and egg production from the BA while getting adaptive features from the LC by exploiting heterosis displayed in crosses. Distribution of six-week old BA chicks from three government breeding stations (Mikolongwe, Bwemba and Choma) was initiated to smallholder farmers in the three administrative regions of

[1] Indigenous in this document shall imply local to the area, has lived with the people, breed and survive under adaptation from human and physical environment, management and breeding practices. The term also distinguishes local from other recently and purposely-introduced breeds so called exotic. Terms indigenous and local will be used interchangeably throughout the thesis.

Malawi, namely, the South, Centre and the North, respectively. The program however, lacked strategies to monitor implementation procedures and benefits (Safalaoh, 1992). It appears to have failed meeting the objectives but continues (Safalaoh, 2001).

The failure of the BA x LC cross breeding program is due to several factors and associated production constraints. The BA breed was introduced into the country without evaluating the breed under prevailing local conditions (diseases, low and erratic feed base, temperature, rainfall pattern). Production environments and systems, available genotypes, farmers' goals and functions of species were overlooked, as was the case for most developing countries, where such programs were implemented (Timon, 1993). BA were introduced into LC flocks that were non-characterised in terms of their production and husbandry practices. To establish a working base for present and future programs, there is need to carry out such studies under existing production systems if reliable information regarding their performance potentials and extent of benefits to get from any breeding program are to be achieved.

Studies on LC production, characteristics and their scavenging production systems are few and mostly done in northern Malawi (Ahlers, 1999; Hüttner et al., 2001). Yet scavenging is the sole system of raising LC. Meaningful development of genetic and non-genetic improvement programs requires valid scientific information but might be unsuccessful and unsustainable if failing to apply a holistic approach. For such programs to be initiated there is need to generate adequate information on production and reproductive parameters, husbandry practices, growth physiology and constraints under the prevailing environment. The current proposed study seeks to characterise chickens through research and monitoring.

The work on poultry is chosen because most rural people raise LC (Malawi Government, 1994). With the current land declining rate (average farm size estimated at less than one hectare per household), keeping of large species of livestock such as cattle is not viable to majority in rural areas. LC has potential to contribute to nutrition, poverty reduction, social, cultural, gender and household equity in rural areas. All previous studies, though not fully conclusive, show that the species has potential for improvement requiring definition of entry points and determination of levels for improvement.

In almost all past programs, especially in research, there has been virtually little or no farmer participation. This is particularly due to the fact that most research were on-station oriented, based on fewer demands than anticipated by researchers (Werner, 1993). Local knowledge of farmers remained untapped and farmers were receiving extension messages as prescriptions in a top-down system. In most cases such messages had problems of adoption or were not fitting into the farming systems and goals, and lacked feeling of ownership by farmers, leading to unsustainable development efforts. Involving farmers means they should participate in developing and implementing research and programs from the beginning (exploratory phase). This approach motivates farmers and provides incentives to developmental oriented research, enables proper understanding of the environment (both social and physical) into which animals will fit and allows programs to be tailor-made for their success and sustainability. The proposed study seeks to address this through a community based systems research approach.

The problem statement

Review of literature has shown that rural chickens have potential food and non-food contribution to human livelihood, especially in smallholder rural communities. Rural chickens have also been asset starters for most poor (vulnerable) groups in societies. Genetic and non-genetic factors and their interaction contribute to their potential and diversity; hence both management and breeding strategies could be used to improve productivity in rural chickens. The problem is that proportions and extent of each component (genetic and non-genetic) are currently not known. Priorities on strategies also depend on target groups, their goals and objectives, their socio-economic status and current production potentials, bearing in mind sustainability of programs. All these can only be identified and properly designed after thorough characterisation of the species within the context of their farming systems and farmer participation.

General hypothesis

Phenotypic variation in production and reproduction performance traits exist in local (indigenous) chickens in Malawi that provides potential to improve their productivity and contribution to food security through genetic and management strategies.

Objectives of the study

General

To evaluate phenotypic and genetic characteristics of local chickens, and their production system for sustainable utilisation, improvement and conservation of the species in a low-input crop/livestock mixed farming integrated system.

Specific

i. to characterise the low-input production and marketing systems and potential for LC
ii. to evaluate productive and reproductive parameters for LC under scavenging conditions
iii. to compare productive and reproductive performance of the species raised on-station and those evaluated on-farm under scavenging system
iv. to evaluate growth potential and nutritional parameters of local chickens
v. to determine efficiency of LC production system and to value flock output
vi. to compare growth performance of BA and LC under scavenging conditions
vii. to estimate genetic parameters for production traits for LC on free-range

2. Literature review

2.1 Origin and evolution of chicken domestication

There is conflicting information about the actual centre and time of domestication as well as ancestors of the domestic chicken. Horst (1989) reported that all domestic fowls originated from small jungle fowl (*Gallus gallus*) of South-East-Asia. Crawford (1990a) reported that chickens were domesticated from the red jungle fowl in the Indus valley about 2000 B.C. West and Zhou (1989) also mentioned domestication in India around 2000 B.C. but reported that chickens were first domesticated from red jungle fowl in South-East-Asia well before the sixth millennium B.C. These authors concluded that the red jungle fowl was a convincing ancestral wild form of the domestic fowl, commonly called chicken, unlike the other two species *Gallus sonnerati* and *Gallus lafayettei* that other authors previously reported on. All above authors derived their evidences from archaeological, vegetation, climatic and geographical information. Through DNA fingerprinting, Siegel et al. (1992) further verified the red jungle fowl was an ancestral form of the domestic chicken.

From the original centres, chickens, as other livestock species underwent domestication and migration processes. Diamond (2002) defines domestication as breeding a species in captivity and thereby making the species modified from its wild ancestors in ways making it more useful to humans who control its reproduction and food supply. This process led to evolutionary changes in domestic species in such a way that they started differing in morphology, physiology and behaviour from their wild forms. While in domestication, chickens underwent selection and migration (Horst, 1989; Crawford, 1990a; Diamond, 2002). From these centres of origin, migration of chickens followed an east-west axes pattern of other livestock, rather than a north-south axes pattern. According to Diamond (2002) similarity of latitude led to species sharing same day lengths, seasons, climates, habitats and diseases that made them to require less evolutionary changes than do locations at different latitudes. The north-east-west migration pattern of chickens is clearly reported by authors unlike to migration and domestication process in Africa. Crawford (1990a), Marle-Köster and Casey (2001) and Tadelle (2003) reported that chickens may have come through Egypt to Africa during the iron age period. Marle-Köster and Casey (2001) stated that East Africa-Indian traders and European settlers most probably introduced domestic chickens to Southern Africa. Crawford (1990a) reported that origin of chickens from India to East and West Africa was more likely because of a well early-developed trade between India and east coast of Africa.

Crawford (1990b) reported that the initial purpose of domestication of chickens was first for cock fighting, then religious and cultural. During this time, selection was based on feather colour and morphological variants. Only much later did man begin to use domestic chickens for food. Following domestication and migration east-west, major evolutionary changes took place in chickens due to intensive artificial selection for traits of economic importance in the west (Siegel et al., 1992). This led to developing a specialised meat-type and egg-type commercial stocks after the 1950s (Crawford, 1990b). The selected and improved breeds, however, reduced genetic variation, became more similar to each other but became distanced from their jungle fowl ancestor, unlike the unselected non-commercial chickens (Siegel et al., 1992). The later constituted the generally called local or indigenous chickens common in Africa and other developing countries (Horst, 1989). On the other hand, high yielding fowls are now used worldwide (Crawford, 1990b).

There is no information on origin of domestication of chickens in Malawi. According to Crawford (1990a), local chickens were found in Mozambique by 1600. Since these share borders, it may be reasonable to speculate that chickens were domesticated in Malawi by that time. Southern and eastern routes could be probable entry points of chickens to Malawi.

2.2 Poultry production and importance in Africa

Poultry production in Africa follows the status of other developing countries in Asia (Aini, 1990) and Latin America (Kyvsgaard et al., 1999). Poultry in Africa is skewed towards chicken production (Branckaert and Gueye, 1999). In 2003, chicken population in Africa was estimated as 1.3 billion, with Nigeria, Morocco, South Africa and Algeria producing over 120 million chickens each (FAOSTAT, 2004). In Sub-Saharan countries excluding South Africa (SSA), aggregate chicken population was 775 million. In Africa, 3 million metric tonnes of meat were produced, of which 1 million came from SSA countries excluding South Africa (FAOSTAT, 2004). Kleyn (2004) reported that poultry production in Africa increased by 60 % between 1995 and 2000. Kleyn (2004) further reported that little poultry meat is exported, and, if any, mostly to other African countries.

Production is demarcated into two sectors, the commercial, high input-high output sector and the rural, village sector. The commercial sector follows *'all in-all out'* intensive production of meat (broilers) and eggs (layers), uses high yielding strains bred and supplied by international breeding companies. Due to need for high capital and inputs, skilled management and markets, commercial sector is often restricted to urban and peri-urban areas or markets in SSA.

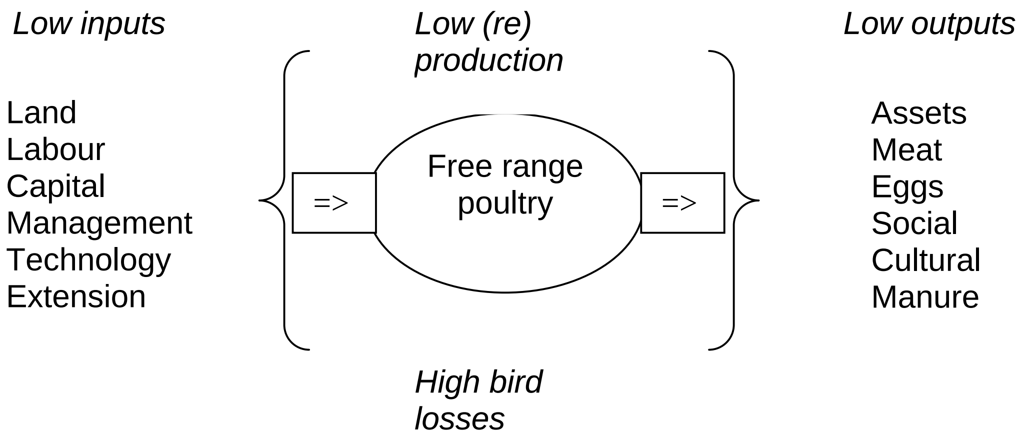
The village poultry sector is synonymously called traditional, rural, scavenging, family, indigenous or extensive poultry production. These terms basically summarise the characteristics of poultry produced and their production system. As described by several authors, traditional poultry is basically chicken production; is an almost omnipresent activity among smallholder farmers in the developing world; stems from traditional practice throughout Africa; and is raised with minimal input under free-range, scavenging system (Gueye, 1998; Branckaert and Gueye, 1999; Kyvsgaard et al., 1999). Gueye (1998) reported that nearly 80 % of chicken population in Africa, as in Asia (Aini, 1990) are predominantly indigenous breeds raised under extensive system. Since these chickens are maintained with very low land, labour and capital inputs, even the poorest social strata of the rural population keep them. While the commercial sector has high and specialised output, the traditional chicken has low productivity, with diversified output and a complex of constraints such as high mortality in chicks, disease, parasites, predation and poor feeding. Village chicken production follows a route of *‘production by the masses’* since they are raised in small flocks sizes of 5 – 20 or more but by the majority rural masses (Panda and Mohapatra, 1993; Gueye, 1998). Village poultry production is generally known as a sidelined sector among smallholder farmers. Women and children are mostly caretakers. By following traditional practices of production, this village poultry has been a component of small farms for centuries and is assumed to continue in the foreseeable future in Africa and Asia (Ramlah, 1996; Branckaert and Gueye, 1999).

Importance of chickens in all societies include source of protein food, income, use in traditional and religious ceremonies, among others. Order of importance of each function, however, differs between countries and societies as reported by several authors. For example, Dessie and Ogle (2001) reported equal importance of functions of chickens in terms use for sacrifice, sale and consumption as perceived by farmers in Central Highlands of Ethiopia. Ekue et al. (2002) reported that main functions of local chickens among farmers in Cameroon were to sell for income and as source of food. Missohou et al. (2002) reported that farmers used chickens mainly for household consumption and only few sold their chickens to earn income in Southern Senegal. Despite differences in order of importance of roles local chickens play to rural communities, multifunctional use of local chickens was obvious.

2.3 Rural poultry production and breeding systems in Malawi

2.3.1 Free-range (extensive) system

Free-ranging is a popular terminology in Malawi that relates to smallholder sub-sector livestock production system in rural areas. In the case for poultry, birds are let free in the morning and they roam around the homesteads looking for feed through scavenging. Most feed scavenged and the quantity is not known and there is also little information from research on scavenging. However, farmers may supplement the birds, usually at irregular intervals with left over from human food and by-products from food processing (Safalaoh, 1997). Feed supplementation is not standardised and depends on periods of food availability to households (Ahlers, 1997; Gondwe et al., 1999a). Other production factors of free-range system are not properly documented but follow similar production systems for chickens reported in almost all countries in Africa (Minga et al., 2000; Tadelle et al., 2003a) and elsewhere (Huque et al., 1999). National reports by Upindi (1990) and Kampeni (2000), and review studies by Safalaoh (1997) show that local chickens produce in a low-input low-output system illustrated in figure 2.1. Birds from different flocks and of different age-groups scavenge together. Major capital investment is the procurement of breed stock, using cash or non-cash traditional stock sharing systems (Gondwe et al., 1999a), and where done, construction of night shelter (locally called *khola*). Most likely and in general contribution of external inputs is insignificant.



Source: Diagram based on several country and technical reports

Figure 2.1. Low-input, low-output relationship in rural poultry production systems

National and technical reports have documented several disease related constraints to rural poultry production in Malawi (Christensen, 1986; Upindi, 1990; Kampeni, 2000).

2.3.2 Breeding systems

Breeding programs in rural areas define breeding activities carried out by communities at subsistence level, considering their production environments, breeding goals and objectives, selected traits and mating methods (Sölkner et al., 1998). Village breeding programs usually include food, ecological conditions, economic and social benefits of livestock, while at the same time being risk conscious. It requires understanding these factors in order to incorporate and exploit traditional breeding programs.

Unplanned random mating is practised in chickens within flocks and between flocks that scavenge together. Traditional breeding systems exist (Gondwe and Wollny, 2002) but have not been documented in details. Farmers exchange breeding stock with other farmers in traditional stock sharing systems and this goes with preference for particular phenotypes (Ahlers, 1997). Gondwe et al. (1999a) observed that sharing breeding stock is more often between members within the village than between members outside village households (Table 2.1). In similar studies, there appeared to be a declining trend in proportion of cockerels in flocks with age while breeding hens stay in flocks for long periods of over two years. Gueye (1998) reported that on village fowl flocks, males are generally removed from flocks at an early age for sale, home consumption or for cultural purposes. Keeping hens for long reproductive periods may indicate their preference for reproduction (Sölkner et al., 1998).

Table 2.1. Various sources where farmers obtain breeding chickens in rural areas, Malawi

Source	n	Percent (%) of respondent
Market place	33	10.6
Members within the village	229	73.9
Other places[1]	48	15.5

[1]Include people outside the village or neighbouring areas, veterinary centres where Black Australorp chickens are distributed to farmers

Source: Gondwe et al. (1999a)

Traditional breeding systems have, however, been overridden by crossbreeding programs in traditional chicken production, the case common for most livestock in developing countries (Iniguez, 1998). Gueye (1998) also reported that local chickens have undergone disorderly crossing with exotic strains in the whole African continent. Apart from the Black Australorp and local chicken crossbreeding program, DANIDA (since 2000) introduced another crossing of Hylines with local chickens under semi-scavenging conditions in rural households of central Malawi. DANIDA strategy followed the Bangladesh Poultry Model that has been described by many authors (Nielsen, 1996; Ahmed, 2000; Dolberg, 2001) as a tool for poverty alleviation and improvement of nutrition among the poor (categorised as landless) in Bangladesh. DANIDA project was terminated prematurely in 2002 due to withdrawal of funds. Bunda College of Agriculture initiated (since 2001) multiplication centres for rural poultry (chickens, ducks and pigeons) in surrounding villages, with the aim to evolve to open nucleus-breeding centres (described in Gondwe et al., 2003). The two programs have devolved to farmers and hence include elements of farmer participation in terms of farmers utilising and managing their birds and resources. Committees were established among farmers as decision-making bodies. While open nucleus breeding programs are recommended to improve and conserve indigenous species under village breeding programs (Iniguez, 1998), performance evaluation and characterisation are still inadequate to initiate one in Malawi. Indigenous breeding systems are still poorly understood.

2.3.3 Constraints to rural poultry production in Malawi

The main challenge in rural chicken production is Newcastle disease (NCD) whose severity wipes almost the entire flock (Ahlers, 1997; Haule and Jere, 1999). The disease is endemic occurring during the hot season (September to December). In recent years the disease started as early as May, in some cases persisting within flocks throughout the year (Gondwe et al., 1999a). The symptoms mask the effects of other diseases that only become identified after intervening in NCD. Vaccines are available, the problem being logistics and administration of the vaccine as they are available in large doses. Some vaccines such as La Sota require a cold chain. Extension services are weak and inadequate to facilitate vaccination and other husbandry technologies. This results in farmers using their traditional remedies such as *Alovera species* locally called *Dema* (Ahlers, 1997). Losses in adult chickens occur primarily due to NCD (Hüttner et al., 2001), while predation, climatic stress, external parasites, inadequate feed, poor housing and care cause losses in chicks. DANIDA program attempted to intervene into these constraints through postgraduate student research studies (DAHI, 2001).

2.4 Current state of research studies on rural poultry in Malawi

Initial rural studies on chickens comprised work by Ahlers (1997) in Mzuzu Agricultural Development Division (ADD), Northern Malawi. The study focused on characterising production systems for poultry in Malawi through flock monitoring. Flock size ranged from 10 to 15 birds per household, the flock fluctuating with season. Flock composition by age structure was skewed in favour of adults, signifying more chick losses during their early growth stages. Housing, feeding and disease husbandry practices were also characterised in detail during the study. Since the other focus was on Newcastle disease control and prevalence, the study neglected measuring growth parameters such as live weights and different phenotypes within flocks. On the other hand, the study incorporated farmer participation and showed potential importance of working with farmers for technological development and adoption. Following studies by Ahlers (1997) were those conducted in the areas as part of Basic Animal Health Services (BAHS) programs. Production systems and constraints for cattle, small ruminants and chickens, and effects of disease control and management intervention were documented (Hüttner et al., 2001). In their studies, mortality, off-takes due to slaughter and sales, and livestock movements were main causes of herd or flock dynamics. Trends in livestock dynamics due to the above causes differed between species and seasons and these were linked to utilisation of the species or epidemics in case of mortalities. Users of interventions (especially Newcastle disease control) increased their flock sizes, just like was the case for cattle herds and small ruminant flocks. This also increased their utilization as noted by their respective increases in off-take rates. Lack of individual identification led to combining groups of livestock by age within flocks. In case of chickens, chick mortalities and individual weighing were not recorded. Emphasis was on health and all aspects of traditional breeding practices were ignored in the studies.

Results from a survey on rural poultry revealed the existence of a diversity of different species in Malawi (Gondwe et al., 1999a). Chicken species were the most dominant (83 % of the population) seconded by pigeons (15 %), ducks (1.8 %). Other poultry species constituted less than 1 % of the population. The study also identified phenotypic differences within the species based on morphology (Table 2.2). Similar findings of species prevalence were reported by Lwesya (unpublished, 1998) who also reported a declining trend in number of each species as perceived by farmers. Hüttner et al. (2001) also observed this declining trend in cattle, small ruminants and chickens in Northern Malawi.

Production characteristics of chickens under village conditions showed that male chickens were heavier (1.8 kg mature live weight) than females (1.3 kg), averaged over different ages (Gondwe et al., 1999b). Age determination was based on the memory of the farmers.

Table 2.2. Local names for free-range chickens based on Chewa and Tumbuka languages in Malawi

Species	Local name	Phenotypic description	Naming basis
Chicken	Kachibudu / Chigunyu / Bunthuke	Rumpless, without tail feathers	Morphology
	Kameta / Kamkulike	Naked neck	
	Masapa / Kamabuluku	Feathered legs	
	Simboti / Kambwata / Kambwita	Dwarf, with short legs	
	Kansilanga / Masakalala	Freezled	
	Tsumba	Feather cap on head	
	Kawangi / Kawandwe	Black and white spotted feathers resembling a predator bird *Kawando*	Colour of Feathers
	Chiphulutsa / Choto	Grey feathers like ash	
	Veterinary / Mikolongwe	Black Australorp chickens bought from veterinary centres	Origin
	India	Exotix strain called after Indian River	

Source: Gondwe et al. (1999a)

Other studies were basically on-station and involved evaluating productivity of indigenous chickens in comparison to Black Australorp (BA) chickens under intensive system of management (Jere et al., 1996; Kadigi,1996; Safalaoh et al., 1996). Kadigi (1996) reported live weights of 1.8 and 2.3 kg at 20 weeks for indigenous and BA chickens, respectively. The results were not significantly different ($p>0.05$). Both species were observed to have poor feed conversion (>4.5g feed per unit gain). The results observed in indigenous chickens under intensive system were similar to those obtained in the survey for birds on free-range system (Gondwe et al., 1999b). Table 2.3 shows results of some traits studied. Beya (unpublished, 1997) observed a negative gross margin of MK62.00 per local chicken raised intensively to 20 weeks.

Preliminary crossbreeding evaluation studies, (Gondwe unpublished, 1994) reported low prevalence of BA chickens or their crosses in the villages (4 to 8 % of chicken population). Improvements of productivity of indigenous chickens in the villages were not observed or reported. Reasons attached to the failures of Smallholder Poultry Improvement Programme (SPIP) included

Table 2.3. Live weights and feed conversion ratios (g:g) for local, BA and crosses (BA x Local) under different production environments

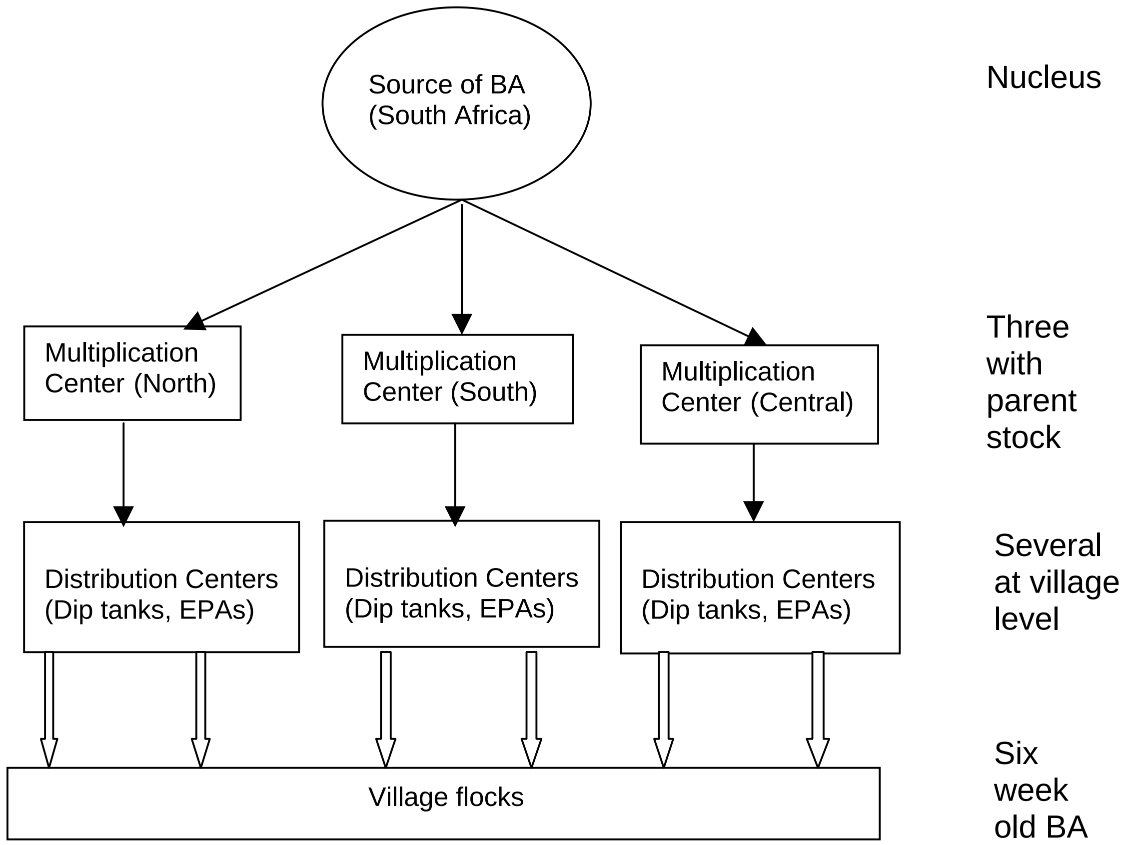
Trait	n	Breed	Mean / range	Management	Source
Initial weights (0-1 week), g	250	BA	42	Intensive	Beya (1997)
	120	Local	51		
Weight at 8 weeks, g	250	BA	579		
	120	Local	484		
	90	Local	317-345	Intensive	Jere et al. (1996)
	90	Crosses	356-462		
Weight at 16 weeks, g	90	Local	791-1066		
	90	Crosses	1220-1382		
Adult female weight (> 20 weeks), g	799	Local	1400-1500	Extensive, flocks survey	Gondwe et al. (1999b)
Adult male weight (> 20 weeks), g	418	Local	1900-2000		
Feed conversion ratio (to 20 weeks)	120	Local	9.36	Intensive	Beya (1997)
Feed conversion ratio (to 8 weeks)	90	Local	7.2-10.1	Intensive	Jere et al. (1996)
	90	Crosses	4.2-5.5		

n = number of chickens recorded; BA = Black Australorp

- poor distribution structure of BA chicks. The beneficiaries of the birds were not the target clientele (farmers) but public workers and friends of responsible personnel for distribution in the villages (veterinary assistants)
- fewer numbers of BA chicks were distributed than the demand for the birds
- farmers could not afford to purchase the chicks
- farmers were not aware of the objectives of programme. Some farmers viewed the intervention of BA to be used for egg and meat production and not for crossbreeding
- lack of initial evaluation of village chickens and their production system. There were more indigenous cocks that they could easily out compete the few BA cocks.
- lack of adaptation of BA chickens under local environment leading to their possible elimination from flocks before reproducing

The unpublished studies were however, of qualitative survey type but the findings of SPIP agreed with the observation reported elsewhere (Timon, 1993) that most crossbreeding programs failed. It can be assumed that crossbreeding programs are complicated for rural poor farmers having low levels of education and are not easy to be maintained under extensive farming systems, where mating is uncontrolled. A combination of operational, biological and management constraints cause failure of crossbreeding programs.

Malawi Government continues promoting crossbreeding programme of BA with LC. With external funding from African Development Bank (ADB), multiplication and distribution are shown in Figure 2.2. The parent stock was rejuvenated five years ago with new stock from South Africa. The system adopts a multi-tier multiplication scheme. At farmer level, there is no established breeding strategy and system.



Source: Adapted from Upindi (1990)

Figure 2.2. Multiplication and distribution scheme for Black Australorp chickens in Malawi

2.5 Studies on village (rural, indigenous) poultry in other countries

The general recognition of the importance of village chickens to rural masses in Africa and other developing countries (Branckaert and Gueye, 1999) has led to increasing number of studies focusing on their production and production system over the last decade (Pedersen, 2002a). According to the summary presented in Table 2.4, many countries have initiated studies on village poultry. Common observation is that most studies were based on general surveys and not focussed and provided information on flock demography, socio-economic characteristics of farmers keeping chickens, production system and management, mortality and other health related constraints. Focused studies on feeding and growth trials have usually been on-station, following intensive *ad-lib* feeding system. These plus few on-farm monitoring studies provided information on growth and reproduction characteristics and potential of local chickens. Marketing studies are very

Table 2.4. Countries in Africa where village poultry studies have been conducted

Country	Year of study / report	Type of study	Nature of study	Author(s)
Botswana	2000	General production & management system	Survey and observations	Aganga et al. (2000)
Botswana	2003	Nutrition	Feeding trials	Aganga et al. (2003)
Burkina Faso	2003	General production & farming system	Survey and monitoring	Kondombo et al. (2003)
Cameroon	2002	Characterisation	Survey on production system	Ekue et al., (2002)
Chad	1999	General production description	Survey	Mopate and Lony (1999)
Morocco	2001	Phenotypic characterisation	Survey and monitoring	Benabdeljelil and Arfaoui (2001)
Ethiopia	2002	Nutrition	Feeding trials	Dana and Ogle (2002)
Ethiopia	2003	Growth & survival	Breed & management comparison trials	Demeke (2003)
Ethiopia	1996	General	Surveys, observation and trials	Dessie and Ogle (1996)
Ethiopia	2001	Characterisation	Survey on production system	Dessie and Ogle (2001)
Ethiopia	2003	Phenotypic & genetic characterisation	Surveys, observation and trials	Tadelle (2003)
Kenya	2001	Nutrition	Feeding trials	Ndegwa et al. (2001)
Kenya	2003	Nutrition	Feeding trials	Kingori et al. (2003)
Nigeria	1999	Genetic characterisation	Microsatellite analysis	Wimmers et al. (1999)
Nigeria	2001	Growth & reproduction	Ecotype comparison	Adetayo & Babafunso (2001)
Nigeria	2002	Nutrition	Feed survey	Sonaiya et al. (2002)
Nigeria	2003	Nutrition	Feed survey / modelling	Olukosi and Sonaiya (2003)

Senegal	1998	Growth prediction	Modelling	Gueye et al. (1998)
Senegal	2002	General production system	Survey	Missohou et al. (2002)
South Africa	2001	Phenotypic characterisation	Growth comparison trials	Marle-Köster and Casey (2001)
Tanzania	2001	General production	Growth, reproduction & survival	Mwalusanya et al. (2001)
Tanzania	2003	Health	Survey on helminths	Magwisha et al. (2003)
Tanzania	2003	Marketing	Survey	Mlozi et al. (2003)
Zambia	2001	Phenotypic characterisation	Survey & monitoring	Mushota (2001)
Zimbabwe	2002	General production	Surveys, observation and trials	Pedersen (2002a)
Zimbabwe	2003	Health	NCD and Helminths	Horning et al. (2003)
Zimbabwe	2001	Health	Survey on poultry losses	Kusina et al. (2001)
Zimbabwe	2004	Characterisation	Production system	Maphosa et al. (2004)
Zimbabwe	2004	Characterisation	Production system	Muchadeyi et al. (2004)

limited, while breeding and breeding system studies are missing. Reviews by Aini (1990) and Ramlah (1996) show that similar types of studies were initiated and conducted in Asian countries.

2.6 Improvement strategies for rural poultry

Tables 2.5a and b show values of traits commonly studied on local chickens. Results allow similar development oriented conclusions, that village chickens comprise mostly of local or indigenous breeds and are raised on low-input scavenging system (Gueye, 1998); that due to their sizes, low inputs and care, rural chickens are the best starting point to mitigate rural poverty even for the poorest and marginalized in societies (Dessie and Ogle, 1996; Dolberg, 2001). Flock sizes are small and averages range from 5 – 20 birds of different age-classes. Supplement feeding to scavenging is variable and depends on availability of supplement, usually energy rich by-products from human food. Housing is also variable, ranging from roosting in trees, in traditionally made houses to human dwelling units and kitchens. Women and children dominate in management of chickens (Dessie and Ogle, 2001; Missohou et al., 2002; Muchadeyi et al., 2004). Growth rates and egg production have been described to be low while losses in numbers were reported to be quite high in rural chickens especially in chicks (over 60 % of chicks hatched) due to disease, parasites, predation and neglected management care (Aini, 1990; Gueye, 1998; Mopate and Lony, 1999; Pedersen, 2002b; Tadelle et al., 2003b). Adult losses were mainly occurring from disease outbreaks (Minga et al. 2000; Hüttner et al., 2001). Newcastle disease was pointed the primary mortality cause in rural poultry flocks especially where intervention projects do not exist (Mopate and Lony, 1999). While Newcastle is still an important disease (Ahlers, 1999; Brackaert and Gueye, 1999; Mwalusanya et al., 2001; Kusina et al., 2001), importance of other diseases, helminths and external parasites is becoming increasingly recognized (Kyvsgaard et al., 1999; Pedersen, 2002b; Maphosa et al., 2004). Aini (1990) reported that these local chickens are considered secondary to other agricultural activities; rely on minimal inputs, do not have a breeding program with close inbreeding occurring among them. Panda and Mohapatra (1993) reported that problems in rural poultry are complex. Gueye (1998) reported that village poultry production stems from ancient traditional practices and has been kept by village communities for many generations. Their values to households and societies include food, income, offers to ceremonies, and medicines. Aini (1990) and Gueye (1998) reported that local chicken meat and eggs are preferred by societies to broiler meat and layer eggs and that they fetch premiums when sold.

Most reports did not result to develop strategies to utilise the potential of rural poultry. The existing diversity in phenotype and the constrained expression of growth and reproduction potential made researchers and reviewers to strongly point out the potential to improve production and productivity for rural poultry. Sonaiya (1990) suggested an improvement programme by looking at breeding, feeding, health and marketing strategies. Kitalyi (1998) suggested a step-wise improvement approach to cater for the high variation in production

Table 2.5a. Review of production and reproduction parameters in rural chickens from different studies in Africa

Reference	Country	Management	Chick weight, g	Weight at 8 week, g	Weight at 20 week, g	Adult weight, g	Age at first egg, week
Adetayo and Babafunso (2001)	Nigeria	Intensive, trial	24.3-26.5	-	858-1025	-	22
Demeke (2003)	Ethiopia	Intensive, trial	36	240	1300	-	-
Demeke (2003)	Ethiopia	Scavenging, trial	36	197	985	-	-
Dessie & Ogle (2001)	Ethiopia	Scavenging, survey	28	185	-	1035	28
Msoffe et al. (2004)	Tanzania	Intensive, trial	26-30	118-358	741-1089	-	-
Ndegwa et al. (2001)	Kenya	Intensive, trial	-	187-200	1677-1724	-	-
Tadelle (2003)	Ethiopia	Scavenging, survey	-	-	-	-	27
Tadelle et al. (2003b)	Ethiopia	Intensive, trial	30.8	150	643-877	-	-
Pedersen (2002a)	Zimbabwe	Semi-scavenging, trial	33	256	993	1756-2714	27

Table 2.5b. Review of production and reproduction in rural chickens from different studies in Africa

Reference	Country	Management	Flock size	Female: male ratio	Egg weight, g	Hatch rate, %	Chick survival, %
Adetayo and Babafunso (2001)	Nigeria	Intensive, trial	-	-	38	-	-
Mopate & Lony (1999)	Chad	Scavenging, survey	16.3	6	-	79	55
Dessie & Ogle (2001)	Ethiopia	Scavenging, survey	-	4	-	81	39
Mwalusanya et al. (2001)	Tanzania	Scavenging, monitoring	16.2	-	44	84	60
Missohou et al. (2002)	Senegal	Scavenging, survey	23	-	38	77	57
Kondombo et al. (2003)	Burkina Faso	Scavenging, survey	34	-	-	64	68
Msoffe et al. (2004)	Tanzania	Intensive, trial	-	-	43	62	-
Maphosa et al. (2004)	Zimbabwe	Scavenging, monitoring	23-35	4-6	44-49	68-73	38-66
Tadelle (2003)	Ethiopia	Scavenging, survey	-	3		69	51
Pedersen (2002a)	Zimbabwe	Semi-scavenging, trial	-	6	44	72	45

system and among farmers. This approach was recommended for adoption in Tanzania as reported by Minga et al. (2000) and is outlined in Table 2.6.

Table 2.6. A step-wise approach to improving rural chicken production in Africa

Step	Strategy
1	Improve hygiene, housing, preferential treatment of chicks, control of devastating diseases to end up with a healthy flock
2	Improve management of free-range chickens through supplementary feeding, better housing and disease control programs. The free-range chicken be transformed into backyard chickens
3	Improve free-range productivity through selective breeding for high yielding traits and for disease resistance. Improved management will simultaneously accompany this.
4	Commercial village chicken production systems with multiplication and distribution of high yielding types.

Source: Kitalyi, (1998)

The approach sounds appropriate, considering the social-cultural background of the rural people who are the custodian of rural chickens, and the insufficient nature and extent of studies conducted so far. Owing to this approach, a farming systems approach is the best strategy to address rural poultry improvement. Dessie and Ogle (1996) suggested the need to improve management first in rural chickens, thus supporting the approach published by Kitalyi (1998). The Bangladeshi poultry model registers success probably through utilising an almost similar approach (Dolberg, 2001) that started in a rather trial and error manner. On the other hand, there has been many smallholder animal improvement projects that have ended up inconclusive or without any impact (Nielsen, 1996; Dolberg, 2001). One of the reasons could be due to the fact that many projects aim to achieve fast and sometimes, commercial output by skipping some important production processes and stages (Sölkner et al., 1998). Failure to recognise and follow the farming systems leads to lacking step-wise system that also takes into consideration of biological, ecological and socio-economic issues (Preston, 1995).

2.7 Ecotype and phenotype characterisation in rural chickens

Ecotype is a terminology used to refer to chickens from one (agro) ecological zone or area, as distinguished from those in another zone. In some cases, regional names have been used to describe populations distinguished by ecotypes. Where chicken populations from different zones were studied, this ecotype was regarded as a source of variation.

In most studies, local chicken populations have been characterised based on ecotypes, thus associating different types with ecological areas or zones (Minga et al., 2000; Adetayo and Babafunso, 2001; Marle-Köster and Casey, 2001; Tadelle et al., 2003b). Depending on the country or region, significant and non-significant differences in performance and reproductive traits have been reported. South African ecotypes have been described as different lines based on these significant differences on growth (Marle-Köster and Casey, 2001) while in Nigeria, Adetayo and Babafunso (2001) concluded that lack of significant difference meant the chickens were one genetic group. Tadelle (2003) evaluated genetic distances between and within ecotypes and found genetic variation in both, but was higher within ecotype than between ecotypes. Recent results from Tanzania (Msoffe et al., 2004) showed significant differences on growth, reproduction and survival parameters between some of the seven ecotypes studied and similarity among others. The conclusions from results may be true for South Africa while in other countries, sampling effects, treatment structures (mixed ages) and numbers might have contributed to differing results. In most rural areas (mostly in remote places) different phenotypes (described by morphology with local names) exist within an ecological zone as identified in Malawi (Gondwe et al., 1999a) and Zambia (Mushota, 2001). Msoffe et al. (2004) noted presence of different phenotypes within an ecotype and their possible effects to their observed variation. The authors suggested to include the observed physical parameters in the description of ecotype by geographical region. The variation due to different phenotypes within ecotypes could probably confound the results based on ecotype unless adjusted for. All current study results did not adjust for phenotype effects within an ecotype. On the other hand, genetic grouping by ecotype was commonly followed due to simple designing and sampling processes. Properly designed genetic analysis using microsatellites could be the solution to solve the confounding conflict as worked out in Nigeria (Wimmers et al., 1999) where new genetic groups for rural chickens were created based on genetic similarity rather than earlier grouping based on ecotype. On the other hand, results of genetic grouping showed some degree of correlation with naming pattern by farmers. High correlation coefficients between farmers' morphological description and scientific cluster trial analyses have been observed in crop diversity (Sadiki et al., 2001). Within ecotype (between phenotype) diversity has been identified using farmers' knowledge in crop (Jarvis et al., 2000).

2.8 Are local chickens breeds?

Horst (1989) described local chickens as indigenous, “non-descript” unimproved dual-purpose birds. Sonaiya (1990) reported that free-range chickens are exclusively local breed resulting from several crossings with exotic breeds during cockerel exchange programmes. Gueye (1998) stated that in Africa, local chickens descended from disorderly crossings of local and exotic strains, without a systematic breeding system. Sonaiya (1990) and Gueye (1998) however, reported separately presence of distinct local breeds in other countries (Table 2.7).

Despite the description of these breeds, the authors still doubt as to whether these represent true genetically distinct breeds. According to Gueye (1998) only chickens from Egypt may represent true breeds. Based on the pictures reported by Marle-Köster and Casey (2001), the four South African chickens may represent breeds.

Table 2.7. Distinct local breeds described from different African countries

Country	Breed	Basis of description
Egypt	Fayoumi, Dandarawi, Dokky	Growth & reproduction traits
Sudan	Baladi, Betwil	Growth traits and physical appearance
Morocco	Beldi or Roumi	Growth traits*
Cameroon	Dzaye, Tsabatha, Dongwe, Zarwa	Feather colour
Mali	Kokochie	-
Burkina Faso	African, Konde	Origin
South Africa**	Koekoek, Naked neck, Lebowa-venda, Ovambo	Production traits

Source : Horst (1989), Sonaiya (1990), Gueye (1998), *Benabdeljelil and Arfaoui (2001), **Marle-Köster and Casey (2001)

Horst (1989) also described local chickens according to major genes of dwarf (*dw*), naked neck (*Na*), frizzle (*F*), silky (*h*) and slow feathering (*K*). Dwarf gene is recessive and sex linked, reduces body size between 30 and 10 %, and reduces metabolism, thereby improving fitness and disease tolerance. Naked neck shows incomplete dominance, leads to loss of neck feathers and reduction in secondary feathers. The gene improves ability of feed conversion, improves adult fitness but leads to reduced embryonic survival. Frizzle gene shows incomplete dominance, causes curling and reduction of feathers, and improved ability for feed conversion. Slow feathering gene is dominant, sex linked and causes delay of feathering.

The current ecotype, phenotype and genetic studies show the variation in both qualitative and quantitative traits of local chickens. However, almost all studies fail to conclude whether these chickens can be grouped into breeds. This is true considering the fact that there are no organizational structures or breeding societies for local chickens. The management and non-systematic breeding system, and the indiscriminate crossing described by Aini (1990) and Gueye (1998) between exotic and local chickens, and between different local chickens make it impossible to distinguish these into breeds. As described by Pedersen (2002b), the term *'local'* is a better description of free-range chickens.

2.9 Methods of phenotypic and genetic evaluation in poultry

2.9.1 Growth curve analysis

Apart from analysis of conventional measured parameters such as weights and weight gains, growth curves have been used in most livestock to describe growth processes through use of mathematical models. These models provide summary of information from a sequence of points and assist to get a more objective comparison of growth efficiency for species, breeds, lines or hybrids (Knizetova et al., 1991; Mignon – Grasteau et al., 1999). Chambers (1990) reported that growth curve functions are better estimators for growth than physical weights or weight gains. Estimated parameters include hatch weights, age and weight at point of inflections, asymptotic weights and specific growth rates. In poultry, these parameters have been used to compare and predict growth patterns in populations and in selection programs where direct measured traits show strong antagonism or where traits are lowly heritable while growth parameters express high heritability (Barbato, 1992; Kerr et al., 2001). The functions have also been used to determine breed and sex differences, nutritional effects and partitioning and analysing growth of different tissues.

In poultry, Gompertz (Mignon – Grasteau et al., 1999) and Richard’s (Knizetova et al., 1991; Hyankova et al., 2001) functions have been applied in chickens; the re-paramaterised Janoschek growth curve was applied for analysis of growth in ducks in Germany (Gille and Salomon, 1998). Gompertz model uses three parameters while Richard’s uses four, a reduction of one parameter from the original five-parameter logistic functions. Gompertz function has been recommended to provide better fit for data in poultry studies (Knizetova et al., 1991). Major problems in using growth curves involve obtaining data over sufficient range of time to fit all parameters in the model (Mead and Curnow, 1987).

Growth curve functions have to date only been applied to poultry that have been improved through selection or crossbreeding. Except for the general growth function fit to data for local chickens in Ethiopia (Tadelle, 2003), there are no records of using growth curve analysis for rural poultry. Growth curves can provide more useful information in detecting efficiency of the systems of production in local chickens and distinguish differences due to genetic groups and environmental effects (Sabbioni et al., 1999).

2.9.2 Estimating genetic parameters

Characterisation of animal populations would be complete if both phenotypic and genetic parameters are determined and this is a prerequisite before starting any breeding programme (Wollny, 1995; Prado-Gonzalez et al., 2003). Genetic parameters such as heritabilities (h^2), correlation among traits and repeatabilities should be computed from the (co)variance components. These parameters are population specific, influenced by the population structure, environment and management practices animals are exposed to, hence use of values derived from elsewhere would not be valid (Chambers, 1990).

Parent-offspring regression and sib analyses have been used to estimate genetic parameters (Chambers, 1990). These methods were replaced by sire-dam models (Wei and van der Warf, 1993). Most recent studies in poultry adopted animal model in estimating genetic parameters and breeding values (Mielenz et al., 1994; Hu et al., 1999; Mignon – Grasteau et al., 1999). REML procedure has been used to derive solutions from their mixed model equations (Wei and van der Werf, 1993). Animal models include more information including animal relationship in the analysis than other methods. Wei and van der Werf (1993) found that an additive model had a lower error variance and a higher additive variance than the sire-dam model when applied to estimate egg production traits for White Leghorn. The sire-dam model ignored the animal relationships other than parent-progeny, hence underestimated h^2 values. Prado-Gonzalez et al. (2003) supported use of animal models in estimating genetic parameters in Creole chickens when maternal and permanent environmental effects are to be estimated. Animal models have robust flexibility with high factor adjustment capabilities and work even on population structures that have been subjected to selection (Bruns, 1992). In poultry, all results showed performance traits having medium-high h^2 estimates with some negative correlations between production and reproduction traits. Hu et al. (1999) reported low h^2 values for growth traits in ducks and attributed that to unfavorable effects of subtropical climates. Prado-Gonzalez et al. (2003) reported low-medium heritability values for body weights of Creole chickens raised under deep litter system. The authors concluded that genetic progress could be limited in expression by tropical environment and management systems.

Apart from the Creole chicken study (Prado-Gonzalez et al., 2003), currently there is no record of studies to evaluate genetic parameters for different traits for rural chickens. Lack of infrastructure is the most challenging constraint in livestock identification, recording and characterization for conservation goals in rural traditional livestock systems. There is no recording system in place. Bruns (1992) reported problems of estimating genetic parameters from data collected from animals under extensive systems. These included small flock sizes, one-sire flocks (and hence confounding effects between flock and sire), and unidentified parentage, mostly the sire. Parentage identification is critical in rural chicken flocks with free-ranging and random mating system. These problems limits use of conventional methods and leads to biased results (Bruns, 1995).

Maternal effects have received considerable attention in chickens, and in several cases conflicting results have been reported (Pinchasov, 1991; Hu et al., 1999; Sewalent and Johansson, 2000). In chickens, most of the prenatal maternal effects do not exist, with exception of factors that lead to different egg sizes, weight and quality (Prado-Gonzalez et al., 2003). Pinchasov (1991) found high positive correlation (r = .89) between egg size and initial chick weights. This correlation declined remarkably within three days of chick life and reported that after 18 days, all effects were due to feed and environment. Prado-Gonzalez et al. (2003) reported that in Creole chickens, maternal effects disappeared after four weeks of age. This also suggests few postnatal maternal effects, especially in commercial production systems where the hen does not nourish the offspring. Hu et al. (1999) reported that relative influence of maternal effects is generally lower than 10 % (3 – 8 % of total variance) depending on trait. While these studies showed variable results, there is an indication of less maternal influence on offspring that disappear within few days. The egg is the only vehicle for maternal effects in poultry (Selawent and Johansson, 2000).

2.10 Rate and level of improvement required in rural chickens

Documents are available that report the need to characterize rural chickens for improvement through selection, just like in other livestock (Wollny, 1995) but almost all lack information as to what level should this improvement be. Value judgment can however be based on considering the target group, primary functions and socio-economic status. Any improvement should match the main functions, needs and utilization patterns of the target group (Werner, 1993).

Majority smallholder farmers in Malawi are below poverty line (NSO, 2000) with lower animal protein intake (< 5 kg per capita per annum) in their diets. Use of livestock is more for subsistence than for market oriented production. With such a group, development technologies should also aim at sustaining equity among farmers. Although there are no analyses of equity so far such as use of Lorenz-curves and Gini Coefficients (Ibrahim, 1998), rural chickens are more widely owned and they rank first among all livestock species with more equity among smallholder and landless farmers (Dolberg, 2001; Gondwe and Wollny, 2002). Improvement technologies and levels that will bring major shifts in resources will also affect the equity factor and hence make the low resource endowed farmers even poorer. With this in mind, the low educational status and the fact that subsistence is number-based than productivity (bearing risk aversion in mind), strategic low levels of improvement in a step-wise approach seem plausible, unless the goal is to change to market oriented improvement. Care must be taken for antagonistic adaptive and fitness traits that are more important for the survival of birds at subsistence level (Wollny, 1995; Wollny, 2003). Loss of adaptive traits will increase resource burden on farmers and hence reducing their unit productivity and diversity (FAO, 1999). Most previous development policies overlooked the importance of adaptation when initiating livestock improvement programs in developing countries (Drucker et al., 2001). Dolberg (2001) observed that rural chickens are the only livestock owned by the poorest. As households accumulate more wealth they favour owning larger livestock species and ignore chickens. This demonstrates the role of chicken as asset starters, hence their improvement does not necessarily require a strong market orientation.

Most research goals aim to characterize for selection programs and hence are targeting at market-oriented improvement where productivity takes priority rather than numbers, which is the reverse of the subsistence sector (Werner, 1993; Wollny, 2003). On the other hand, broiler and layer industry utilises internationally developed strains (Safalaoh et al., 1998). There is no need to develop other strains for broiler and layers from local chickens. Unlike in other species such as beef cattle and small ruminants, it would not be justifiable to select for market production in rural chickens. This places rural chickens in a unique position whose status can only be determined with detailed studies and analyses.

2.11 Production efficiency and economic evaluation

Economic evaluation of a technology or production system allows assessing the suitability and efficiency of the system by looking at inputs and outputs. Any changes in technology results in changes in inputs. Innovations that are based only on enhancing the biological efficiency may not be adopted by farmers if additional expenses exceed the value of production (Kitalyi, 1999; Permin and Bisgaard, 1999).

Tadelle et al. (2003a) evaluated local chickens in Ethiopia and identified their impact on rural societies. Based on initial value of breeding females, they estimated a gross margin of 68 % for scavenging chickens. The authors could not include value of socio-cultural roles and functions of scavenging chickens. In Kenya, Upton (2000) reported a rate of return on breeding hens of 226 %, estimated from survey data on scavenging chickens. Rural chickens have food, asset, social and economic values. Unfortunately these functions do not have monetary values due to lack of records of consumption and quantities. There is also lack of testing and application of appropriate methodologies for the valuation of such functions. This makes economic evaluation difficult under rural situations utilizing conventional methods. Ayalew et al. (2003) stated that conventional productivity evaluation criteria are inadequate to evaluate subsistence livestock production due to failure to capture non-market benefits of livestock and the fact that multiple limiting inputs exist in the production process. Monetary value as an aggregate measure of inputs and outputs in the production systems is the most convenient unit. Ayalew et al. (2003) recommended utilizing broad evaluation models at flock level of production. Farm animal genetic valuation methodologies (Drucker et al., 2001) are under development and their application in poultry is still limited.

2.12 Role of gender in livestock and rural poultry husbandry

In most low-income countries women play major role in attaining household food security (Quisumbing et al., 2004). Women produce over 70 % of domestic food in Sub-Saharan Africa. Women are producers of food, managers of natural resources, managing children and provide proper balance for nutritional needs for households (Brown et al., 2001). On the other hand, the role of men is to bring income to households for non-food goods and services. This gendered division of labor is linked to cultural and social norms and takes place even on farming and livestock production activities and systems. Tied to cultural and social power, men as husbands claim ownership of major household assets and concentrate on commercially oriented agriculture and livestock production. Included in major household assets, and hence their ownership by husbands are land and large sized animals such as cattle. Right and status of small species such as chickens are in the hands of women who have the authority to slaughter or sale. Similar pattern of gendered differentiation in ownership was identified in Malawi, especially on smallholder chicken production (Haule and Jere, 1999). Since women manage households and are food security conscious, income from sales of small livestock species is directly utilized towards achieving food needs of the households, unlike that income from sales of large animals. This shows that small stocks such as chickens have more domestic basic and food security functions than large stocks. Targeting and empowering women in households, means achieving food security goals, and improving small livestock will directly contribute to this with less risks and interference from men (Miller, 2001). Men who usually attend meetings usually do not share the technologies gained to their women. Time constraint is more acute for female-headed households. Appropriate technologies (with labor saving elements) and trainings, together with increased participation provide solution to this (Haule and Jere, 1999).

HIV/AIDS plague is highly prevalent in Africa and negatively affects agricultural productivity by decreasing labour productivity, eroding household assets and hinders transfer of knowledge from one generation to another (Resnick, 2004). Southern Africa has highest prevalence of HIV/AIDS in the world. Gillespie et al. (2004) reported that about 30 million people are infected with HIV/AIDS in Sub-Saharan Africa. Accurate statistics are not available for Malawi and neighbouring countries but the problem is pandemic and contributes to household food insecurity (Kleyn, 2004). A USAID (nd) brief reported that 14 % of Malawi human population (850,000 adults and children) was HIV positive in 2001. As noted by Quisumbing et al. (2004), women are the most frequent victims of HIV/AIDS due to their roles in traditional societies. Since women lead in subsistence agricultural activities, the impact of HIV/AIDS has direct consequences on production of both crops and livestock, especially poultry production.

3. Overview of study area, farmer demography and study concepts

3.1 Overview of Malawi

Malawi is a tropical landlocked country located in Southern Africa lying along coordinates 8^o 20^o S; 32^o 36^o E. Malawi is bordered by Mozambique, Tanzania and Zambia. Total area is approximately 118,000 sq km, of which, one third is water. Arable land constitutes about 34 %; other land being permanent pastures, forests and woodlands, estates and public land. Malawi's economy is predominantly agricultural with about 86 % of the population living in rural areas practicing mostly subsistence farming. Agriculture accounts for 33 – 37 % of the GDP and 85 % of the export earnings (Malawi Government, 1999b; World Bank, 2004). Tobacco is the main cash crop, accounting for 70 % of agricultural export earnings; seconded by tea (7.5 %), sugar cane (7.4 %) and coffee (4.1 %). Maize (grown on > 90 % of cultivated area) is the main staple food but also acts as an income earner for the majority in rural areas. The calculated contribution of livestock to the National GDP is very minimal (7.0 % to agricultural GDP and 2.0 % to national GDP) (Malawi Government, 1999b).

Latest statistical release reported a total human population of 9.9 mio (NSO, 2000), projected to be 11.9 mio in 2004 (NSO, 2003). This represents an annual growth rate of 2.0 % since 1987. About 11 % of the population lives in urban areas (cities and municipality), 3.0 % in districts (per-urban areas) and the large rest in rural areas. Urbanization was estimated to increase at 4.7 % per annum. Literacy rate had increased from 42 % in 1987 to 58 %, the rate being higher in males (64 %) than females (51 %). About 10 % of those aged under 20 years were orphans (either losing one parent or both). Infant and under five of age mortality rates were 118 to 120 per 1000 births. The mean household size had reduced from 7.5 to 4.3 by 1998, with 76 % of the households being male headed in both rural and urban areas (NSO, 2000). Based on human development index (HDI), Malawi is at position 165 in the world, the thirteenth poorest country. Per capita GDP based on purchasing power parity (PPP) is 580 US$, with a life expectancy of 37.8 years (UNDP, 2004).

3.2 The study area

Data for the current study were collected from studies on-farm in villages of Mkwinda and Mitundu Extension Planning Areas (EPA) and on-station at Bunda College of Agriculture (BCA), University of Malawi. Mkwinda and Mitundu EPAs surround BCA and belong to Lilongwe Agricultural Development Division (LADD) in Lilongwe district. The area is located within the coordinates 14.10^o S, 33.47^o E, with an altitude of 1200 m above sea level (Garmin GPSMAP 76CS, Garmin Ltd, www.garmin.com). This area is in the medium to high rainfall, plain agro-ecological zone. Most arable farming takes place in this zone. Tobacco is the main cash crop, while maize is the staple food crop. Several other crops are grown. Over the past four years, annual precipitation for Lilongwe averaged 932 mm (NSO, 2003). Two seasons are distinct by precipitation; a wet-warm season (November to April) and a dry season (May to October). In this study, three seasons were defined: cold-dry (May to August), hot-dry (September to November) and hot-wet (December to April) to consider also temperature changes during the dry season. Average temperatures and relative humidity for Lilongwe as recorded at Lilongwe International Airport, which is approximately 60 km from the research site, are shown in Figure 3.1.

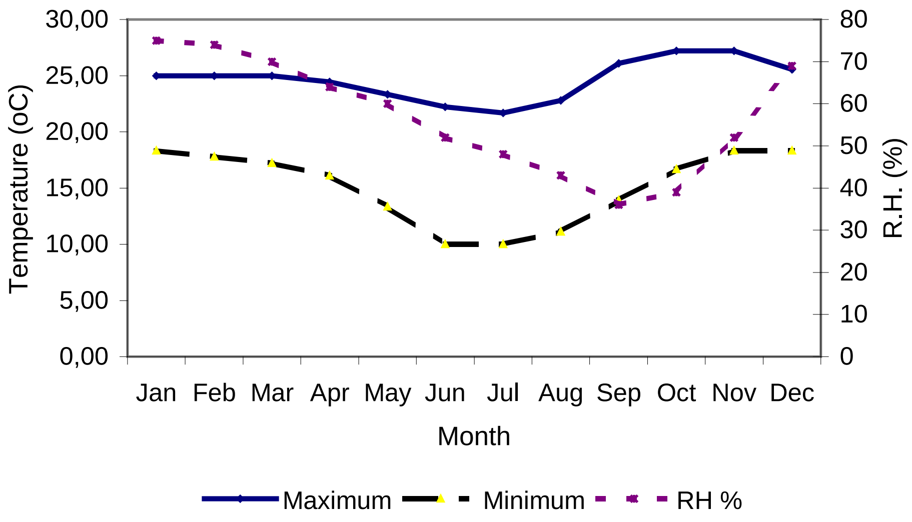


Figure 3.1. Average temperatures and relative humidity (R.H.) for Lilongwe

Source: Sperling's BestPlaces (nd)

3.3 Farmers and their demography

The majority of farmers are smallholder resource poor, about 82 % of households keep chickens, pigeons and ducks. Table 3.1 shows demographic characteristics of farmers in the two EPAs. Most people belong to *Chewa* tribe and are Christians of various denominations. However, there is presence of traditional religion, locally called *Gule* or *Nyau* or *Mpingo wa Aron* that commands a significant proportion of the community. This religion carries most of its ceremonies and initiations during the dry season and during funerals.

Majority of the farmers were illiterate or had just gone to lower primary education (up to Standard 5) and their main occupation is subsistence farming, supplemented by casual labour (*ganyu*) and small-scale businesses. Eighty-four percent were married. Male members of households usually venture into business of collecting firewood from nearby Dzalanyama Forest and selling in Lilongwe City, which is about 30 km away. Most houses (75 %) were grass thatched. Most households were food insecure with seasonal shortages, e.g. 75 % of households had no food by January during this study and became largely dependent on relief food supplies.

Average household size was 5.4 (SD, 2.4, median, 5.0) ranging from 1 to 20. Farm size was 2.4 (SD, 2.0, range from 0.4 to 35) acres (0.97 ha) per household or 0.5 (median, 0.4) acres (0.2 ha) per capita.

Table 3.1. Demographic characteristics of farmers in the study area

Parameter	n		Percent (%) of observation	χ^2>P value
Tribe	2258	Chewa	97.30	0.0001
		Lomwe	0.31	
		Ngoni	1.15	
		Tumbuka	0.27	
		Yao	0.84	
		Others	0.13	
Religion	1545	Christian	77.29	0.0001
		Moslem	0.46	
		Traditional	22.25	
Education of farmer	1561	None	37.79	0.0001
		Std 1 - 5	36.71	
		Std 6 - 8	25.27	
		Secondary above	0.23	
Main occupation	1571	Farmer	93.12	0.0001
		Business	2.31	
		Formal employment	4.57	
Type of housing*	133	Grass thatched roof	75.19	0.0001
		Iron sheet roof	21.05	
		Tiles roof	3.76	
Food status by January*	133	Finished	75.19	0.0001
		Available	24.81	

Source: this study; n = number of households; * Based on farmers on on-farm chicken monitoring study only

3.4 Livestock status and distribution

Table 3.2 shows statistics of livestock species, chicken phenotypes kept per household, and members of the household responsible for the management of chickens. Majority farmers kept between one and two species. Few farmers had more than two species (range of 1 – 5). Each flock of local chickens had different phenotypes, ranging from one to more than four.

Dominant livestock species and their distribution among households are shown in Figure 3.2. This is a Lorenz curve, which was constructed following the guidelines described by Ibrahim (1998). It shows level of equity of distribution of an asset among households in a society. Within the rural society of farmers in the area, livestock are also important assets and therefore their parity of distribution provides criterion to assess the importance a particular species plays in food security and poverty reduction.

Table 3.2. Number of livestock species, flock diversity of chickens by phenotype kept by farmers and main responsible person on chickens in the household

Parameter	n		Percent (%) of observation	χ^2>P value
Number of livestock species kept per household	2253	One	51.66	0.0001
		Two	42.12	
		Three	5.06	
		Four	1.02	
		Five	0.13	
Number of chicken phenotypes as locally recognized per household	2242	One	40.01	0.0001
		Two	32.07	
		Three	18.69	
		Four and above	9.23	
Responsibility for keeping chickens	2108	Children	1.52	0.0001
		Family	2.23	
		Wife	77.47	
		Husband	11.81	
		Husband and wife	5.88	
		Grandmother	0.24	
		Other combinations	0.85	

Source: This study; n = number of households

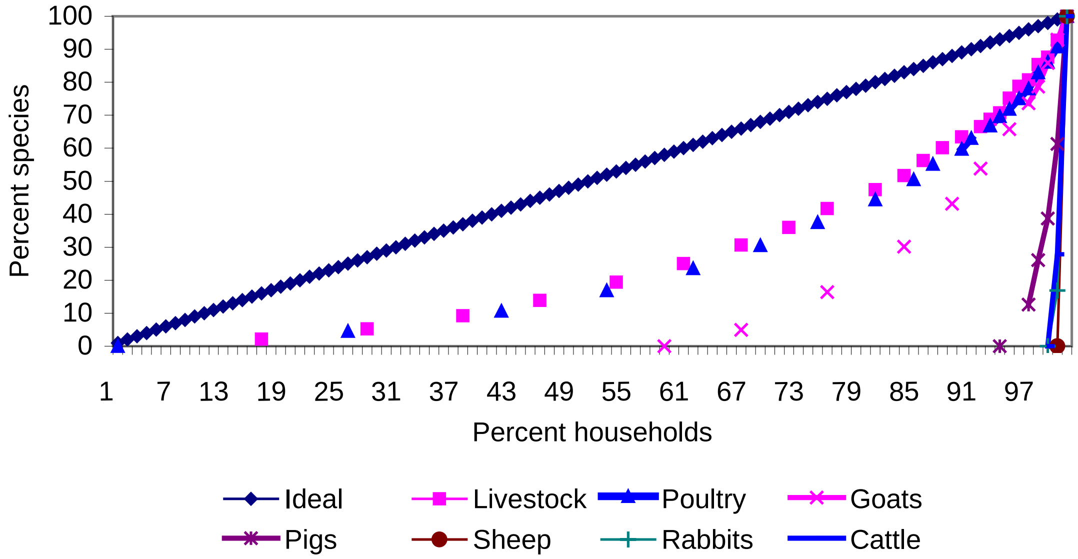


Figure 3.2. Lorenz curves for different livestock species kept by households in Mitundu and Mkwinda EPAs[1] (own data)

[1] Notes: Ideal curve is a line of perfect distribution of asset, i.e. 50 % of households own 50 % of the asset. The livestock curve is a line of actual distribution e.g. about 66 % of households own 30 % of livestock. The further the curve moves away from the ideal line, the more disparity the distribution of the species.

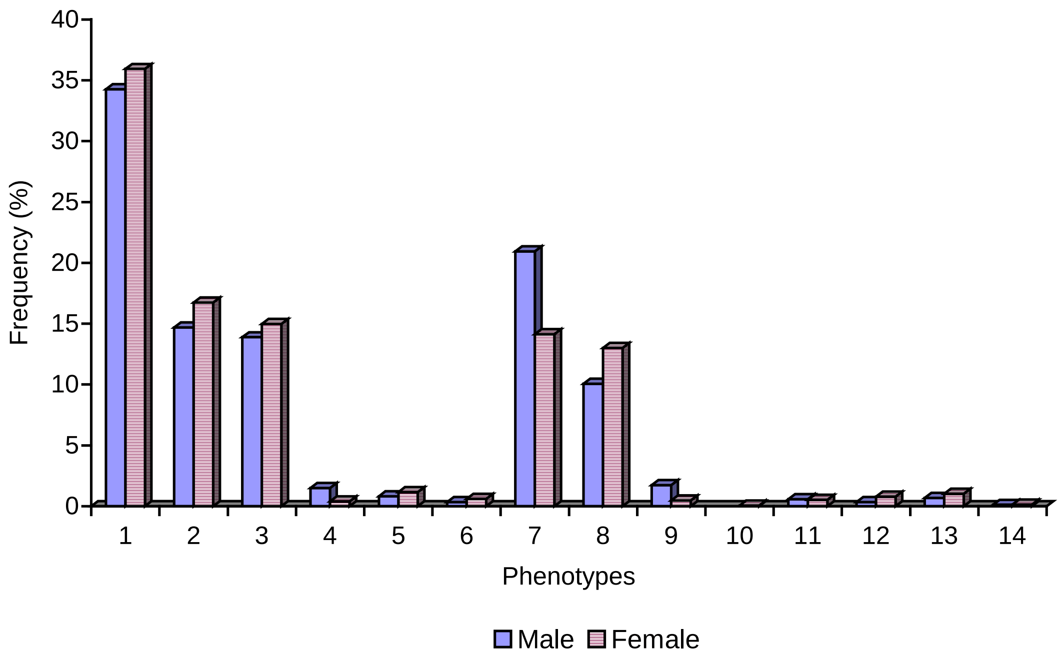
Majority farmers keep livestock in the area. The common types of livestock kept were chickens and goats. Lorenz curve for livestock follows closely that of poultry (r^2 = 0.83), seconded by goats (r^2 = 0.21). The influence of other species is small.

3.5 Responsible members of household for keeping chickens

All members of the family raised poultry. Women, however, dominated the responsibility for keeping and managing chickens (Table 3.2).

3.6 Chicken phenotypes

Based on mendelian phenotypic traits of size, colour, feathering and plumage as described in Gondwe et al. (1999a), 14 different types of chickens were observed (Figure 3.3).



1. Yakuda (black); 2. Yoyera (white); 3. Yofira (red and brown); 4. Mawanga (multicolour); 5. Kameta (naked neck); 6. Simboti (dwarf); 7. Kawangi (spotted); 8. Chiphulusa (greyish); 9. Black Australorp; 10. Exotic; 11. Kachibudu (rumpless); 12. Kansilanga (freezled); 13. Tsumba (feather hill head); 14. Kamabuluku (feathery shanks)

Figure 3.3. Phenotypes of chickens in household flocks of the study

Six phenotypes were described by colour of feathers (1,2,3,4,7 and 8); 4 by plumage (11, 12, 13 and 14); while 5 (naked neck) and 6 (dwarf) are due to morphology. 9 is an exotic dual-purpose breed (Black Australorp) that Government distributes to farmers intending to improve local chicken productivity through crossbreeding. 10 constitutes culled hybrids strains (either hylines or broiler strains) that farmers buy and keep on their free-ranging flocks.

Yakuda (1), *Kawangi* (7), *Yoyera* (2), *Yofira* (3) and *Chiphulusa* (8) were the dominating phenotypes in the area. Numbers of male and females were similar.

Black Australorp had more males than females. Diversity of phenotypes existed in rural chickens though in unequal proportions. In flocks, these mixed and bred at random.

3.7 Nature and scope of the study

On-farm, an average of 134 households from the villages in the study area joined the study. Choice of farmers was based on willingness to participate in the village poultry project and ability to cooperate during chicken weighing, flock observation and data recording. Under FAO Village Poultry project (Gondwe et al., 2003), these farmers formed community village poultry groups (Figure 3.4). Through these groups, farmers shared cost of NCD vaccine and communally vaccinated their chickens against NCD at three monthly interval, between May and December; farmer meetings were organized on-site where trainings, group discussion and feedback seminars on what has been observed from their chicken flocks were conducted. Newsletters on village poultry that included farmer pictures were written and disseminated to farmers. Though farmers recorded dates for next vaccination, reminders were done through the newsletters.

Figure 3.4. Khombe poultry women group

Though dealing with a community, the study focused on monitoring individual household flocks. FAO Village Poultry project established village multiplication centers (Figure 3.5) that were supposed to be the other points of study. By 2003, there were five centers with traditional poultry structures established and managed by the community. High rate of early chick mortality made it impossible to monitor chickens from these centers and were therefore, excluded from the study.

Figure 3.5. Nsabwe multiplication centre

NCD vaccination was a major incentive to work with farmers. Figure 3.6 describes the vaccination programme that was adopted in the villages. La Sota oral vaccine (1000 cloned doses, Lohmann Animal Health GmbH) was used throughout the study. This was purchased and stored at Bunda College of Agriculture to keep the cold chain. Upon arranging with farmers, field technicians took the vaccine to farmers at 05:00 hours in the morning. Together with farmers, vaccine was diluted and its administration demonstrated; this was followed by vaccine distribution. Farmers and their household members administered the vaccine to individual chickens before releasing them to scavenging. Because of effectiveness of the vaccine, more farmers were encouraged to join the village groups.

Through the project, different drugs for common diseases observed and reported by farmers were purchased. These were provided to farmer flocks that experience animal health problems free of charge. However, diseases recurred into the flocks often because of insufficient frequency of application of drugs.

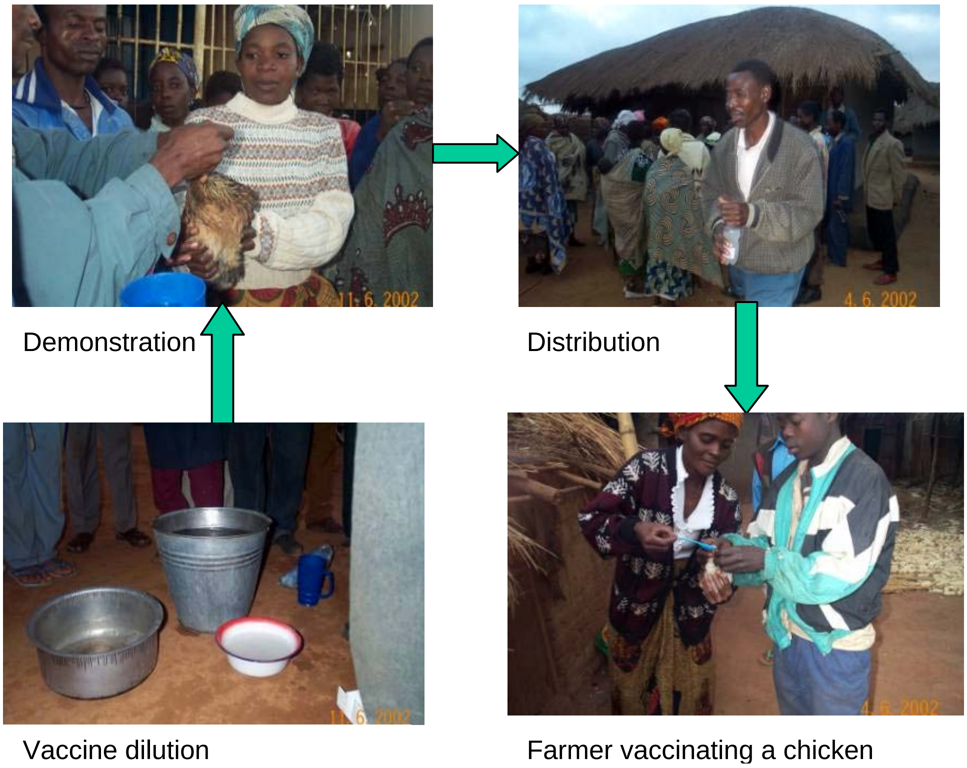


Figure 3.6. A vaccination program using La Sota oral vaccine in the villages

Based on remoteness, villages were clustered into three areas. These were named Village 1 covered Khombe – Malimbwe area, no access by road to the west; Village 2 covering Mwenda – Chilowa area, no access by road to the east; Village 3 covering Nsabwe area that was near the road and trading centers.

On-station trials were conducted at BCA that is surrounded by the monitored villages. Structures similar to those on-village multiplication centers (Figure 3.5) were built. These were constructed at three sites of the BCA farm, namely, Sakhula, Students' Farm and Small Animal Unit (SAU). Local chicken parent stock was purchased from different villages within and outside Lilongwe. Management of chickens was free-ranging as in the villages.

However, during laying and egg brooding, hens and cocks were randomly allocated into pens on a deep litter house demarcated into 30 pens of 1.5 x 2.0 m. Each pen housed three hens and one cock. One cock was rotating between two pens every day. On average the house contained 15 cocks for breeding. Other cocks were introduced replacing those that had served about five hens. Locally constructed nests were placed in these pens. On-station technicians closely monitored laying behaviour of hens so that each hen lays in one pen. After laying, a hen brood eggs. The hen was released to scavenging with chicks once hatched. During lay and brooding, on-farm formulated breeders mash (17 % CP, 2800 kcal/kg ME) was provided to hens and cocks. The purpose of this mating design was to determine pedigree for the chicks hatched. Figure 3.7 shows the deep litter house with mating pens. At Small

Figure 3.7. A mating khola

Animal Unit and Sakhula, hens that were left on free-range were assigned a cock and were breeding while there.

Nesting places were prepared and placed inside the traditional kholas (Figure 3.8). Other hens came from participating farmers in the villages and were allocated to pens. After hatching, the hen and its chicks were taken back to their owners. Management of vaccination and disease treatment was similar to that practiced in the villages. Maize bran was supplemented to birds on free-range more regularly than is the case in the villages.

Figure 3.8. Inside section of the traditional khola at Small Animal Unit, with nesting places, one with a hen sitting on eggs.

On-station experimental trials on feeding and growth potential were conducted at Small Animal Unit. Fifty individual cages (34x33x33 cm) were constructed locally and placed inside the unit (Figure 3.9). Water and feed troughs made from clay were fitted to each cage. Feed troughs were curved on top to prevent spillage. Underneath the cage was a metal container that was used to collect droppings. Growing chicks of an average of 9 weeks were collected from farmers and introduced into cages till there were 20 weeks. Growers' mash (18 % CP, 3200 kcal/kg ME) was provided to birds during cages.

A marketing study was conducted at the commodity markets of Lilongwe that surround the catchments for the study area. These included Mitundu rural market and two urban markets, Lilongwe and Kawale. Live local chickens sold in these markets were observed and marketing parameters such as selling prices, sellers and source of chickens were recorded.

Figure 3.9. Metabolic cages at Small Animal Unit

Details of methodologies for specific studies are outlined in each chapter. Chapter 13 provides a general discussion on local chicken production and its production system, as well as possible strategies to improve their production and contribution to food security among rural poor households. Chapter 14 summarizes the entire results. All references are presented in Chapter 15.

4. Local chicken production system in Malawi: Household flock structure, dynamics, management and health[1]

4.1 Abstract

A monitoring study on household flocks of scavenging chickens was carried out from August 2002 to August 2003 in 27 villages near Lilongwe, Malawi. The objective was to evaluate the local chicken production system by investigating flock structure, utilization, management and constraints. Farmers and researchers through measurement and recording on household flocks jointly obtained data. Mean flock size was 12.9, with a range of 1 to 61 birds. Flock dynamics of over 8 weeks old chickens constituted of 91 % migrating out of flocks and 9 % into the flocks. Primary functions based on flock dynamics included household consumption, participation in socio-cultural ceremonies, selling, exchanging breeding stock and gifts in that order of importance. Of the migrants out of flocks, 43.9 % were due to losses from diseases, predation and theft. Most flocks (85 %) were housed in human dwelling units. Scavenging was the main source of feeds. Majority (77.6 %) farmers supplemented erratically their chickens with energy rich feeds, mostly maize bran. Most supplementation took place during the cold-dry season. Village chicken production offers diverse functional outputs but faces animal health (diseases, parasites, predation) and management (feeding) constraints, which require an integrated intervention approach at community and household level.

Keywords: local chickens, flock dynamics, on-farm monitoring, scavenging

4.2 Introduction

Local chicken production is common in rural smallholder households. These chickens are produced extensively (free-range) on scavenging feed resource base (SFRB). This means local chickens, unlike intensively raised chickens, exist and produce in a broad spectrum of socio-economic and physical production environments. This environment includes feeding, breeding and health management that also interact with variant human culture, marketing and other utilities. A production system can be generally defined when all factors of the production environment and interaction between local chickens and human beings are described. Currently this production system for village chickens is generally described as to be low-input low-output (Safalaoh, 1997). Despite being low-output, products from these village poultry are diverse and are utilised by majority human beings in both rural and urban areas with little restriction and taboos (Tadelle et al., 2003a).

Noting their importance, studies to describe local chicken production systems in Malawi were initiated in late 1990s (Ahlers, 1997, 1999; Safalaoh, 1997), just like in other countries in Africa (Minga et al., 2000; Dessie and Ogle, 2001; Missohou et al., 2002). Such initiatives were important to contribute to better understanding of the production system for rural chickens (Kondombo et al., 2003). Understanding the production, management and breeding systems, and the associated factors for local chicken production is essential to develop holistic improvement strategies (Branckaert and Gueye, 1999). Knowledge of the production system will, therefore, form a basis for improving local chickens production (Mwalusanya et al., 2001;

[1] Paper to be submitted to Tropical Animal Health and Production

Dessie and Ogle, 2001). Studies are still limited in this area of rural poultry production system, which is true for many developing countries (Kondombo et al., 2003; Tadelle et al., 2003b). Often, such studies have usually been based on short surveys. The current study investigated the production system for local chickens in smallholder farmers in rural areas through flock monitoring. The objectives were: (i) to evaluate household flock structure and its characteristics; (ii) to monitor flock dynamics and determine primary output based on the dynamics; (iii) to evaluate flock management in terms of feeding, housing and health; and (iv) to identify constraints and potentials.

4.3 Materials and methods

4.3.1 The study area

The study was carried out in 27 villages of Mkwinda and Mitundu Extension Planning Areas (EPA) of Lilongwe Agricultural Development Division (LADD). Demography of farmers in the area, livestock distribution and community farmer participatory activities are outlined in Chapter 3.

4.3.2 Data collection

Data were derived from a monitoring study of chicken production among smallholder farmers in the study area. Monthly mean of 134 households (flocks), minimum of 91 farmers in October, 2002 and maximum of 176 flocks in June, 2003 participated in the study from August 2002 to August 2003. Over eight weeks old chickens were individually identified through wing or leg tags.

Data for household flock sizes and structure included monthly recording of number of mature breeding cocks and hens and non-breeding stock that included chicks and growers. Types of feed offered as supplement to chickens and periods of supplementing were recorded. Quantities of feed offered could not be measured because farmers provided feed erratically.

Flock dynamics included weekly monitoring of migration of over eight weeks old growing and adult chickens into and out of household flocks. For each individual migrant, reasons for such migration, live weight at migration and age (based on hatch dates and previous weighing for migrants out), sex and phenotype were recorded. Farmers retained wing and leg tags for birds that were either consumed or were found predated or dead. Migration of chicks less than eight weeks of age was not included due to difficulties encountered by farmers and researchers to follow such losses with accurate identification.

Monitoring of flock health included occurrence of diseases and parasites, deaths, predation and other losses of growing and adult chickens. Researchers visited households once a week and during the visits, farmers reported incidences. Farmers and research assistants were trained to identify and diagnose important diseases. This training was taking place regularly (at least once in every four months) as part of feedback seminars to farmers based on previous observations. The training was participatory and included discussion on local knowledge of farmers on various diseases and parasites. Local names of important disease known by farmers were documented. English equivalent names and appropriate veterinary drugs were included in the document. As an intervention, sick birds were treated using veterinary drugs bought from pharmacies and veterinary clinics. Identification and diagnosis of diseases and parasites was based on farmer's local knowledge, facilitated by training (Gueye, 1998).

After one year, 1714 month-flock observations were recorded (35.94 % in 2002 and 64.06 % in 2003). During the cold-dry season, 43 % of the observations, 37.86 % in hot-wet, and 19.14 % in hot-dry seasons were recorded.

4.3.3 Data manipulation and analyses

Qualitative data were subjected to frequency analysis using the Frequency procedure of SAS (SAS, 1999). Cross tabulations were generated to determine the association between factors. Chi-square test was used to determine the strength of the association. Where possible, other explanatory effects on possibility of events were determined using Logistic regression model through Proc Logistic procedure of SAS (SAS, 1999).

Where quantitative data was used, appropriate analyses were applied. These included Proc Means and correlation procedures of SAS (SAS, 1999).

4.4 Results

4.4.1 Household flock status and structure

On monthly average, flock size of 12.9 (median of 12.0) was observed during the study period in rural areas (Table 4.1). This flock size comprised of more chicks and growing chickens, followed by breeding hens and least were breeding cocks. For those flocks with cocks and hens, sex ratio constituted 4.70 (median of 4.00) hens per cock. For all parameters, distribution showed wide range (minimum-maximum values). This distribution was skewed for some parameters (especially sex ratio), hence median values were necessary to be included.

Table 4.1. Average household flock size and flock structure by age-group during the study period

Parameter	n	Mean	Median	SD	Range
Flock size	1427	12.90	12	8.37	1 - 61
Hens	1613	5.17	4	3.57	0 - 37
Cocks	1713	0.81	0	1.17	0 - 9
Chicks and growers	1451	7.11	6	6.23	0 - 52
Flock sex ratio (female:male)	784	4.70	4	3.06	1 - 30

n = number of month – flock observations; SD = standard deviation

4.4.2 Household flock dynamics and use pattern for chickens

During the study period, flock dynamics of growing and adult chickens constituted 9.45 % of migration into the flock and 90.55 % out of the flock (n = 815 chicken migrants). Primary causes of flock dynamics were summarised into seven categories (Table 4.2). Migration into flocks represented intake. Of this intake, majority chickens were brought into flocks for breeding. Few farmers bought chickens to raise them, while some chickens came into flocks presented as gifts.

Table 4.2. Factors that contributed to dynamics of growing and adult chickens in village flocks by type of migration (frequencies expressed in percent (%) of birds (n) observed migrating)

Factor	Migration[1]				
	Into flock n = 75		Out of flock n = 732		Overall n = 807
Household consumption	1.33	(0.12)	28.42	(25.77)	25.90
Sales or direct barter	9.33	(0.87)	9.43	(8.55)	9.42
Gifts	5.33	(0.50)	0.68	(0.62)	1.12
Acquiring breed stock	84.00	(7.81)	3.83	(3.47)	11.28
Ceremonies	-		13.80	(12.52)	12.52
Diseases	-		30.05	(27.26)	27.26
Predation and other losses	-		13.80	(12.52)	12.52

[1]Numbers in brackets are percentage of overall migration. Others are percentage migration within type of migration (column); n = number of chickens recorded migrating during the monitoring period

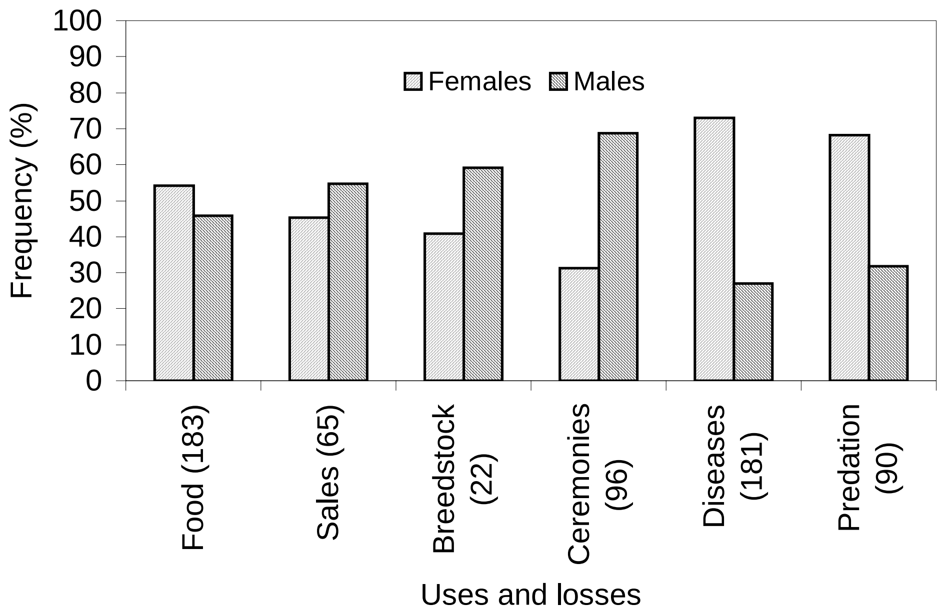
Migration out of flock, which represented flock off-take, was the most important component of flock dynamics for growing and adult birds. When calculated as a proportion of flock size, monthly migrants out of flocks constituted 38.74 % (median, 40.00; SD, 2.39, n = 524 observations with full flock structure) of household flock sizes excluding chicks. This off-take was 16.89 % (median, 16.67; SD, 2.47; n = 370) when calculated based on flock size including chicks. Of these migrants out of flocks, 56.16 % was off-take for household and community functions while 43.85 % was due to losses. Household use included slaughtering chickens for household food followed by contributing chickens to socio-cultural and communal functions. Other functions included selling of live chickens for cash or direct barter, providing or exchange breeding stock with other farmers, and least, giving out chickens as gifts.

Communal ceremonies, diseases, predation and theft contributed to off-take only. Diseases caused higher loss than predation and thefts.

More male chickens than females ($p<0.05$) were slaughtered during socio-cultural ceremonies (Figure 4.1). Only male chickens were presented for gifts. Females dominated ($p<0.05$) for those lost due to diseases and predations.

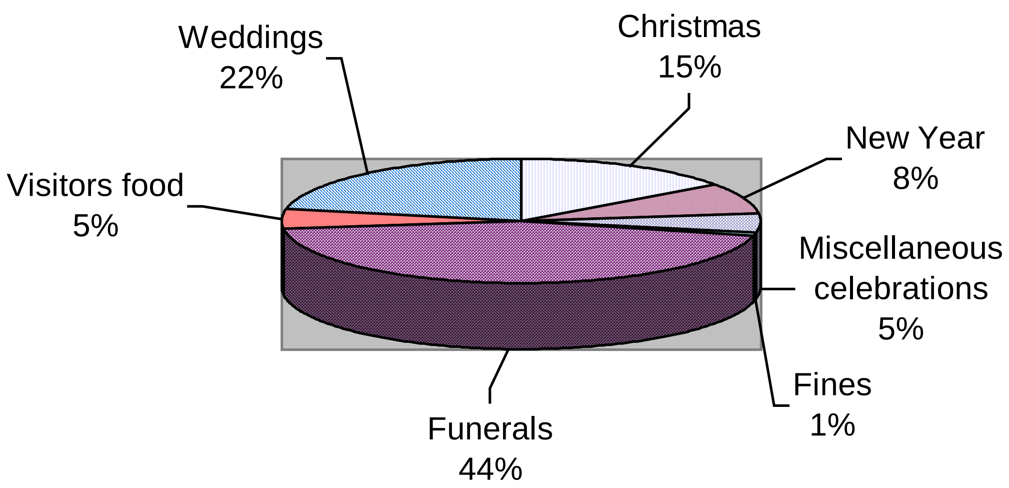
Sales of birds were by cash (67.57 % of birds sold), barter with kitchenware, clothes and mats (23.18 %), and paying wages to hired labour working on crop gardens. When compared between seasons, sales for cash took place in all seasons but were more during the hot-dry season. Farmers were providing or exchanging chickens to be used for breeding mostly during the hot-dry season.

Constituent socio-cultural ceremonies where chickens are utilized were important as shown in Figure 4.2. Funeral and wedding ceremonies were important communal events where households participated and contributed a chicken for slaughter.



Number in brackets = number of birds with identified sex within the off – take category

Figure 4.1. Distribution of chickens migrating out of flocks by type of off-take by sex (each category is considered separately)



n = 101 chickens migrating out due to ceremonies

Figure 4.2. Social and cultural activities associated with chickens migrating out of flocks due to communal and household ceremonial functions

4.4.3 Age and live weights at migration

Age structure and mean live weights for chickens at migration (Table 4.3) showed that chickens migrated into flocks, for example for breeding while in growing stage (< 20 weeks). Male chicken migrants into flocks were significantly ($p<0.05$) heavier

Table 4.3. Mean age and live weights for chickens at migration into or out of flocks

Purpose of migration	Age (weeks) at migration			Weight (g) at migration		
	N	Mean	SD	n	Mean	SD
Migration into flock						
Breed stock acquisition	55	18.7	6.0	62	913.8	379.5
Migration out of flock						
Household consumption	127	26.5	13.0	207	1249.6	416.9
Sales	50	23.8	9.5	69	1152.6	485.4
Gifts	-	-	-	5	1320.0	406.3
Breed stock sharing	17	20.4	7.3	27	1088.2	383.0
Ceremonies	75	28.9	13.0	101	1307.5	395.2
Diseases	150	24.9	16.7	216	834.8	533.6
Predation	74	22.4	14.9	98	920.6	523.6

n = number of birds observed migrating on the stated purpose with age or weight record

(1199.0 g, SD, 510.8 g) than females (810.1 g, SD, 335.14 g). Birds migrating out of flocks showed a consistent age range of 20 to 28 weeks at migration. Birds provided for breeding had least age while those provided to ceremonial functions were older ($p<0.05$). Their live weights were not significantly different ($p>0.05$). Migrating chickens due to diseases, parasites and predation had significantly ($p<0.05$) lower live weights than birds utilised by households. Male chickens migrating out were significantly ($p<0.05$) heavier (1223.7 g, SD, 548.8 g) than females (996.9 g, SD, 448.5 g).

4.4.4 Farm- gate prices of birds

Farmers sold their chickens at an average price of MK170.32[2] (SD, MK58.66, range, MK40.00 – MK350.00) per live chicken or MK142.79 (SD, MK42.59, range, MK72.46 – MK251.57) per kg live weight of chicken. Farmers, however, bought young (9.0 weeks old), weighing 765 g at an average price of MK79.29 (SD, MK40.87) per live chicken or MK98.17 (SD, MK26.76) per kg. Direct sales and sales through barter took place at farmer household level and there was no report of farmers taking their chickens for sale at the market.

4.4.5 Housing for rural local chickens

Three types of housing were used for night shelters for local chickens in the study area. These were human dwelling units (84.5 % of flocks), household kitchens (8.05 % of flocks) that are built separate from main house, and traditional poultry houses (locally called *khola*) (7.41 % of flocks).

[2] 1 US$ = MK85.00

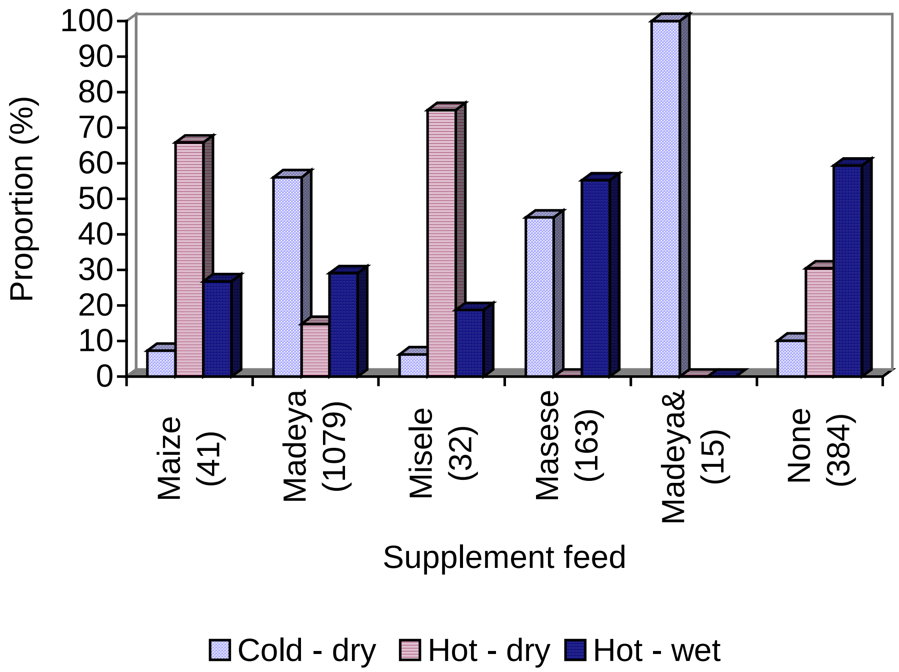
4.4.6 Feeding management

Scavenging (free-range) system was the sole system of raising local chickens. A significant ($p<0.001$, χ^2 - test) majority of farmers (77.6 %) provided supplement feed of unknown quantities (Table 4.4). In order of proportions of supplements used, feedstuffs included maize bran *(madeya)*, brewers' waste (a by-product from local beer brewing locally called *masese*), maize grits *(misele)*, and whole maize grain. Most ingredients except brewers' waste were supplement fed in all seasons (Figure 4.3). Maize and maize grits were offered to chickens more often during hot-dry season, seconded by hot-wet season and least in cold-dry season. *Masese* were supplemented in cold-dry and hot-wet seasons only. *Madeya* were supplemented more (56 %) in the cold-dry season and least (15 %) in hot dry season.

Table 4.4. Frequency distribution (% flocks) of supplement feeding to local chickens by feed type and season

Season / Supplement Feed	Cold dry n = 737	Hot dry n = 328	Hot wet n = 649	Overall n = 1714	χ^2 statistics[2]
Maize	0.41	8.23	1.69	2.39	***
Maize bran *(Madeya)*	82.09	48.78	48.38	62.95	***
Maize grits *(Misele)*	0.27	7.32	0.92	1.87	***
Brewers wastes *(Masese)*	9.91	-	13.87	9.51	n.s.
Madeya and *Masese*	2.04	-	-	0.88	-
None	5.29	35.67	35.13	22.40	***
χ^2 statistics[1]	***	***	***	***	

[1], test for supplement feeds within season; [2], test for a supplement feed between seasons (Figure 4.3); Significant levels (χ^2 Test), *** = p < 0.001; n.s. = not significant (p>0.05); n = number of flocks observed during the study period



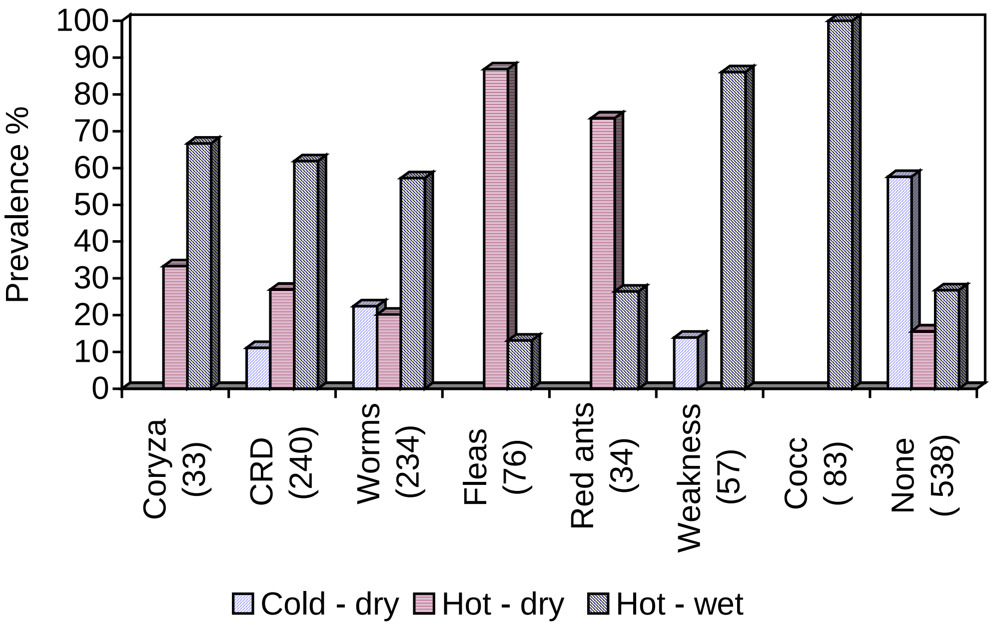
Madeya& = Madeya and Misele; In brackets = number of flocks fed that supplement feed

Figure 4.3. Frequency distribution of supplement feed used by season

4.4.7 Flock Health

Cases of occurrence of disease and parasite infection in household flocks were used to evaluate flock health status. These infections and their relative seasonal distribution are shown in Figure 4.4. In the cold-dry season, flocks were infected with chronic respiratory disease (CRD), internal parasites (helminths) and unspecified ailments described by general weakness of birds. In the hot-dry season, infectious coryza and red ants were observed in addition. Coccidiosis was reported specifically during the hot-wet season. Overall, CRD and helminths were common infections prevalent in all seasons. External parasites (notably fleas) infestation ranked third in terms of prevalence, while coccidiosis and weakness ranked fourth. Multiple infections were also observed on some flocks. For example, combinations of CRD and internal parasites (3 %) and CRD and coccidiosis (2 %) were observed.

Thirty-two percent (32 %) of flock observations were non-infected. Of these, more were in the cold-dry season followed by hot-wet season and least in the hot-dry season. Monthly trends of flocks infected by diseases and parasites (Figure 4.5) showed that during the hot-dry season, 70 to 90 % were in October and November. During the hot-wet season, over 90 % of flocks were infected in January and February. A transition period from the end of the hot-dry season to beginning of the hot-wet season (October to February) had high rate of flock infection.



CRD = Chronic respiratory disease; Cocc = Coccidiosis; in brackets = number of month-flocks observations. Respective local names: Coryza = *Chikwirikwiti*; Coccidiosis = *Kamwazi*; CRD = *Chifuwa*; Helminths = *Nyongolosi*; Fleas = *Utitiri / Nthata*; Red ants = *Linthumbu*; Weakness = *Kuwumbwa*

Figure 4.4. Household flock infection cases compared between seasons

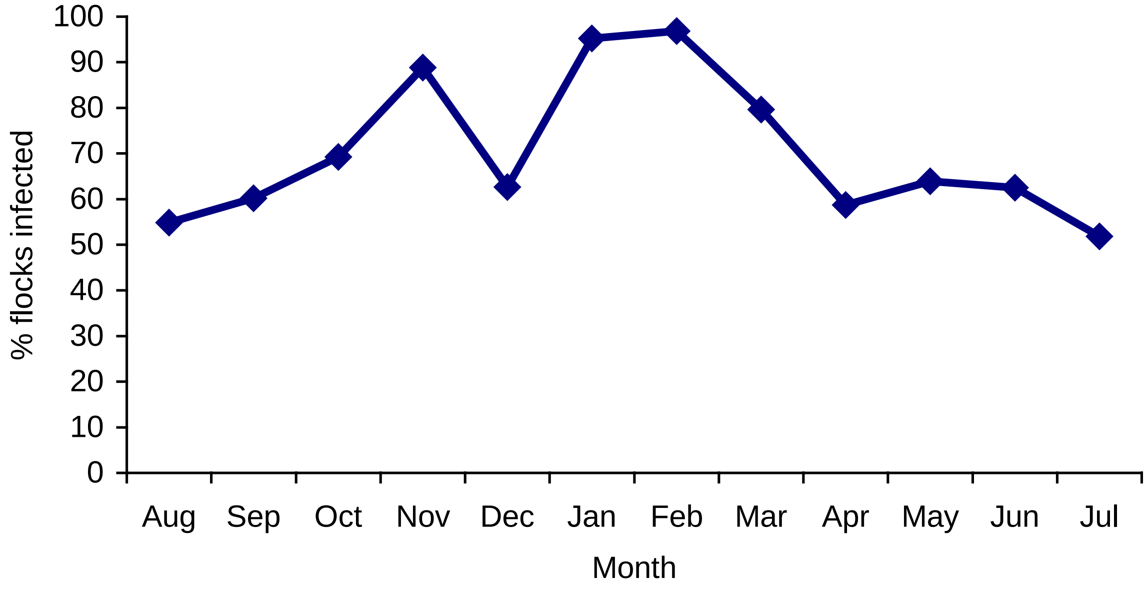


Figure 4.5. Monthly means of aggregate cases of disease and parasite infections of household flocks

Impact of prevailing infections was evaluated by monitoring off-take from flocks of growing and adult chickens due to losses and their causes (Table 4.5). All diseases and parasites that infected local chickens, except coccidiosis (according to farmers perception and observed recovery of birds infected with coccidiosis), led to mortality in growing and adult chickens. Internal parasites (helminths) were most important cause of mortality. The occurrence of NCD was due to the fact farmers delayed to vaccinate their chickens.

Table 4.5. Causative factors for loss of growing and adult chickens in household flocks (n = 320 growing and adult chickens lost from flocks)

Cause	Frequency (%) of total losses
Helminths	25.24
CRD	7.35
Infectious Coryza	3.19
NCD	21.41
Ectoparasites	2.56
Egg peretonitis	0.96
Other diseases	2.56
Predators	20.13
Accidents	7.03
Missing (unknown cause)	4.79
Theft	4.47
Food poisoning	0.32

Apart from diseases and parasites, predators contributed to losses. Predators reported were wild cats (*Felis sp.*) locally called *Vumbwe*, *Msangala*, *Likongwe;* hawks *(Accipiter sp.),* African Kites (*Chelictinia sp.*) called *Kamtema;* and domestic dogs (*Canis familiaris*). Predation was more common in the hot-wet season, followed by cold-dry season and was commonly during daytime when chickens went scavenging. Accidents included cars and bicycles hitting chickens, fire burns, house falling on chickens, chickens hit by falling trees and house furniture falling on chickens.

4.5 Discussion

4.5.1 Flock characteristics

Household flock sizes and structure observed in the study fall within the ranges reported in Malawi (Ahlers, 1999) and other countries in Africa (Dessie and Ogle, 2001; Mwalusanya et al., 2001; Ekue et al., 2002; Tadelle et al., 2003a). This is true even for sex ratio that these authors reported to be high and in the ranges of one male for three to five females in a household flock. For example, Missohou et al. (2002) reported that number of cocks per household flock was 0.9 in Southern Senegal, which agrees with the result of the study that several households do not keep a breeding cock. In Zimbabwe, Maphosa et al. (2004) reported flocks sizes of 23 chickens in a communal area and 35 chickens in a small-scale commercial area, which were higher than flock sizes observed in this study. Number of chicks and growers reported by above authors from various countries were higher than those observed here.

4.5.2 Flock dynamic

Results from flock dynamics showed that there was more exit of growing and adult chickens from flocks than intake into flocks. The main purpose of chickens migrating into flocks was for breeding. This finding agrees with earlier observations from a survey of local chicken production in the area and in Northern Malawi that farmers acquire or exchange breeding stock with their friends and relatives (Gondwe et al., 1999a). Both male and female chickens were involved in migration for breeding purpose. Breeding stock exchange took place among households within and between neighbouring villages. The number of chickens and households involved in breeding stock exchange was, however, seemingly small. This implies that most replacement stock come from own reproducing hens in a flock. This practice may lead to inbreeding and consequences of inbreeding depletion in these small flocks.

Flock exit demonstrated primary functions of local chickens. These functions were dominated by use as source of animal protein for households followed by functions to participate in socio-cultural ceremonies of the communities, especially funeral and wedding ceremonies. Selling of chickens ranked third followed by providing breeding stock to friends and relatives. The findings agree with those of many authors in different countries in Africa and elsewhere. Order of importance of functions, however, differs among authors. For example, Dessie and Ogle (2001) reported equal importance of functions of chickens in terms use for sacrifice, sale and consumption as perceived by farmers in Central Highlands of Ethiopia. Ekue et al. (2002) reported that main functions of local chickens among farmers in Cameroon were to sell for income and as source of food. Missohou et al. (2002) reported that farmers used chickens mainly for household consumption and only few sold their chickens to earn income in Southern Senegal. Despite differences in order of importance of roles local chickens play to rural communities, multifunctional use of local chickens remains obvious. Uses of local chickens for traditional medicines and sacrifices reported by Tadelle et al. (2003a) for Ethiopia were not observed in this study.

Some functions of chickens were associated with seasons primarily because of seasonal occurrence of certain socio-cultural events, e.g. slaughter of chickens for Christmas and New Year. Wedding ceremonies usually took place during dry seasons. Funerals were, on the other hand, taking place at all times of the year and members of the communities offered chickens to be consumed during the ceremonies.

Proportion of migrants out of flocks due to diseases, parasites and predation was significant. The low live weights of chickens that died due to diseases are probable indications of poor body condition. Lower live weights for chickens predated indicate that younger and weaker ones are at high risk of predation. Diseases and predation are factors of natural selection.

The limited migration of chickens into flocks in relation to migrants out of flocks indicates that flocks sustain from offspring to replace aging and lost breeding stock while offering products for household use. Tadelle et al. (2003a) reported that reproduction is a primary function for households to keep chickens. Reproduction is a function without direct utility and could not be depicted directly in the monitoring studies. Age of chickens when utilized or lost showed that majority were in growing phase. This shows that farmers utilized chickens that were hatched from the flocks and did not replace breeding stock, especially hens. Gondwe et al. (1999a) reported that farmers kept their breeding stock for a long time of up to three years. Hens are maintained as an asset to reproduce and sustain the flock.

4.5.3 Housing system

The observed housing agrees with housing systems for local chickens observed in Tanzania (Mwalusanya et al., 2001), Senegal (Missohou et al., 2002) and Ethiopia (Dessie and Ogle, 2001). Housing systems in Burkina Faso (Kondombo et al., 2003) and Morocco (Benabdeljelil and Arfaoui, 2001) included night roosting in trees, which was not observed in the study area. Keeping local chickens in *Kholas* at night were more common in Northern parts of Malawi (Ahlers, 1999) than in this study area. Types of housing differ between regions and countries, agreeing with observations by Kitalyi (1998).

4.5.4 Feeding system

The observation that majority farmers supplemented their local chicken flocks agrees with what Sonaiya et al. (2002) observed in Nigeria. The use of by-products from human food processing to supplement scavenging chickens has been reported in Northern Malawi (Ahlers, 1999) and in other countries in Africa (Kitalyi, 1998, Roberts, 1999; Dessie and Ogle, 2001 and Kondombo et al., 2003). The findings from the current study agree with the results from these reports. This study further identified specific ingredients used, their relative importance and seasonal distribution in supplementing local chickens. Maize bran was the common and important supplement. Household human leftover food was not regarded as supplement feed but part of the scavenging feed resource all households provided to chickens as wastes thrown into hips of refuse from where chickens could scratch and eat. Farmers who also brew local beer supplemented *Masese*.

Most feed supplements were provided during the cold-dry season than in the other two seasons ($p<0.001$, χ^2 - test). The odds ratios of supplementing local chickens also show seasonal influence on supplementing. This seasonal trend reflects availability of ingredients noting that all supplements were waste by-products from maize whose household stock varies by season, being more abundant during cold-dry season following crop harvest. Dessie and Ogle (2001) and Kondombo et al. (2003) reported similar seasonal influence on supplementing feed to chickens in Ethiopia and Burkina Faso. In Malawi, most rural households run out of human food from home-grown crops during hot-dry season (September to November) (FEWSNET, 2002; Oygard et al., 2003). Subsequently there are less by-products available resulting in farmers to reduce supplementation to their local chickens. During the hot-wet season, most households depended on relief food (FEWSNET, 2003; Oygard et al., 2003), from which, *madeya* was used to supplement chickens.

Parameter estimates from logistic regression showed that apart from season effect, chicken housing system and number of hens in a flock were important determinants of likelihood of supplementing feed to scavenging local chickens. Chickens housed in traditional *kholas* were more likely to be supplemented (odds ratio of 4.22) than chickens housed in human dwelling units and kitchens. Coincidentally, those farmers with separate chicken houses (*kholas*) had home-grown food available even during the hot-wet season. This is also a reflection of availability of the feedstuffs among households to supplement to local chickens. On the other hand, the likelihood of supplementing local chickens increased with increase in number of hens ($p<0.001$, χ^2 – Wald test). Number of cocks and chicks as covariate factors were not significant ($p>0.05$). This observation suggests that farmers consider flock sizes based on hens and, therefore, do not put preferential treatment on supplementing feeds to chicks and cocks. In their monitoring study, Maphosa et al. (2004) observed similarly to this study that there is no preferential treatment to chicks during supplemental feeding. Those findings are in contrast to Kitalyi (1998) and Kondombo et al. (2003), who observed that supplementation was mainly provided to chicks.

Since all feedstuffs supplemented to scavenging local chickens belonged to energy sources (NRC, 1994), chickens find and satisfy protein needs and other nutritional deficiencies from scavenging feed resource base (Samnang, 1998). Roberts (1999) and Olukosi and Sonaiya (2003) determined the scavenging feed resource base and reported to constitute of among other, animal protein sources such as insects, earthworms, termites, ants and other metazoans. Local chicken production is not competing with human nutrition. All the supplement feeds observed were by-products and of little or no use for humans.

4.5.5 Flock Health

NCD vaccination was effective that breeding chickens survived through the cold-dry and hot-dry seasons, which are major infection periods. This indeed shows the importance of NCD on rural poultry production as reported by many authors (Ahlers, 1999; Branckaert and Gueye, 1999; Dessie and Ogle, 2001; Mwalusanya et al., 2001; Kondombo et al., 2003 and Kusina et al., 2001). However, despite successful NCD prevention, prevalence of other diseases and parasites, and subsequent mortality revealed presence of health problems in free-ranging local chickens in addition to that due to NCD. Pedersen (2002b) reported similar health problems on NCD vaccinated flocks in Zimbabwe. Maphosa et al. (2004) reported high chick mortality (60 %) in NCD free flocks in Nharira and Lancashire areas of Zimbabwe. Predation was also reported an important cause of losses from chicken flocks by Mwalusanya et al. (2001), Pedersen (2002b) and Kusina et al. (2001). In their study in Tanzania, Magwisha et al. (2003) found that all growing and adult chickens observed were infected with helminths. These helminths infections usually contribute to reduced productivity, reproduction and immunity against other infections such as NCD (Horning et al., 2003) due to reduced formation of proteins to synthesise immunoglobulins. Rural chicken production therefore, faces a multitude of health problems and other causes of mortality and losses.

Seasonal pattern of disease, parasites, and to some extent, predation observed in the study may be due to some association between seasonal factors and the infection agents. Overall, infection rate in the hot-dry season was highest. Hüttner et al. (2001) observed high adult chicken mortality between September and December in Northern Malawi. Kusina et al. (2001) also reported that farmers in Zimbabwe perceived that diseases and parasites were severe during the hot-dry season. Internal parasites are associated with wet and humid conditions (Magwisha et al., 2003). High temperatures during hot-dry season and feed shortages especially during rainy season may contribute to reduced immunity and susceptibility to diseases. Just as NCD, knowledge of seasonal pattern and importance of infections is helpful in designing strategic measures of interventions. This information could be, for example, used to develop a management calendar recommending appropriate control or preventive measures when risk is highest over the year.

Health problems cause losses in flocks and reduce their productivity (Magwisha et al., 2003), hence require interventions. While NCD vaccination using *La sota* was effective, treatment against other diseases using modern medicines faced challenges of drug misadministration, availability and knowledge of correct treatment by farmers. Most infections were contagious, thus a single infection spread to other birds in a flock and even to other flocks. This implied treatment should be applied to all chickens in a flock and even those from neighbouring flocks, thus requiring a community approach. There was no observed use of traditional remedies on control of diseases and parasites in the study area. This may be due to loss of indigenous knowledge (as per views from some farmers when asked), deforestation and seeking for modern medicines. Vaccines were available for coryza and gumboro (possibly shown in those described by weakness) and could be used to prevent the diseases but were, unlike NCD, expensive. The health constraint is a complex situation calling for an integrated community management approach.

Possibility of breeding for disease resistance should be explored, especially for internal parasites, which were the most important single cause for loss of birds. Gauly et al. (2001) and Gauly et al. (2002) reported high repeatability values (r = 0.55 to 0.87) and medium heritability values (0.10 to 0.19) for mean log fecal egg count for helminth *Ascaridia galli*, thus showing potential high genetic variance that can be utilized to select for helminth resistance in chickens.

4.6 Conclusion

The current study analysed the production system of local chickens by flock size and structure, feeding, housing and health. Primary outputs were determined from exit of growing and adult chickens from flocks. The multifunctional role of local chicken production included use of chickens for home consumption, traditional household and communal functions, sale for cash and barter with household needed items, breeding stock sharing and exchange and providing gifts. Close to 40 % of the output were, however, losses due to diseases and predation. Flocks depended on scavenging feed resource base. Farmers usually supplement feed their chickens with different but mostly non-quantified energy type of by-products from maize. This supplement feeding was the main input observed in the study and did not compete with human nutritional needs. However, supplementation is closely associated with level of human nutrition.

Constraints included disease, parasite and predation challenges, feeding without preferential treatment for chicks and current housing system. Single technical interventions, such as NCD vaccinations, are apparently not sufficient to improve the efficiency of the system. Most practices observed on managing and consuming local chickens are traditionally related. These traditional practices seem likely to remain in the near future. An integrated intervention approach requiring minimal external inputs should be directed at both household and community level.

5. Breeding structure of local chickens under scavenging production system in Malawi[1]

5.1 Abstract

The breeding structure of scavenging local chickens was evaluated in 134 participating households in 27 rural villages of Lilongwe, Malawi from August 2002 to August 2003. The objective was to analyse the breeding system and structure of local chickens by observing population of flocks during scavenging. It was observed that chickens from on average 10 neighbouring flocks scavenge together and mate during free-ranging. About half (52 %) of the households kept no breeding cock. A breeding population was therefore, composed of hens and cocks from neighbouring flocks observed mixing during scavenging and not from individual household flocks. A breeding structure based on the neighbourhood flocks comprised of 4.3 (SD, 2.6) cocks and 33.6 (SD, 13.9) hens per breeding population. Breeding female to male sex ratio was 10.1 (median, 7.8). Effective population sizes were low and estimated as 15.2 (SD, 8.16) assuming random union of gametes or 13.4 (SD, 6.74) assuming differing family sizes. Both effective population sizes were lower than 50 % of the actual population size (N = 37.85, SD, 14.67). Assuming no exchange of breeding birds between populations the estimated inbreeding rate per generation was 3.85 % (SD, 1.76 %). The small number of breeding cocks contributed to low effective sizes and the perceived inbreeding. It is concluded that local chickens breed during scavenging and this breeding system provides opportunity for individual household flocks that have no cock to mate. Cocks, therefore, play a prominent role in providing genetic material to the community managed poultry population. Enhancing community breeding stock exchange of cocks between neighbourhood populations seems the most plausible approach to increase effective size and reduce inbreeding.

Keywords: breeding structure, cocks, hens, inbreeding, community, population.

5.2 Introduction

Local chickens occupy a unique position in an integrated smallholder crop-livestock production system in that they are widely owned with an equitable distribution compared to other livestock (Gondwe and Wollny, 2002). Despite the low inputs, and usually neglected, these free-ranging chickens provide variety of output to both individual households and the rural and urban communities (Branckaert and Gueye, 1999). It also appears that this free-ranging chicken production system will continue in many developing countries including Malawi in the foreseeable future. It is therefore, necessary to look at ways of improving production of local chickens, firstly by describing and understanding the production system. Researchers took initiatives to study scavenging chickens in different countries and reported various aspects on flock structure, management and health constraints (Ahlers, 1999; Minga et al., 2000; Dessie and Ogle, 2001; Missohou et al., 2002). Currently in-depth studies are still limited (Kondombo et al., 2003) and breeding issues are ignored.

As one component of the production system, the breeding system for local chickens under village management needs to be defined. The objectives of the study were: (i) to identify the breeding structure of local chickens in a free-ranging production

[1] Paper submitted to Farm Animal Genetic Resources Information

system; (ii) to determine effective population sizes; (iii) to estimate inbreeding, evaluate its consequences and suggest possible solutions.

5.3 Materials and methods

5.3.1 The study area

The study was carried out in 27 villages of Mkwinda and Mitundu EPAs of LADD in Malawi. Demography of farmers in the area, livestock distribution and the farmer-researcher community participatory approach are outlined in Chapter 3.

5.3.2 Data collection

Data were derived from household flock monitoring study of chicken production among smallholder farmers in the study area following the approach detailed in Chapter 4.

Data for household flock sizes and structure included monthly recording of number of mature breeding cocks and hens and non-breeding stock including chicks and growers. Chickens from neighbouring households were observed to be scavenging together during daytime. Together with farmers, flock movement and mixing pattern were followed and verified by direct observations once every month. Based on the assumption that uncontrolled mating takes place during scavenging, a census was taken once a month, comprising of all breeding chickens in the community of chickens that scavenged together. This census of cocks and hens included flocks whose households were not participating in monitoring studies. That is, records for each household flock under study included its flock size and structure, number of households with flocks scavenging together, and a count of number of hens and cocks in that group of households. From this, flocks that composed a regular breeding population was established. These composite flocks differed from village to village, depending on the set up of the villages.

After one year, there were 1714 month-flock monitoring records (35.94 % in 2002 and 64.06 % in 2003). Cold dry season had 43 % of the observations, 19.14 % in hot dry and 37.86 % in hot wet seasons.

5.3.3 Data editing and analysis

In order to determine the breeding structure, sex ratio, actual and effective population sizes were calculated for the established group of flocks that mix during scavenging. Sex ratios were determined by dividing number of females by males. When calculating effective population size, two formula were used

$$N_e = \frac{4 N_m N_f}{N_m + N_f} \qquad (5.1)$$

and

$$N_e = \frac{4 N_m N_f}{2 N_m + N_f} \quad (5.2)$$

where

N_e is the effective population size
N_m and N_f are number of cocks and hens per breeding population

Formula 5.1 is the Wright equation that is frequently used to estimate N_e for populations with unequal sex ratio (Falconer, 1989). The equation accounts only for unequal sex ratio while assuming random union of gametes from a given pool. Formula 5.2 was suggested by Nomura (2002) to account for unequal sex ratio (that is also done by the standard formula) and variation in mating success (number of mates) within each sex, which is a realistic condition in most domestic animals. In this study, information on mating preferences by cocks and hens, and subsequent reproductive success for individuals within sex was not collected due to logistical constraints since mating was uncontrolled. However, such characteristics were assumed to occur in extensively kept local chickens and lead to variations in mating success of parents within each sex, especially males. This is why the second formula was included to determine N_e. Variation in mating success was assumed negligible for hens.

Rate of inbreeding per generation (ΔF) was computed from the estimated effective population sizes using the equation

$$\Delta F = \frac{1}{2N_e} \quad (5.3)$$

Data were analysed for descriptive statistics using Proc Freq procedure for qualitative data and Proc means and correlation procedures for quantitative data (SAS, 1999).

5.4 Results

5.4.1 *Prevalence of breeding cocks in household flocks*

The first step to determine the breeding structure of local chickens was to identify the breeding cocks and hens. Figure 5.1 shows prevalence and distribution of breeding cocks among household flocks. Fifty-two percent (52 %) of the household flocks kept no breeding cock, 41 % had between one and two cocks and less than 8 % of flocks had more than four cocks.

Availability of breeding cocks in household flocks showed seasonal variation (Figure 5.2). Chi-square test was significant ($p<0.05$) for association of month and availability of cocks among flocks. However, the trend was that the proportion of flocks that had cocks was greater during the cold-dry season (especially June and July), but lowest during the hot-dry season (August to September).

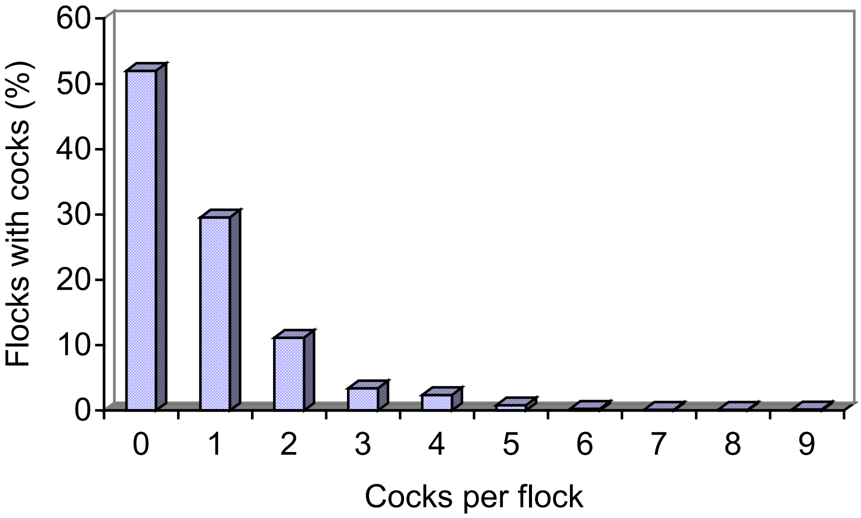


Figure 5.1. Distribution of breeding cocks among household flocks (percentage of flocks owning breeding cocks)

5.4.2 Flock hen composition and trends

Breeding hen structure was stable in households, with an overall mean of 5.17 (SD 3.57) per flock. Monthly trends and variations in hen flock size (Figure 5.3) were non-significant ($p>0.05$). It is these hens that were accessed by the breeding cocks the communities share. For those households with cocks, individual flock sex ratio was 4.70 (median, 4.00; SD, 3.06) hens per cock.

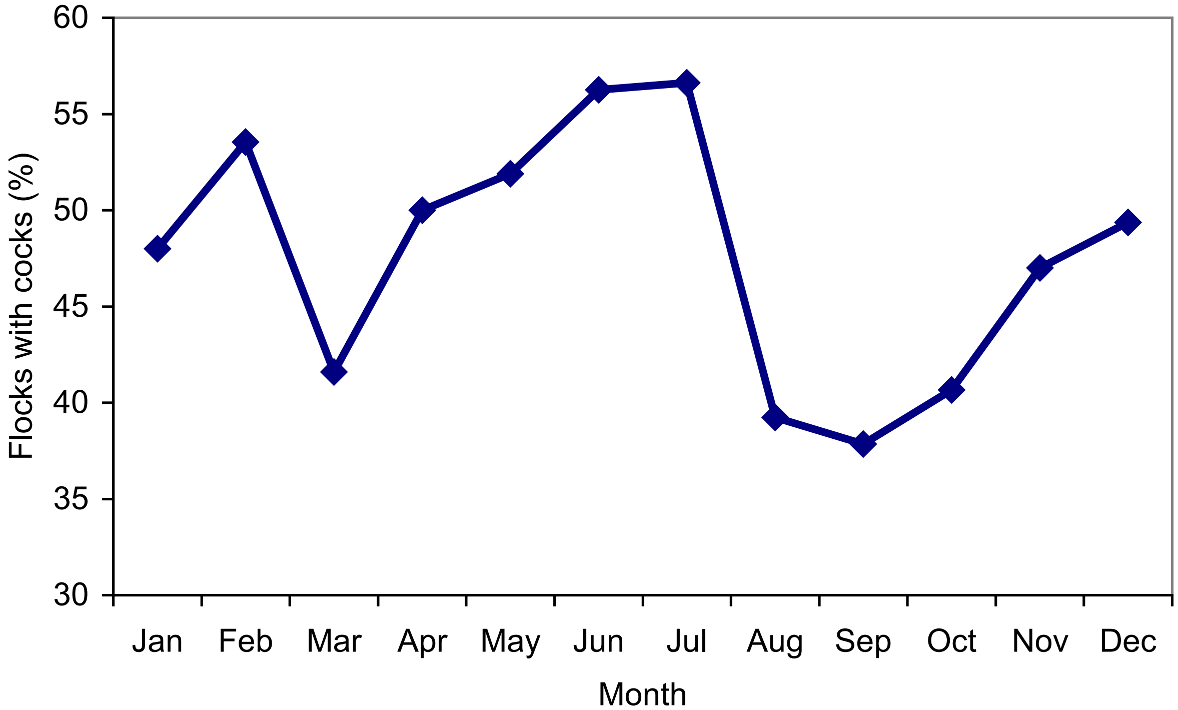
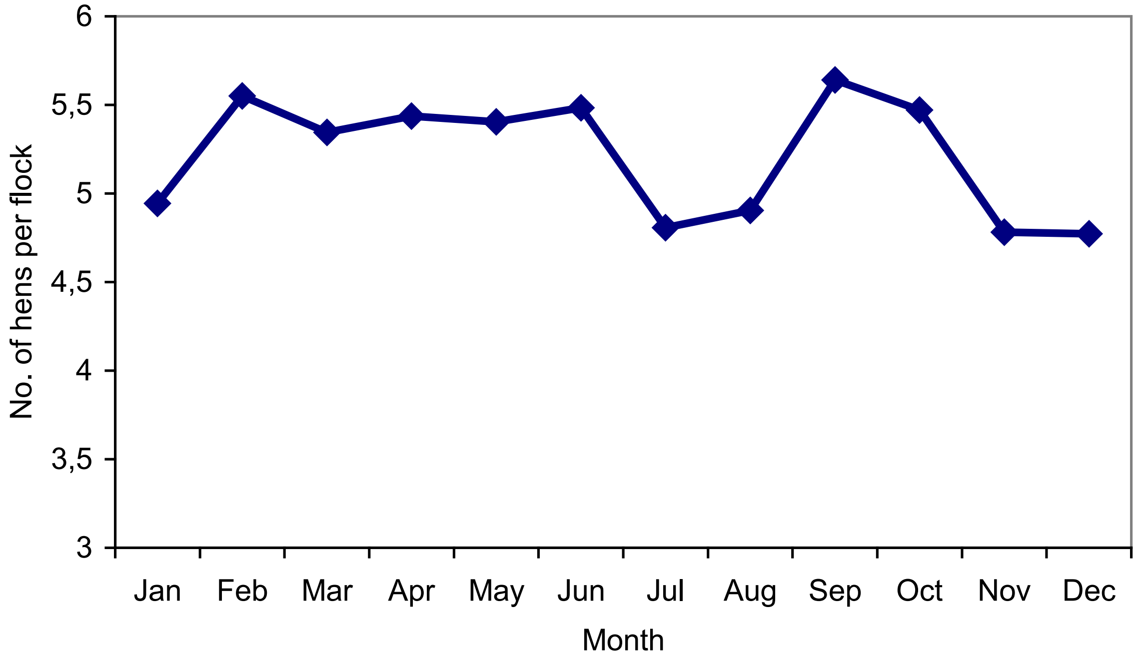


Figure 5.2. Monthly distribution of proportions of household flocks with breeding cocks



n = 1613 month-flock observations

Figure 5.3. Average monthly sizes (number) of breeding hens per household flock

5.4.3 Community breeding flocks

Flocks comprising of hens and cocks from neighbouring household flocks that moved and scavenged together were observed. In some areas, villages were small and separated from another village by gardens, grasslands and graveyards. In such villages, neighbouring flocks were similarly separated. In villages close to each other, neighbouring flocks did not follow boundaries of villages. From these observations, number of households whose flocks scavenge and breed together was established (Table 5.1) and defined a community of breeding flocks.

5.4.4 Breeding population size and structure

The next step was to determine the structure and size of breeding population of local chickens in rural areas. A breeding population, defined as a population of parents that share common gene pool *'more than the rest'*, comprised an average size (N) of 38 individuals per community, with fewer cocks than hens (Table 5.1). The mean sex ratio was 10 hens for every cock (median of 8). Cocks constituted 12.14 % (median, 11.43 %) of the actual breeding population (N). Effective population sizes were 15.19 using the Wright equation (5.1) and 13.35 using the Normura (2002) equation (5.2). The difference between the two estimates was significant ($p<0.001$, t-test) but their Pearson correlation coefficient was high ($r = 0.995$) and significant ($p<0.001$).

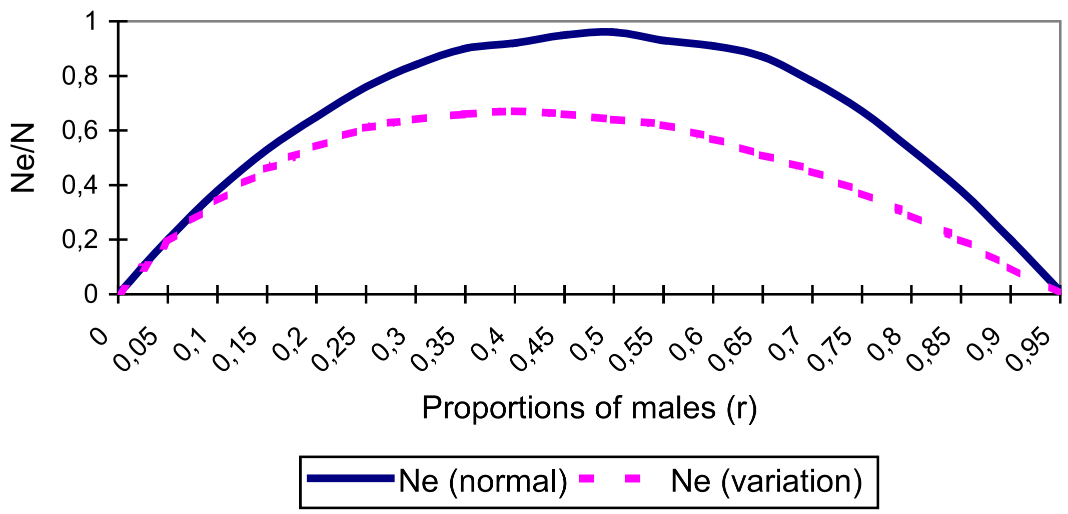
Effective population sizes as proportions of actual population sizes (N_e/N) were below 50 % using both equations. All parameters showed wide ranges (min-max) of observations but were normally distributed except for sex ratio.

Table 5.1. Breeding population structure and their average sizes

Parameter	n	Mean	Median	SD	Range
Mean number[1] of flocks	1699	9.58	9.00	3.63	1 – 30
Number of cocks	1664	4.31	4.00	2.62	0 – 15
Number of hens	1625	33.62	31.00	13.87	3 – 80
Population sex ratio[2]	1573	10.12	7.75	7.24	1.5 – 60.0
N	1586	37.85	36.00	14.67	4 – 82
N_e[3]	1573	15.19[a]	14.06	8.16	3.00 – 43.15
N_e[4]	1573	13.35[b]	12.44	6.74	2.40 – 35.09
N_e[3] / N (ratio)	1573	0.41	0.40	0.16	0.06 – 0.96
N_e[4] / N (ratio)	1573	0.36	0.36	0.13	0.06 – 0.69

N = actual breeding population size (sum of cocks and hens); [1]Number of household flocks that constituted a community breeding population of chickens; [2]Expressed as number of hens per cock; [3]Effective population size based on Wright equation (5.1) assuming random mating (union of gametes) with equal access of all cocks to females; [4]Effective population size based on Nomura equation (5.2) assuming uncontrolled and with different mating rates and reproductive success of cocks to hens; [ab]T-test showed significant difference between the two N_es (P<0.001); n = number of month-flock observations monitored during the study period

Ratios of N_e/N were plotted against different extrapolated proportions of males in the actual population (Figure 5.4) to provide some indication on the role of family size variation. Using the curve for N_e (with variation in family sizes), effective population size is maximised at about 60 % of the actual size and when the proportion of males is about 35 % of the actual size.



Ne(normal) = N_e determined by equation 5.1 assuming random union of gametes but unequal numbers between sexes. Ne(variation) = N_e determined by equation 5.2 assuming variation in family sizes among cocks and unequal numbers between sexes

Figure 5.4. Ratios of effective population sizes extrapolated for different proportion of cocks to total population

5.4.5 Estimated inbreeding

Rates of increase in inbreeding per generation were estimated from the effective population sizes. As shown in Table 5.2, rates of inbreeding per generation were high and significantly greater ($p<0.05$) than 2.0 %.

Table 5.2. Estimated rates of inbreeding (ΔF) in percent per generation

Parameter	Mean[a]	Median	SD	Range
ΔF (from N_e normal)	3.85	3.50	1.76	1.16 – 9.38
ΔF (from N_e variation)	4.28	3.88	1.85	1.42 – 9.82

[a] Means significantly different from 2.0 % at 95 % CI; N_e normal = N_e determined by equation 5.1 assuming random union of gametes but unequal numbers between sexes. Ne variation = N_e determined by equation 5.2 assuming variation in family sizes among cocks and unequal numbers between sexes

5.5 Discussion

5.5.1 Breeding structure

The majority of households depend on breeding cocks from neighbouring flocks for reproduction in this study. Scavenging system offer an opportunity for neighbouring flocks to mix and breed. Pedersen (2002b) observed a similar situation in Zimbabwe. Farmers were benefiting from breeding cocks from other flocks. Farmers were aware that owning of individual cocks would possibly result into cock fighting in relatively small populations. Some farmers, therefore, transferred cocks to their relatives and friends, while others consumed or sold the cocks. This is in line with what Gueye (1998) reported that males are generally removed from the flocks at an early age for sale, home consumption or for cultural purposes. These flocks are therefore, not closed units. Unlike hens, the cocks from neighbouring flocks were communally used in breeding and exchange of genetic material. This depicts a structure of a traditional breeding system in scavenging chicken production. With this structure where neighbouring flocks breed together, sex ratio determined per household flock is meaningless. Rather sex ratio of a community breeding population should be used in designing breeding programs.

5.5.2 Effective population size

The theory of effective population size helps to describe structure of breeding populations for individuals that practice polygamous mating system. The parameter is influenced by number of breeding animals, their sex ratios, and other factors that lead to varying family sizes. These factors include different levels of fertility among parents, mating potential and success, and viability of offspring (Henson, 1992; Van der Werf, 1999; Nomura, 2002). In this study, only the structure of breeding populations was determined, other controlling factors were difficult to observe under this scavenging system with uncontrolled mating between cocks and hens. This, and the scarcity of similar studies to compare with, led to the use of the two equations to estimate effective population sizes. The effective population sizes estimated by both methods were small, showing that local chickens breed in small populations. The parameters may reflect a best estimate under the assumption of no exchange of breeding animals between defined sub-populations and might therefore, be an underestimation of the true population size. Falconer (1989) and Henson (1992) reported that the sex with fewer individuals chiefly influences the effective population size in small populations. This influence by number of cocks is because of the competition for mates that enhance an increase in variance of mating success (Nomura, 2002). Increasing the number of cocks would lead to significant increase in effective population sizes until such a point when additional increase is constrained by the number of hens. These effective population sizes were below 50 % of the actual population sizes. The sex ratio determined from the communal breeding population is more realistic than the ratio determined for individual households.

It is established that apart from major effect of sex ratio, variation in family sizes, especially for males play a second important role (Nomura, 2002) and causes an important deviation of the effective size from the breeding system of an ideal population with N_e = N (Falconer, 1989). Variance of family size from hens was considered negligible in the current study, based on the assumption that one mate could suffice production of fertile eggs per clutch. The significant difference between the N_es determined by the two equations; the low N_e/N ratios, and observed high correlations coefficients (r = 0.70) between number of cocks and N_e/Ns provide indication that variation in family sizes for cocks existed. Ratios of N_e/N plotted against different extrapolated proportions of males (Figure 5.4) further supports the role of family size variation. Using the curve for N_e (with variation in family sizes) to estimate desirable proportion of males in the breeding population is justified.

5.5.3 Implications of the estimated effective population size

Local chickens are bred as communal populations of small sizes and not as individual household flocks. Populations exist as sub-populations (where mating is effective) of a continuum of chicken population in the area. With such observed small population sizes dispersive processes may lead to local differentiation of sub-population due to random drift. A detailed assessment through randomly sampled DNA of chicken by each sub-region and the application of microsatellites could provide a better insight into this issue. Breeding stock exchange takes place in the villages (Gondwe and Wollny 2002) and this could limit extent of population dispersion. However, Gondwe et al. (1999a) observed that this breeding stock exchange took place between farmers within the same village. Current observations support this and furthermore, other birds exchanged for breeding ended up being consumed. The effects of breeding stock exchange need to be explored further. In this study, migration of breeding flocks was assumed to take place at random and therefore, averaging out.

The estimated rates of inbreeding per generation were significantly greater than normally acceptable ranges of 1 – 2 % (Henson, 1992). Assuming no counteracting forces, local chicken sub-populations are likely subjected to forces of inbreeding and random drift. General knowledge exists on the negative effects of inbreeding on phenotypic values especially fitness traits (Delany, 2003; Reed et al., 2003; Szwaczkowski et al., 2003) such as reproduction and viability. It is therefore, reasonable to speculate that some of the perceived constraints (especially on survival, see Chapter 4) are partly due to inbreeding effects. Small breeding population size for local chickens and the related consequences are therefore, constraints that require a breeding approach when developing improvement programs for rural chickens. Past efforts by government to improve local chicken production through crossbreeding programmes failed (Safalaoh, 2001). Failure to recognize the breeding structure and consequences of effective population sizes might have contributed to the programme collapse.

Sustainable means of minimising possible threats from inbreeding and breed differentiation need to be identified and included in the stepwise approach to improving local chicken production suggested by Kitalyi (1998). Observations from farmers themselves, and from analyses of trends of cocks and hens showed that farmers maintain breed stock for years. Longevity of breeding animals (especially females) is a characteristic of traditional breeding system in low input systems (Sölkner et al., 1998) and probably indicates farmers' goal to reproduce. With this situation in mind, the promotion of exchange of breeding cocks seems plausible. A cock represents a communal genetic resource and is a major contributor to the perceived inbreeding, by affecting both effective population sizes and distribution of family sizes. Change of sex ratio through increasing number of cocks is not an option due to possible cock fighting. Moreover, the observed sex ratio for the breeding population is within the suggested ratio of 6:1 to 8:1 that Jeyaruban and Gibson (1994) reported to be ideal at reducing inbreeding in laying poultry. Exchange of cockerels between neighbourhood flocks (i.e. community breeding populations) and from other areas will indirectly lead to increase in proportion of mating cocks and reduce the variance in family sizes.

5.6 Conclusion

Breeding structure showed that local chickens breed in groups of neighbourhood populations whose sizes are small, with potential high rate of inbreeding and population differentiation. Genetic hen material belong to an individual household while that from cocks belong to a community. It is apparent that farmers value hens as an asset to reproduce. Closely monitored interventions optimising existing breeding schemes need to operate both at household and community level. A community breeding stock exchange of breeding cocks seems a most plausible approach.

6. Marketing system and channels for scavenging local chickens in Lilongwe, Malawi[1]

6.1 Abstract

A study was conducted to identify marketing structure, players, prices and profit margins of local chickens in rural and urban Lilongwe, Malawi. One rural market (Mitundu) and two urban markets (Lilongwe and Kawale) were visited three times during dry season and two times during wet season from 2002 to 2003. Male middlemen sold both male and female local chickens of all phenotypes at the three markets. Middlemen at Mitundu bought their chickens from farmers and trading centres in surrounding villages and from Mozambique. Middlemen at urban markets bought chickens from rural and district markets and used public transport for the chickens. Purchasing, selling prices and profit margins were significantly ($p<0.05$) higher for urban markets than for the rural market. Selling prices for all markets were significantly ($p<0.05$) higher during dry season. Profit margins at urban markets were higher during wet than dry season. Chickens sold during dry season were heavier (1.50kg; SE 0.03) than during the wet season (1.38kg; SE 0.03). Live weights positively influenced pricing and profit margins. It is concluded that a marketing chain exists for local chickens. Farmers transact in form of cash and barter at village level, whereas afterwards male middlemen control the market.

Keywords: urban and rural market, local chicken, marketing chain

6.2 Introduction

Selling of local chickens is one of the functions of keeping free-range chickens observed during surveys and monitoring studies. The cash from sales is used to buy household needs including food to improve food security at household level (Kyvsgaard et al., 1999; Kondombo et al., 2003). Some farmers barter their free-range local chickens for food and household items. Missohou et al. (2002) reported that in Senegal, farmers exchanged six local chickens for one goat. Regardless of the mode of sales, this function ranks among the top three most important roles (food, income and socio – cultural) local chickens provide to households and communities (Dessie and Ogle, 2001; Mwalusanya et al., 2001; Ekue et al., 2002).

Marketing channels for local chickens include selling of chickens and eggs at households within the villages, on road sides, during entertainment ceremonies and even in local and city markets (Safalaoh, 1997; Ekue et al., 2002; Missohou et al., 2002). The market channels are described as informal and poorly developed (Branckaert and Gueye, 1999; Mlozi et al., 2003). On the other hand, free-ranging local chickens are claimed to be on demand and fetch high market prices in urban markets of Malawi, Nicaragua and many developing countries in Africa and Asia due to preferred attributes such as being tastier than improved broiler strains (Aini, 1990, Safalaoh, 1997; Kyvsgaard et al., 1999; Branckaert and Gueye, 1999).

Analysis of the marketing system for free-range chickens will help to determine the economic value and importance of local chickens. This information is required to characterise, conserve and develop the poultry genetic resource and to justify

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resource allocation to rural poultry improvement and conservation projects. Branckaert and Gueye, (1999) reported that an established market structure for free-range chickens is a prerequisite for developing family poultry. Even in breeding program development, indices require appropriate economic values that could be derived from such market studies. The current study focussed at studying the existing marketing structure of free-range chickens surrounding the catchments where community participatory village poultry studies were initiated (Gondwe et al., 2003). The objectives were to: (i) identify marketing of free-range chickens in local and urban markets; (ii) establish the marketing chains and players; (iii) determine market prices and estimate profit margins.

6.3 Materials and methods

6.3.1 Choice of markets of study

The study was conducted at three markets, Mitundu, Lilongwe and Kawale between 14 July and 23 August 2002 (during dry season) and between 21 January and 5 February 2003 (during wet season). The choice of these markets was to cover catchments of Mitundu and Mkwinda EPAs of Lilongwe Agricultural Development Division (LADD) where growth performance and constraints of free-range chickens were monitored (August 2002 to August 2003) assuming that at least a sample of the monitored chickens are sold through one of these markets. Mitundu is a local (rural) market open for sales of various food and non-food products. This market is within 15 km to the furthest villages of the study area. Most smallholder farmers in the study area sale and buy their products from this market. The market is approximately 55 km distant from the Mozambique border. Informal cross border trade, especially of foodstuffs, is taking place. Lilongwe market is located in the centre of the city and the distance to the study location is about 35 km. Kawale market is located on the outskirt of the Lilongwe city, five km from Lilongwe market. Both Lilongwe and Kawale markets serve urban communities.

6.3.2 Study protocol

The markets were visited in the morning at between 8:00 and 10:00 a.m. once per week. Each market was visited three times during dry season and two times during wet season. On the markets, locations where live free-range chickens were sold were identified with the help of market officials. After introductions, those selling chickens were briefed on the purpose of the visit. These sellers were asked questions written on a structured questionnaire. Information collected by asking or through observation included: (i) demography of the sellers in terms of their names, gender and education; (ii) number of chickens each seller had for sale; (iii) phenotypes and sex; (iv) source; (v) selling price; (vi) purchasing price; (vii) mode of transport.

Upon requesting the sellers, chickens were individually weighed using a digital scale (CA Kern, 5K5; Kern & Sohn GmbH, Germany) and prices, sex and phenotype were recorded. Based on interviewing traders, transport costs were recorded during the rainy season only. Market levies were fixed at MK5.00[2] per seller per day. In total, 42

[2] 1 US$ = MK85.00

middlemen were interviewed during the study. Of the observed sales, 53 % were during the dry season; 47% during wet season.

6.3.3 Price portfolios and profit margins

Since prices were pegged per live bird, these were converted into per unit live weight for each chicken by dividing price by live weight. Transport costs and levies were taken as transaction costs. Sellers' purchase price of chickens at farmer level was taken as farm-gate price. Profit margins were calculated by subtracting purchasing prices and transaction costs from the selling price.

6.3.4 Data analyses

Quantitative data were subjected to analysis of variance using general linear model (GLM) procedure of Statistical Analysis System (SAS, 1999). Qualitative data were analysed for descriptive statistics using frequency procedures and cross-tabulation of SAS. Appropriate statistical tests were applied to see the effect of factors that may be associated with marketing of local chickens. These factors included season, phenotype, market and sex of chickens. The following linear model was used during analysis of quantitative data

$$y_{ijklm} = \mu + m_i + s_j + p_k + ß_{ijkl} + \varepsilon_{ijklm} \qquad (6.1)$$

Where

y_{ijklm} is the market parameter (price, weights) estimate for bird *m* on market *i*
μ is the overall mean
m_i is the fixed effect of market (i = 1,2,3)
s_j is the fixed effect of season (j = 1,2)
p_k is the fixed effect of phenotype (k = 1,2,3,4,5,6)
$ß_{ijkl}$ is the fixed effect of sex of bird (l = 1,2)
ε_{ijklm} is the residual error

6.4 Results

6.4.1 Market channels and players in local chicken marketing

Local chickens were sold at the three markets. In addition, live goats were also sold at Mitundu market, and sometimes at Kawale. Chickens were the only species sold alive at Lilongwe market. At Kawale and Lilongwe markets, live broiler and culled layer chickens were also sold. All other livestock were sold as meat at the three markets. Presence of local chickens showed that existing commodity markets are used to sale the chickens.

Only male middlemen were involved in selling local chickens. Table 6.1 shows levels of education of middlemen. At Kawale market, majority had attained secondary education. Educational level of the middlemen was highly variable ranging from illiterate to secondary school and differed widely by market.

Table 6.1. Education status of the middlemen involved in selling local chickens (percent of number of observations) within market

Educational level	n	Mitundu	Lilongwe	Kawale
		n = 186	n = 140	n = 142
None	33	13.98	-	4.93
Lower primary (< STD 5)	128	30.65	50.71	-
Upper primary (up to STD 8)	176	41.94	45.00	24.65
Junior Secondary (Form 2)	52	8.06	4.29	21.83
Secondary school leaver (Form 4)	79	5.38	-	48.59
		100.00	100.00	100.00

n = number of observations on the seller according to chicken entries per educational level (rows) and market (columns); STD = Standard, a classification system for grades in primary education

6.4.2 Number of chickens available for sale, their live weights and prices

Mean numbers of chickens sold per middleman per day on each market are shown in Table 6.2 while their live weights; purchasing and selling prices by season are presented in Table 6.3. Local chicken market prices per chicken for Lilongwe and Kawale were significantly ($p<0.05$) higher than those of Mitundu. Kawale offered highest prices per live chicken. Seasonal selling price differences were significantly different for Mitundu market only. For all markets, dry season prices for chickens were higher than wet season prices. Selling prices per kg followed the trend of live chicken prices during dry season.

Table 6.2. Mean number of local chickens sold at the market per middleman per day

Season	Mitundu			Lilongwe			Kawale		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Dry	13	13.6	7.7	4	24.9	12.2	5	21.8	11.8
Wet	13	7.2	4.1	5	33.6	18.9	5	32.2	15.6

n = number of middlemen

Sellers at Mitundu market bought their chickens at significantly lower purchasing prices than those who were selling at Lilongwe and Kawale. Wet season purchasing prices were significantly ($p<0.05$) lower than dry season prices.

Live weights did not differ significantly ($p>0.05$) between markets during the dry season. During the wet season, chickens found at Kawale market were significantly heavier ($p<0.05$) than those at Lilongwe and Mitundu markets. Chickens sold at Mitundu were significantly heavier ($p<0.05$) during dry season than wet season.

6.4.3 Sources and demography of chickens sold

Middlemen bought their chickens from 22 different sources (Table 6.4). It was found that these sellers bought chickens from different places. Buying appears to follow a pattern specific for each market. For example, common sources for chickens sold at Mitundu came from trading centres that surround the market. These are places within rural areas servicing as village markets for rural communities that comprise several neighbouring villages. For Mitundu, other chickens came from villages across the border in Mozambique. Chickens sold at Lilongwe and Kawale markets came mostly

Table 6.3. Least square means for number and live weights of chickens sold, their purchasing and selling prices by market and season.

Parameter	Season	Mitundu (n = 186)		Lilongwe (n = 140)		Kawale (n = 142)		Overall (n = 468)	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Live weights of chickens sold (kg)	Dry	1.49	0.04	1.50	0.05	1.52	0.06	1.50	0.03
	Wet	1.28^{b}	0.05	1.35^{b}	0.05	1.52^{a}	0.05	1.38	0.03
Market selling price per live chicken (MK)	Dry	182.82^{b}	4.10	214.87^{a}	4.87	221.48^{a}	5.51	206.39*	2.81
	Wet	130.72^{b}	4.93	214.19^{a}	5.46	218.46^{a}	4.78	187.79*	2.92
Market selling price per kg live weight (MK)	Dry	129.05^{b}	2.86	151.15^{a}	3.39	149.05^{a}	3.84	143.08	1.96
	Wet	107.94^{c}	3.44	162.14^{a}	3.81	146.80^{b}	3.33	138.96	2.04
Sellers purchasing price per chicken (MK)	Dry	140.41^{b}	3.74	165.90^{a}	4.44	171.64^{a}	5.02	159.32*	2.56
	Wet	104.28^{b}	4.50	146.21^{a}	4.98	150.12^{a}	4.35	133.54*	2.67
Seller's purchasing price per kg live weight (MK)	Dry	99.15^{b}	2.31	115.05^{a}	2.74	114.23^{a}	3.10	109.47*	1.58
	Wet	84.52^{c}	2.78	108.97^{a}	3.08	99.83^{b}	2.69	97.77*	1.65

n = number of chickens observed to be sold and weighed; ^{abc}Means within row with different superscripts show significant differences between markets (p<0.05); * = shows that seasonal differences are significant (p<0.05); 1 US$ = MK85.00

Table 6.4. List of places where sellers buy their chickens for sale at the three markets

Mitundu market		Lilongwe market		Kawale market	
Kambanizithe	*Trading Centre*	Mangochi	*District*	Mitundu Turn – off	*Road from Mitundu*
Kampini*	*Trading Centre*	Mitundu*	*Local Market*	Ntcheu*	*District*
Mozambique**	*Villages along the border*	Mvera	*Local Market*	Lizulu*	*Local Market*
Namagaula	*Trading Centre*	Namitete	*Local Market*	Nsundwe**	*Local Market*
Nsundwe	*Local market*	Nanjiri*	*Local Market*	Mchinji	*District*
Chiunjiza	*Trading Centre*	Salima*	*District*	Machinga	*District*
Other sellers	-	Ulongwe	*Local Market*	Mtakataka	*Local Market*

Description of sources are presented in italics in following column; ** = very important sources (> 30 % of all birds); * = important sources (>15 % of the birds); District = may imply purchased from that district or from local markets from the district from local rural markets. Other sources were reported just as districts. The districts and other sources mentioned are far from the markets (Figure 6.1).

Demographic characteristics of chickens sold at the markets included description of their sex and phenotypes. These together with transport used to bring the chickens to the markets are presented in Table 6.5. Both sexes of chickens were sold at the markets. More females than males were available for sale at Mitundu and Lilongwe markets. All common phenotypes for local chickens were sold at the markets and included *Yakuda, Kawangi, Mawanga*, *Yofiira* and *Yoyera*. *Chiphulutsa* was least available in all markets. *Kansilanga, Kameta* and *Kachibudu* were only found at Lilongwe and Kawale markets.

Chickens were carried to Mitundu market on bicycles. Other sellers just walked to the market with their chickens. However, public transport was the important mode of transport to bring chickens to Lilongwe and Kawale markets from the different sources.

Figure 6.1. Map of Malawi showing sources of local chickens sold at Lilongwe and Kawale markets

Table 6.5. Demographic characteristics of chickens sold at the markets and mode of transport used (expressed as percentage of observations within market)

Parameter		Mitundu	Lilongwe	Kawale
		n = 186	n = 140	n = 142
Sex of chickens sold	Males	36.02	32.86	50.00
	Females	63.98	67.14	50.00
Phenotypes of chickens[1]	*Yakuda*	37.63	35.71	25.35
	Mawanga	9.14	9.29	20.42
	Kawangi	22.04	24.29	23.24
	Yoyera	9.68	8.57	14.08
	Yofiira	15.05	10.00	7.75
	Kansilanga	-	0.71	-
	Kameta	-	2.86	1.41
	Kachibudu	-	-	1.41
	Chiphulutsa	6.45	8.57	6.34
Transport type	Bicycle	91.94	-	-
	By foot	8.06	-	-
	Public transport	-	100.00	100.00

[1]Local names are described in Chapter 3.

6.4.4 Where are farmers in the marketing chain for local chickens?

A structure of free-range chicken marketing is described diagrammatically in Figure 6.2. Local chickens from villages found their way to urban markets through local markets. Male middlemen were in control on the markets. Household flock dynamics (Chapter 4) showed that farmers sold chickens to fellow farmers and middlemen, either directly for cash or through exchange with household items. Female members of households dominated in selling chickens at farm level, especially where sales were through barter. Bartering took place at households especially between farmers and middlemen. Farmers themselves sold their chickens even at trading centres. Participation of farmers in marketing of free-range chickens is at their households and at trading centres. Middlemen control the rest of the channel.

6.4.5 Profit margins of the middlemen

Profit margins before and after transaction costs (TC, Table 6.6) at different markets are presented per live chicken and per unit of live weight (Table 6.7). Significant differences and trends observed in the profit margins follow the pattern observed for prices (Table 6.3). Seasonal differences in profit margins before TC were significant ($p<0.05$) for all markets. Both margins per live chicken and per unit weight were higher in wet than dry season for Lilongwe and Kawale. The reverse was observed for Mitundu market.

6.4.6 Effects of sex, phenotype and live weights of chickens on price and margins

Effects of sex of chickens (Table 6.8) showed that male chickens had significant ($p<0.05$) higher purchasing and selling prices, and profit margins per live chicken than female chickens. But when these were compared on per unit live weight basis, female chickens had higher values than male chickens (p<0.05). Respective Pearson correlation coefficients were negative between live weight of chickens and selling price per unit weight (r = -0.45) and between live weight and purchasing price per unit weight (r = -0.31).

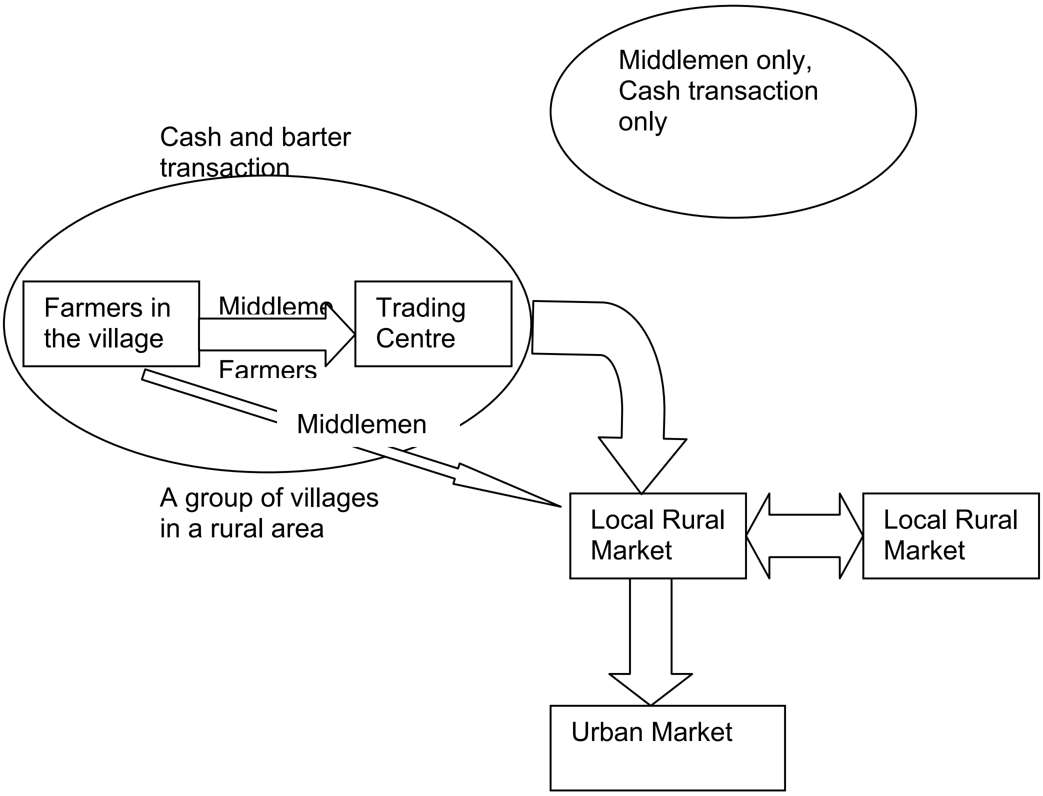


Figure 6.2. Marketing channels, players and flow for local chickens from producers to users

Phenotype did not have significant effects (p>0.05) on pricing and margins for local chickens.

Live weights of local chickens positively influenced purchasing and selling prices but not profit margins. Pearson correlation coefficients were 0.76 for purchasing price, 0.74 for selling price and 0.29 for profit margins (p<0.05, n = 468). Correlation coefficients were 0.59 for selling price and profit margin while they were 0.25 for purchasing price and profit margins.

Table 6.6. Average transaction costs (transport and levy) per bird by market and season

Parameter		Mitundu			Lilongwe			Kawale		
		n	Mean	SD	n	Mean	SD	n	Mean	SD
Market levy	Dry	110	2.03	1.44	78	1.02	0.52	61	1.39	0.97
	Wet	76	3.77	1.98	62	0.93	0.75	81	0.99	1.20
Transport costs[1]	Wet	-	-	-	46	10.80	5.86	81	9.82	10.52
Overall transaction costs (TC)[2]	Dry	110	2.03	1.44	78	1.02	0.52	81	1.39	0.97
	Wet	76	3.77	1.98	46	11.61	6.63	81	10.82	11.06

[1]Transport costs recorded during wet season only. [2]TC for Mitundu considered levies only, same for dry season TC for all markets; n = number of chickens observed; 1 US$ = MK85.00

Table 6.7. Least square means for profit margins from sales of local chickens by market and season

Parameter		Mitundu			Lilongwe			Kawale		
		n	Mean	SE	n	Mean	SE	n	Mean	SE
Profit margins before TC (MK)										
Per live chicken	Dry	110	42.41[b]	1.40	78	48.97[a]	1.66	61	49.84[a]	1.88
	Wet	76	26.45[b]	1.68	62	67.98[a]	1.86	81	68.33[a]	1.63
Per kg live weight	Dry	110	29.90[b]	1.34	78	36.10[a]	1.60	61	34.83[a]	1.81
	Wet	76	23.42[c]	1.67	62	53.18[a]	1.79	81	46.97[b]	1.57
Profit margins after TC (MK)[1]										
Per live chicken	Wet	76	22.68[b]	1.79	46	54.91[a]	2.30	81	57.52[a]	1.73
Per kg live weight	Wet	76	20.07[b]	1.76	46	41.51[a]	2.26	81	39.18[a]	1.71

TC = Transactions costs, covering transport and market levy; [1] TC for Mitundu considered levies only; n = number of chickens observed; [abc] Means within row with different superscripts show significant differences between markets ($p<0.05$); 1 US$ = MK85.00

Table 6.8. Least square means for effect of sex of chicken sold on different parameters

Parameter	Female chickens (n = 284)		Male chickens (n = 184)	
	Mean	SE	Mean	SE
Live weights, kg	1.24[b]	0.02	1.76[a]	0.03
Selling price, MK per chicken	179.89[b]	2.25	224.19[a]	2.82
Selling price, MK per kg	147.53[a]	1.74	130.77[b]	2.18
Purchase price, MK per chicken	131.18[b]	2.07	170.45[a]	2.59
Purchase price, MK per kg	106.70[a]	1.44	98.78[b]	1.81
Profit margin before TC, MK per chicken	48.71[b]	0.87	53.75[a]	1.09
Profit margin before TC, MK per kg	40.83[a]	0.81	31.99[b]	1.02

6.5 Discussion

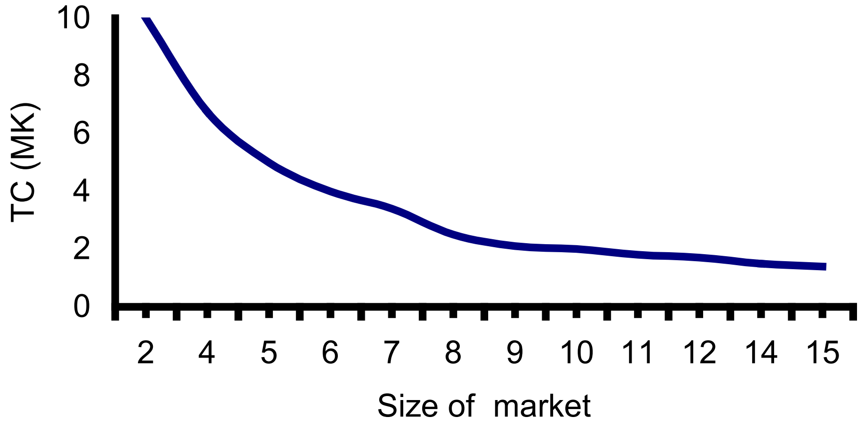
6.5.1 Marketing of local chickens

Results show a connected marketing structure that transfers free-range chickens from producers in rural households to consumers in both rural and urban areas. Middlemen operating in marketing of free-range chickens were also reported in Tanzania (Mlozi et al., 2003), Ethiopia (Dessie and Ogle, 2001) and other countries (Kitalyi, 1998). Dessie and Ogle (2001) observed that farmers could sell their chickens directly at local markets; thereafter, middlemen took over. Though Mlozi et al. (2003) reported presence of women selling processed chickens at the markets, these were not farmers but vendors. The players observed in the study, therefore, agree with those reported in other countries. The market is informal at household level and village-trading centres where farmers participate in. Transactions through barter are also common. After that, middlemen operate local chicken marketing as their main business occupation.

The seasonal trends on numbers available on the markets, pricing and profit margins differed between the rural and the urban markets. Ekue et al. (2002) reported that farmers sell chickens to meet their household needs especially food during wet season. During the dry season, farmers sell their chickens instead of losing them through death from Newcastle disease (Safalaoh, 1997; Dessie and Ogle, 2001; Mlozi et al., 2003). These factors operate at household (farm) level, influence bargaining power of farmers when selling their chickens (Mlozi et al., 2003), and contribute to the seasonal variations. Supply and pricing of chickens at a local market are bound to be affected, reflecting the observations at the rural market. Urban markets counteract these forces by diversifying sources of their chickens depending on market information. The different sources of chickens supplied at urban markets also provided opportunity for more phenotypes observed at these markets than those sold at the rural market.

6.5.2 Transaction costs and profit margins

Transaction costs per bird per middleman were a fixed cost related to size of market (Figure 6.3). These TCs decline at disproportional rate as market size increases.



TC = Transaction costs per bird per middleman; MK = Malawi Kwacha

Figure 6.3. Transaction costs per bird per seller as influenced by size of market (number of chickens sold per middleman)

Farmers sold less than two chickens per month and this would mean high TCs if individually transported and offered at the market. High TCs associated with fewer chickens sold are possible limitation of farmers from selling their chickens at the rural markets. Middlemen at the rural markets such as Mitundu minimised TCs by using bicycles or by just walking to the market. Middlemen in urban markets used public transport to reach distant local market places, so their market sizes had to be large enough and their prices had to absorb TCs.

The higher positive profit margins observed in urban markets than in rural market are comparable to other countries. In Tanzanian markets, middlemen generated 65 % profit margins above what farmers got (Mlozi et al., 2003). Kitalyi (1998) reported that household level prices for chickens were one third that offered at urban markets, also reflecting higher profit margins for middlemen. Most likely seasonal food shortage results in weak bargaining power of farmers.

6.5.3 Effect of sex, phenotype and live weights

The current system of the live chicken market attracts higher profit margins for male than female birds but not per unit of live weight. The influence of phenotype on number of chickens sold, just like the sex effect, merely reflected the relative prevalence of different phenotypes among flocks in rural households (Gondwe et al., 1999a). All phenotypes were available for sale, hence, improving all free-range chicken genetic resources have marketing justification. On per live chicken basis, pricing of free-range chickens was strongly and positively influenced by size of chickens. Sellers do not use weighing scales but estimate weight of chicken by assessing its size and by handling the chicken. The higher positive correlation between selling price and profit margin (r = 0.59) than between purchasing price and profit margin (r = 0.25) shows that selling price determines the profit margins realised.

6.6 Conclusion

This study has found that market for local chickens exists in both rural and urban areas. Both sexes and phenotypes are sold. Marketing at village level takes place through cash and direct barter transaction. Thereafter, marketing of local chickens transact in cash and is controlled by middlemen. While farmers sell chickens to obtain household needs, middlemen operate to make profits and reduce transaction costs. The current system offers prices per live chicken and in this situation, male chickens provide more profit than females on per piece basis. Finally the study has established prices, transaction costs and profit margins of the market chain from producer to consumer of local chickens at different levels. This information could be utilised in valuing the local chicken genetic resources, guiding production and marketing management interventions as well as in developing breeding programs.

7. Phenotypic and genetic analysis of growth and growth curve parameters of local chickens raised under scavenging conditions on-farm and on-station in Malawi[1]

7.1 Abstract

A study was conducted to characterise phenotypic and genetic traits of growth and growth curve parameters of local chickens on-station (n = 1119 at hatch) and on-farm households (n = 2430). Wing tagged hatchlings identified by their dam hens (on-farm) and their dam hens and cocks (on-station) were weighed weekly. Laird form of Gompertz function was fit to data and initial specific growth rate (L), maturation rate (K), age (T_i) and weight (BW_i) at point of inflection (i) were estimated. Genetic parameters for body weights (n = 1125, 539, 292, 248 at hatch, weeks 5, 10 and 15, respectively) and parameters of growth function (n = 299, 318, 318, 256 for L, K, T_i and BW_i, respectively) were estimated using AIREML procedure.

Growth curve fit measured by coefficient of determination (R^2) was 0.86 on-station and 0.82 on-farm. The fit was better for females than males after 20 weeks. Place of study significantly ($p<0.05$) influenced hatch weights and body weights at week 20 only. Males were significantly ($p<0.05$) superior to females after week 10 for body weights. T_i and BW_i averaged 16.4 and 14.7 weeks, 592 and 445 g, on-station and on-farm, respectively. Heritability estimates were moderate to high, ranging from 0.39 to 0.56. Maternal and common environmental effects were pronounced for body weights and L, but were absent for K, T_i and BW_i. Genetic and phenotypic correlations among growth and growth curve parameters were similar in magnitude and direction. Genetic correlations were high and positive between L and body weights at weeks 5 (0.59), 10 (0.67), and 15 (0.73). Thus improving L through selection will change the growth form of local chickens and, through correlated response, improve their juvenile growth. The study has demonstrated potential to improve growth performance of local chickens genetically through selection of growth traits or growth curve parameters under scavenging conditions.

Keywords: local chickens, growth curve parameters, heritability, scavenging

7.2 Introduction

In Malawi, the poultry sector is predominantly chicken, of which about 80 % (approximately 8 million) are non-characterised local, raised in smallholder rural communities (Malawi Government, 1999a). More than 85 % of the human population (currently estimated at 12 million) lives in rural areas and mainly practice subsistence oriented mixed crop-livestock farming (NSO, 2003). Of all livestock, local chickens are the most widely kept by farmers (Safalaoh, 1997; Gondwe et al., 1999a). Scavenging is the sole production system for local chickens, just like in most African countries (Kitalyi, 1998; Dessie and Ogle, 2001; Mwalusanya et al., 2001; Kondombo et al., 2003). These local chickens are raised using low inputs (land, labour, capital) and this offers an opportunity for even the marginalized members in the communities to keep chickens (Gueye, 1998). Outputs from local chickens are acknowledged to be low per bird or per flock but are diverse, ranging from food, income, social, cultural and religious values (Benabdeljelil and Arfaoui, 2001; Muchadeyi et al., 2004). The

[1] Paper to be submitted to British Poultry Science

commercial, intensive production sector is unstable in most African countries due to feed, animal health and resource constraints (Branckaert and Gueye, 1999). This makes local chickens to remain an important livestock with multiplier effect of products due to majority farmers keeping them, though in small flock sizes of 5 - 20 in many countries (Gueye, 1998).

In the late 1990s, local chickens and their potential contribution to rural household food security and genetic resources became increasingly recognised (Kitalyi, 1998; Marle-Köster and Casey, 2001; Dolberg, 2003). Most growth characterisation studies on local chickens were conducted on research institutions using modern intensive management and commercial feeding. Technologies developed on a different production system encounter problems of adoption and genotype by environmental interactions (Lin and Togashi, 2002; Prado-Gonzalez et al., 2003). Detailed on-farm growth studies under actual scavenging production systems, where farmers could participate are scanty while studies to analyse growth forms and genetic parameters of local free-ranging chickens are missing. Growth curves parameters summarise the description of the form of growth (Knizetova et al., 1991; Sorensen and Ducro, 1995) while genetic parameter estimates are useful for genetic improvement. The study was conducted with the following objectives: (i) to evaluate and compare growth performance of local chickens raised under scavenging conditions on-farm and on-station; (ii) to estimate and analyse growth curve parameters; (iii) to estimate genetic parameters.

7.3 Materials and methods

7.3.1 Study area

An on-station study was carried out at Bunda College of Agriculture (BCA) while an on-farm work was carried out on about 134 Village Poultry Project (Gondwe et al., 2003) participating households in 27 villages of Mkwinda and Mitundu Extension Planning Areas (EPA) of Lilongwe Agricultural Development Division (LADD). Details of farmer demography from the villages, livestock distribution, farmer-researcher community participation and climatic features are outlined in Chapter 3.

7.3.2 Study animals

Hatchlings from local chickens of different phenotypes were monitored for their growth in the study, both on-farm and on-station (referred to as places of study in this paper). On-farm, individual farmers' hens whose flocks participated in the study hatched these chicks. On-station, source of hens and cocks is described in Chapter 3. Number and demography of chicks monitored during the study period June 2002 to October 2003 are shown in Table 7.1.

7.3.3 Management of chickens

All chickens, both on-farm and on-station were raised under free-ranging, scavenging condition. On-farm, farmers managed their flocks as is traditionally practiced. Mating was not controlled, hens laid and incubated their eggs, and brood their hatchlings. Weaning was natural. Farmers supplemented their chickens with maize bran, maize grits, brewers' wastes and maize depending on availability of feedstuffs (Chapter 4). A similar practice was used on-station because the intention was to copy farmers' practice. Maize bran (10.1 % CP, as fed) was regularly supplemented because it was the major feed supplement to local chickens by households. Diseases and parasites were treated once diagnosed, while Newcastle was prevented by a village vaccination program.

Table 7.1. Demography of local chickens by number of records

Parameter		Frequency	
		Number	Percent (%)
Place of study	On-station	1119	31.53
	On-farm households	2430	68.47
Season of hatch	Hot-wet	1030	29.04
	Cold-dry	2010	56.67
	Hot-dry	507	14.29
Sex of birds[1]	Female	983	69.27
	Males	436	30.73
Phenotypes by feather colour[2]	*Chiphulusa*	298	8.95
	Kawangi	154	4.43
	Mawanga	299	8.61
	Yakuda	1392	40.02
	Yofira	694	19.98
	Yoyera	637	18.34
Clutch of hatch[1]	One	1357	40.78
	Two	748	22.48
	Three	463	13.91
	Four and above	760	22.83

[1]Only birds with sex identified; [2]local names described in Gondwe et al.(1999a) and Chapter 3

7.3.4 Pedigree structure on-station

The mating design on-station followed randomly allocating breeding cocks to hens by enclosing them in a deep litter house demarcated into pens of 1.5 x 2.0 m (Figure 3.7, Chapter 3). Each pen housed three hens and one cock could rotate between two pens every day. In the course of the study, it occurred frequently to have fewer than three hens per pen due to shortage of breeding hens. On average, the house contained 15 cocks for breeding. New cocks were introduced to replace those that had served about five hens. Locally made traditional nesting boxes were placed inside the pens. Laying hens were closely monitored to make sure each lays in a different nest. This was based on the behaviour that local hens remember their nest (Marx et al., 2002). Cackling of a hen, a special sound soon after laying (Schönau, 2002), was signalling research assistants to visit the nest and to record the egg by date of lay, hen identity and order of lay on the egg using a pencil. These were also entered onto a record sheet with the colour of the egg. Throughout the study, all hens started laying at different times and in most cases, egg colours differed between hens.

Once finished laying, the hen incubated the eggs. Hens were released to the free-range environment soon after hatch. Three sites of the farm, approximately 1000 m apart were used as rearing units. However, some hens came from participating farmers in the villages. Once hatched, these hens were carried back to farmers and were monitored while they remained on-farm.

During mating and incubation in pens, hens and cocks were fed on-farm formulated breeders mash (17 % CP, 2800 kcal / kg ME). Water and feed were provided *ad libitum* in feed troughs and clay pots.

7.3.5 Bird identification and sex determination

All parent hens and cocks, and their offspring were individually tagged with numbered wing bands, both on-station and on-farm. Due to high early mortality (13.36 % of all hatched chicks by week 1 and 43 % by week 5), hatchlings were only tagged after one week. Sex of chicks was visually identified between 8 and 10 weeks.

7.3.6 Data collection

Data on growth included live weights collected from weekly weighing of chicks from day old. On-farm (demarcated into three areas depending on remoteness, see Chapter 3), research assistants and farmers themselves did the weighing early in the morning, before releasing the birds. A grace period of two days was allowed to record weight for the week, in situations of funerals and other emergencies in the community. On-station research assistants recorded live weights (Table 7.2). Sex, phenotype by colour and date of weighing were also recorded. Hanging digital scales (CA Kern, 5K5; Kern & Sohn GmbH, Germany; maximum of 5 kg, graduated to 2 g) were used during the weighing. Extreme differences between numbers of chicks at hatch and at 30 weeks are due to chick mortality caused by diseases, parasites and predation. However, after 20 weeks, farmers were also consuming chickens from their flocks.

7.3.7 Data analysis

7.3.7.1 Growth and growth functions

Growth rate was determined by absolute daily growth rate calculated by dividing the difference in live weights at five weeks interval by the number of days. Exponential (specific) growth rate (EGR) was calculated for five weekly intervals as follows (Brody, 1945)

$$EGR_i = \frac{(\ln BW_i - \ln BW_o)}{t_i - t_o} * 100 \qquad (7.1)$$

Where

$\ln BW_i$ is the natural log of body weight at age $_i$; $\ln BW_o$ is the natural log of initial body weight at age $_o$; t_i - t_o is the five week period in days

Table 7.2. Descriptive statistics for weight (g) of local chickens

Parameter		n	Mean	SD	Minimum	Maximum
On-station						
Hatch weight		1113	30.1	5.1	18	55
Week	1	779	38.0	9.3	20	93
Week	5	539	121.6	50.5	40	242
Week	10	279	287.6	90.7	100	595
Week	15	214	522.8	160.7	220	1115
Week	20	177	777.5	220.7	305	1520
Week	25	118	1023.7	276.4	420	1790
Week	30	95	1222.1	292.1	525	1865
On-farm						
Hatch weight		2403	29.7	5.1	14	54
Week	1	2054	48.7	12.0	22	95
Week	5	1633	124.5	48.1	45	400
Week	10	959	277.9	91.3	90	775
Week	15	600	479.0	156.7	225	1095
Week	20	300	724.8	259.9	335	1705
Week	25	165	995.5	306.4	560	1970
Week	30	87	1312.0	340.8	750	2135

n, number of birds; SD, Standard deviation

7.3.7.2 Growth curve functions

To describe the growth form of local chickens, a three parameter Laird form of Gompertz curve function (Mignon-Grasteau et al., 1999) was fit to the data:

$$BW_t = BW_o x e^{\left(L/K\right)\left(1-e^{-Kt}\right)} \quad (7.2)$$

where BW_t is the body weight at age *t*; BW_o is the hatching weight; *L* is the initial instantaneous (specific) growth rate, $1/BW_t \; x \; dBW_t/dt$ as $t \to 0$ (Brody, 1945) that characterises the pattern of growth before point of inflection; *K* is the exponential rate of decay of *L* that describes the maturation rate in the second part of the curve where growth decreases until the animal reaches asymptotic (final) weight.

The parameters *L* and *K* were estimated for individual birds using NLIN REML iterative (Method, Gauss-Newton) procedure of SAS (SAS, 1999). The parameter BW_o was not estimated, instead, actual hatch weights were used as suggested by Mignon-Grasteau et al. (1999). The function was fit to weights from hatch to 30 weeks. Birds that died before 10 weeks had their body weights data discarded.

Age (T_i) and body weight (BW_i) at point of inflection, where growth rate is maximum were estimated as follows:

$$T_i = \frac{1}{K} x \ln\left|\frac{L}{K}\right| \quad (7.3)$$

$$BW_i = BW_o e^{\left[\left(L/K\right)-1\right]} \quad (7.4)$$

T_i was skewed distributed, hence, was natural log transformed. All other parameters were normally distributed (tested by univariate procedure; SAS, 1999).

7.3.7.3 Models

Body weights and growth rate data were analysed using the following mixed linear model

$$y_{ijklmn} = ɥ + b_i + c_{ji} + s_k + p_l + h_m + t_n + (bw)_{io} + (sw)_{ko} + (hw)_{mo} + (tw)_{no} + a_{ijklmn} + w_o + h_p + \varepsilon_{ijklmn} \quad (7.5)$$

Where

y_{ijklmn} is the observed measure for bird n in week o; ɥ is the overall mean common to all birds; b_i is the fixed effect of place of production (i = on-station, on-farm); c_{ji} is the fixed effect of site as replicate within place of production (three locations on-station and three locations on-farm); s_k is the fixed effect of sex of bird (k = 1,2); p_l is the fixed effect of phenotype by colour of bird (l = 1,2,3,4,5,6); h_m if the fixed effect of hatch number of the bird (m = 1,2,3,4); t_n is the fixed effect of season of hatch (n = hot-wet, cold-dry and hot-dry); a_{ijklmn} is the random effect of bird within hen; w_o is the fixed effect of age of birds in weeks (n = 1,2 …, 30); h_p is the random effect of hen; ε_{ijklmn} is the residual error at particular period o assumed NID (0, $\sigma^2\varepsilon$); Parameters in brackets represents two-way interactions.

Proc Mixed REML procedure (Method, Compound Symmetry) of SAS (1999) was used to analyse the data to take into account the repeated measures and model the variance-covariance matrix structure (Littel et al., 1998) among measures and test the fixed effects adjusted for the covariance (Wolfinger and Chang, 1995).

Parameters of growth curve were analysed using the following mixed linear model

$$y_{ijklmn} = ɥ + b_i + c_{ji} + s_k + p_l + h_m + t_n + (bs)_{ik} + (bh)_{im} + (bt)_{io} + h_n + \varepsilon_{ijklmn} \quad (7.6)$$

with effects defined as in model 7.5. Proc Mixed procedure was also used in a simple way like General Linear Model procedure. For all parameters, least square means were computed and significant differences were determined by least significant difference using Pdiff procedure (SAS, 1999). Phenotypic correlations among traits were determined using proc Corr procedure by correlating residuals to adjust for model effects.

7.3.7.4 Heritability estimates and genetic correlations

Heritabilities were estimated from pedigree data on-station using the following animal mixed model equation

$$y = X\beta + Z\text{ɥ} + Wm + \varepsilon \quad (7.7)$$

where y is a column vector of phenotypic observations; β is a column vector of fixed effects (mean, covariates and systematic environmental effects, place, bird sex, hatch number and season of hatch); ɥ is a column vector of animals' breeding values, ~IND (0, A σ^2_a), where $\sigma^2_a = V_A$, the additive genetic variance, A being the coefficient relationship matrix that contains additive genetic relations among the animals; m is a column vector of maternal effects, ~IND (0, σ^2_m); assume cov(ɥ, m) = 0; X,Z,W are incidence matrices relating fixed effects, breeding and maternal effects, respectively, to the observations (y); ε is a vector of residuals, ~IND (0, σ^2_ε).

Each trait (Table 7.3) was analysed separately using AIREML (Gilmour et al., 1995) due to limited data and consideration of different fixed effects. Heritabilities for each trait were estimated by dividing the additive genetic variance (σ^2_a) by phenotypic variance (sum of σ^2_a, σ^2_m and σ^2_ε). Similarly maternal effects were estimated using σ^2_m as numerator. Genotype correlations were determined by correlating the breeding values for each trait using proc Corr procedure (SAS, 1999).

Table 7.3. Structure of data used in determining genetic parameters and the variance components

Trait	Fixed effects	Records	Cocks	Hens	σ^2_a	σ^2_m	σ^2_ε
BW_o	1, 3, 4	1125	42	147	12.54	10.24	3.06
BW_5	1, 3, 4	539	40	119	895.20	1203	0.11
BW_{10}	1, 2, 3, 4	292	36	83	2008	2231	907.6
BW_{15}	1, 2, 3, 4	248	35	78	2640	1392	1617
L	2, 3, 4	299	36	83	0.0035	0.0026	0.0015
K	1, 3	318	38	90	0.00036	-	0.00004
T_i	1	318	38	90	0.1011	0.00002	0.1111
BW_i	1, 2	256	35	78	16480	2.678	24260

BW_0, Hatch weight; BW_5, BW_{10}, BW_{15}, body weights at weeks 5, 10 and 15, respectively; *L*, initial specific growth rate; *K*, exponential rate of decay; T_i, age at point of inflection; BW_i, weight (g) at point of inflection; σ^2_a, additive genetic variance; σ^2_m, maternal variance; σ^2_ε, residual (environmental) variance; Fixed effects, 1 = place, 2 = bird sex, 3 = hatch number, 4 = season of hatch

7.4 Results

7.4.1 Live body weights

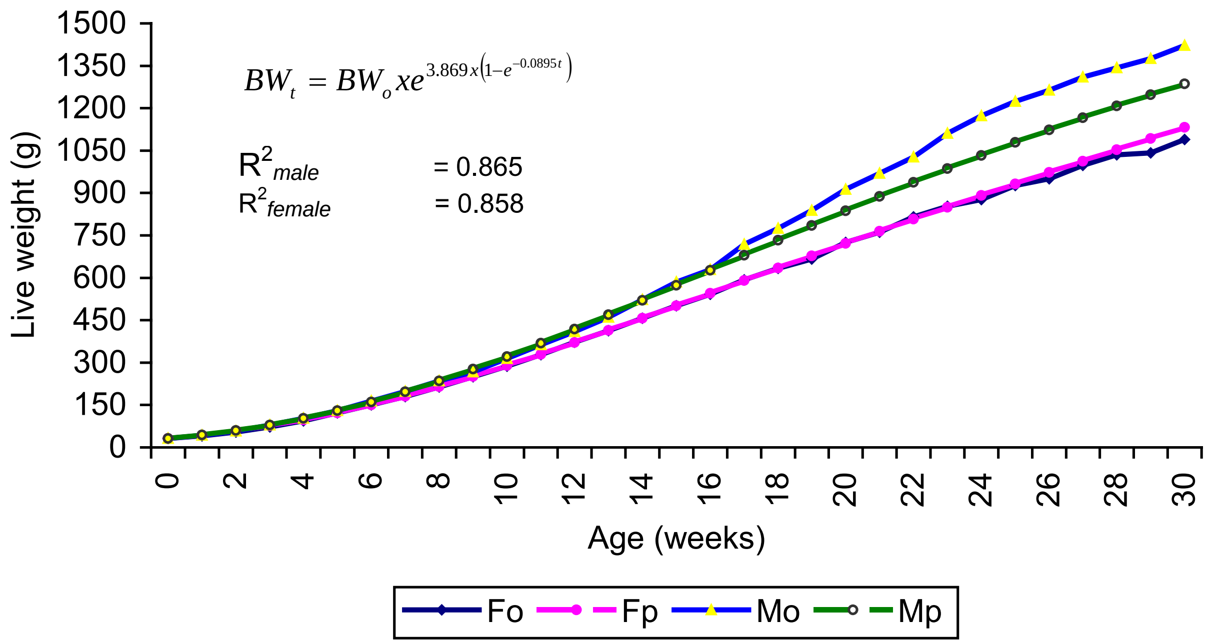
Figures 7.1 and 7.2 show cumulative growth of local chickens on-station and on-farm, respectively. Lsmeans for live weights at different age are shown in Table 7.4. Hatch weights and body weights at 20 weeks were significantly ($p<0.05$) higher on-station than on-farm. Body weights at other ages were similar ($p>0.05$). Sexual dimorphism was expressed after 10 weeks when males were significantly ($p<0.05$) 9 %, 14.6 % and 20.8 % heavier than females at 15, 20 and 30 weeks respectively. Season significantly ($p<0.05$) influenced live weights but without following a specific trend. For example, cold-dry season hatched birds had least body weights ($p<0.05$) at weeks 15 and 20 but became similar ($p>0.05$) to those hatched during hot-dry season at week 30. Hatch (clutch) number significantly ($p<0.05$) influenced weights at weeks 15 and 20 only. However, the trend for all ages showed an increase in body weights with hatch number up to hatch three, thereafter a decline.

7.4.2 Growth rates

Absolute body weight gain per day and exponential (specific) growth rate (EGR) are shown in Figure 7.3. Birds raised on-station had significantly ($p<0.05$) higher EGR between 10 and 20 weeks. A similar trend was observed for daily weight gains, which were significant ($p<0.05$) even for weeks 25 and 30. Unlike EGR, season of hatch (up to week 20) and hatch number (weeks 15, 20 and 30) significantly ($p<0.05$) influenced daily weight gains (Table 7.5). Trends for hatch number were closer to that for body weights. Highest growth rates per day were observed between 15 and 20 weeks of age.

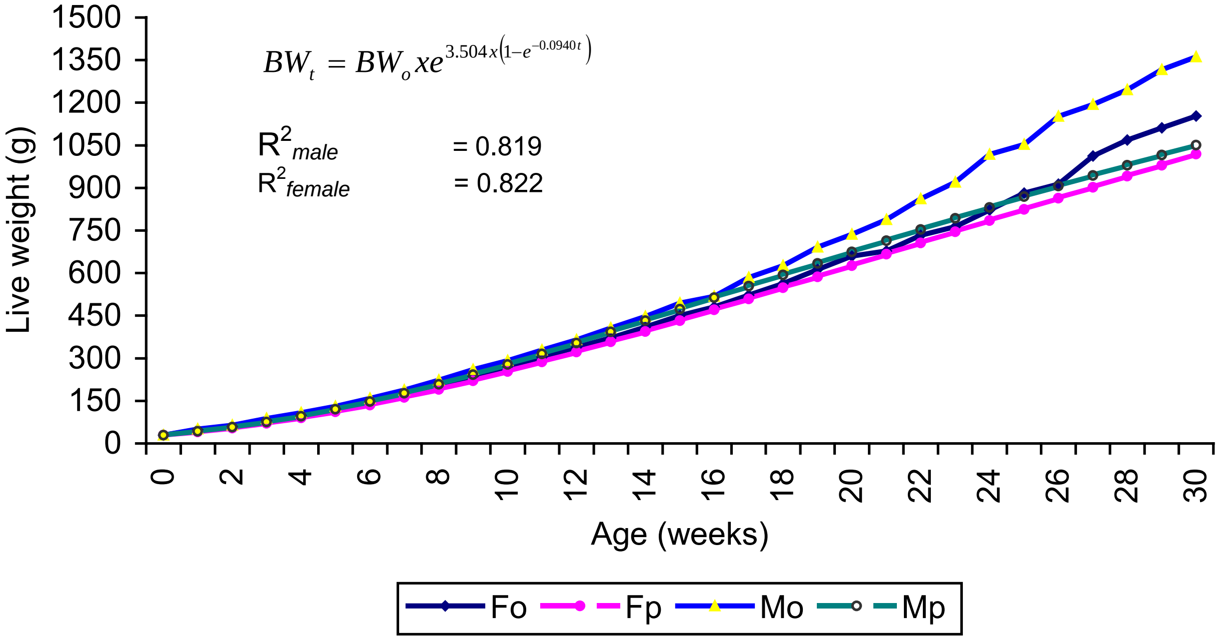
7.4.3 Growth curve parameters

Figures 7.1 and 7.2 show predicted growth curves in relation to observed curves by sex for on-station and on-farm local chickens. Lsmeans for the parameters of growth curve function are shown in Table 7.6. *L, K,* T_i were similar ($p>0.05$) between on-station and on-farm local chickens while BW_i were significantly ($p<0.05$) higher for on-station than for on-farm chickens. Males were significantly ($p<0.05$) higher than females for *L* and BW_i. *L* for chickens hatched during cold-dry season were significantly ($p<0.05$) lower than those for chickens hatched in other seasons. Hatch number influenced *L* and *K,* with hatch two being significantly ($p<0.05$) superior.



Fo, female observed; Fp, female, predicted; Mo, Male observed, Mp, Male, predicted; BW_t, Live body weight at age t in weeks; BW_o, Hatch weight; R^2, Coefficient of determination based on Pseudo R - square

Figure 7.1. Growth curves of on-station local chickens raised under scavenging conditions by sex



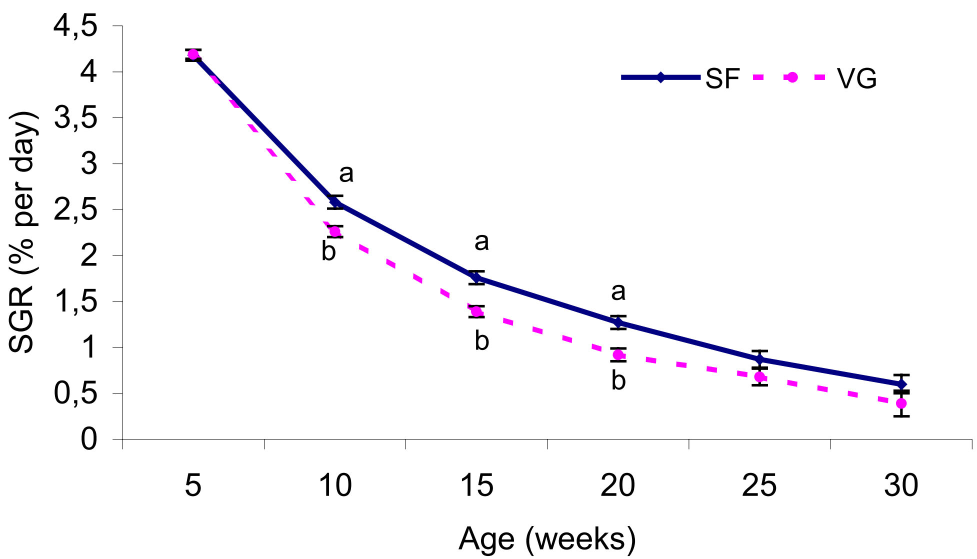
Fo, female observed; Fp, female, predicted; Mo, Male observed, Mp, Male, predicted; BW_t, Live body weight at age t in weeks; BW_o, Hatch weight; R^2, Coefficient of determination based on Pseudo R - square

Figure 7.2. Growth curves of on-farm local chickens raised under scavenging conditions by sex

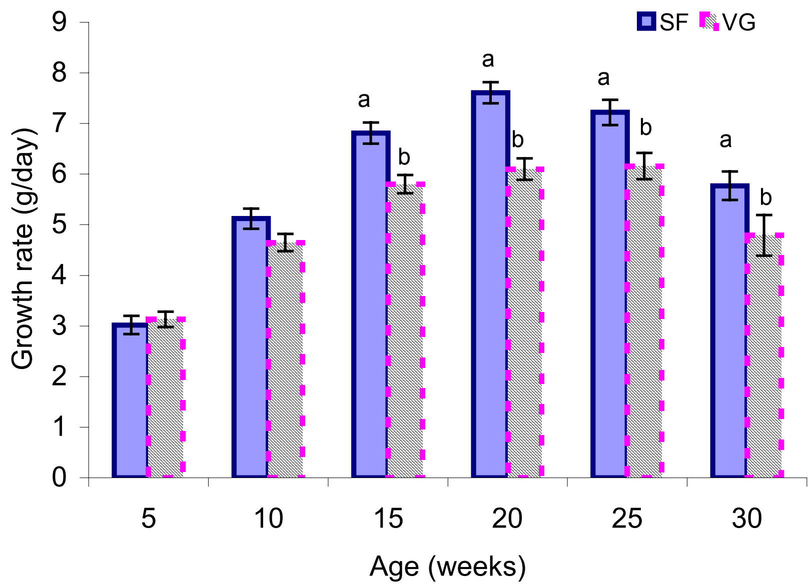
Table 7.4. Least square means and standard errors (SE) of the live weights (g) for local chickens at different ages (weeks)

Fixed effect	Day old		Week 5		Week 10		Week 15		Week 20		Week 30	
	Lsmean	SE	Lsmean	SE	Lsmean	SE	Lsmean	SE	Lsmean	SE	Lsmean	SE
Place of study												
On-station	31.6[a]	0.5	120.9	14.1	310.3	14.6	547.9	14.4	808.3[a]	15.3	1232.5	18.1
On-farm	29.6[b]	0.4	144.9	11.1	307.7	12.0	517.6	12.4	731.9[b]	14.0	1253.5	22.9
Sex of chicken												
Female	30.5	0.3	127.6	9.4	299.0	10.0	509.6[b]	10.1	717.6[b]	11.4	1125.8[b]	16.2
Male	30.6	0.4	138.2	10.9	318.9	11.7	555.9[a]	11.8	822.5[a]	13.5	1360.1[a]	20.2
Season of hatch												
Hot-wet	30.0[b]	0.4	157.0[a]	12.1	329.2[a]	12.6	542.6[b]	12.6	769.6[b]	14.4	1165.3[b]	21.4
Cold-dry	30.5[a]	0.4	126.1[b]	10.5	278.3[b]	11.0	465.9[c]	11.2	689.8[c]	12.8	1267.4[a]	23.3
Hot-dry	31.3[a]	0.5	115.5[b]	15.2	319.4[a]	17.4	589.7[a]	17.0	850.8[a]	19.0	1296.3[a]	22.5
Hatch number												
One	30.5	0.4	130.3	11.1	309.4	11.8	523.9[b]	12.0	773.4[a]	13.4	1213.2	17.5
Two	31.0	0.4	129.1	13.8	316.5	14.9	560.8[a]	15.3	798.6[a]	19.0	1264.4	25.2
Three	30.1	0.5	153.3	16.3	320.0	17.1	546.2[ab]	17.3	779.1[a]	19.2	1264.0	32.4
Four and above	30.6	0.5	118.8	14.0	289.9	15.1	500.1[b]	15.0	729.2[b]	17.6	1230.4	25.1

[abc]Means in a column within a fixed effect with different superscripts differ significantly ($p < 0.05$)



A



B

[ab] lsmeans with different superscripts differ significantly ($p<0.05$)

Figure 7.3. Specific growth rates (SGR in percent growth per day, A) and absolute growth rates (g/day, B) for on-farm (VG) and on-station (SF) scavenging local chickens (lsmeans and SE adjusted for fixed effects of sex, season and hatch number)

Table 7.5. Least square means for absolute growth rates (g/day) by season and hatch number for local chickens at different ages

Fixed effect	Week 5		Week 10		Week 15		Week 20		Week 30	
	Lsmean	SE	Lsmean	SE	Lsmean	SE	Lsmean	SE	Lsmean	SE
Season of hatch										
Hot-wet	3.48[a]	0.17	4.81[b]	0.18	6.04[b]	0.19	6.44[b]	0.22	5.10	0.37
Cold- dry	2.70[b]	0.14	4.28[c]	0.15	5.49[c]	0.17	6.41[b]	0.20	5.69	0.40
Hot-dry	3.06[ab]	0.21	5.56[a]	0.26	7.37[a]	0.28	7.71[a]	0.29	5.06	0.37
Hatch number										
One	2.88	0.15	5.00	0.17	6.37[ab]	0.18	7.19[a]	0.20	5.95[a]	0.29
Two	3.10	0.20	4.80	0.22	6.16[b]	0.25	6.74[ab]	0.31	3.70[b]	0.43
Three	3.33	0.23	5.21	0.24	6.95[a]	0.26	7.33[a]	0.29	5.94[a]	0.56
Four and above	3.00	0.19	4.52	0.22	5.72[bc]	0.24	6.16[b]	0.28	5.54[a]	0.45

[abc]Lsmeans within a column in a category with different superscripts differ significantly ($p<0.05$)

Table 7.6. Least square means and standard errors (SE) of the parameters of the growth curve functions for local chickens

Fixed effect	*L*		*K*		T_i (weeks)		BW_i (g)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Place of study								
On-station	0.34	0.009	0.087	0.004	16.43	1.06	592.32^{a}	21.57
On-farm	0.35	0.008	0.097	0.003	14.70	1.06	445.84^{b}	29.18
Sex of chicken								
Female	0.34^{b}	0.007	0.091	0.003	15.68	1.04	488.28^{b}	18.94
Male	0.35^{a}	0.007	0.093	0.003	15.41	1.05	549.88^{a}	20.94
Season of hatch								
Hot-wet	0.36^{a}	0.008	0.095	0.003	14.95	1.05	500.73	22.64
Cold-dry	0.33^{b}	0.007	0.088	0.003	16.54	1.05	511.29	20.13
Hot-dry	0.35^{a}	0.011	0.092	0.005	15.18	1.08	545.22	29.02
Hatch number								
One	0.35^{b}	0.008	0.093^{ab}	0.003	14.94	1.05	502.93	21.24
Two	0.37^{a}	0.009	0.101^{a}	0.004	14.02	1.07	503.78	26.49
Three	0.34^{b}	0.011	0.084^{b}	0.005	17.11	1.08	554.62	28.58
Four and above	0.34^{b}	0.009	0.090^{b}	0.004	16.28	1.07	514.99	26.85

[ab]Means in a column within a fixed effect with different superscripts differ significantly ($p<0.05$); *L*, initial specific growth rate; *K*, exponential rate of decay; T_i, age at point of inflection; BW_i, weight (g) at point of inflection

7.4.4 Phenotypic correlations

Adjusted phenotypic correlation coefficients between body weights and parameters of growth curves are shown in Table 7.7. High and positive correlations were observed between *L* and body weights at weeks 10 and 15. The negative correlation was strong between *L* and T_i, *K* and T_i, *K* and BW_i but weak for L and BW_i and hatch weight. T_i was negatively correlated to body weights at weeks 5, 10 and 15. Body weights at different weeks were positively correlated, stronger coefficients between close by weights.

Table 7.7. Phenotypic correlation coefficients between live weights (BW_0, BW_5, BW_{10}, BW_{15} and BW_{30}) and growth curve parameters (*L, K,* T_i *and* BW_i)

	K	T_i	BW_i	BW_0	BW_5	BW_{10}	BW_{15}	BW_{30}
L	0.84 (717)	-0.71 (717)	-0.35 (611)	-0.29 (753)	0.34 (742)	0.53 (673)	0.49 (560)	0.23 (131)
K		-0.94 (717)	-0.66 (611)	-0.11 (717)	0.27 (706)	0.28 (650)	0.19 (557)	0.02^{ns} (131)
T_i			0.74 (611)	0.05^{ns} (717)	-0.22 (706)	-0.22 (650)	-0.10 (557)	0.05^{ns} (131)
BW_i				0.05^{ns} (611)	-0.05^{ns} (600)	0.13 (555)	0.33 (491)	0.46 (122)
BW_0					0.03^{ns} (1307)	0.09 (943)	0.10 (775)	0.21 (155)
BW_5						0.56 (931)	0.47 (759)	0.15 (155)
BW_{10}							0.75 (678)	0.42 (153)
BW_{15}								0.55 (155)

L, initial specific growth rate; *K*, exponential rate of decay; T_i, age at point of inflection; BW_i, weight (g) at point of inflection; BW_0, Hatch weight; BW_5, BW_{10}, BW_{15}, BW_{30}, body weights at weeks 5, 10 15 and 30, respectively; ns, not significantly different from zero (p>0.05); number in brackets is number of observations

7.4.5 Heritabiliy estimates

Additive, maternal and environmental variances are shown in Table 7.3 while direct and maternal heritability estimates are shown in Table 7.8. BW_{15} and *L* had higher h^2 than the rest, with lowest h^2 for BW_{10}. Maternal effects were high and increasing with age up to BW_5 and they declined thereafter. L was the only growth curve parameter that expressed maternal effects which was almost equivalent to that of body weight at week 15. Overall, all direct heritability estimates were moderate to high (0.39-0.56).

7.4.6 Genetic correlations

Genetic correlations between body weights and growth curve parameters (Table 7.9) followed an almost similar trend observed for phenotypic correlations in direction and magnitude. Correlations coefficients among *L, K,* T_i and BW_i were lower than phenotypic values except between *L* and *K*. On the other hand, genetic correlations coefficients between growth curve parameters and body weights were higher.

Similarly genetic correlations were higher among body weights than corresponding phenotypic values.

Table 7.8. Direct and maternal heritability (h^2) estimates for growth and parameters of the growth curves

Parameter	Direct		Maternal	
	h^2	SE	H^2	SE
BW_0	0.48	0.07	0.40	0.05
BW_5	0.43	0.03	0.57	0.03
BW_{10}	0.39	0.26	0.43	0.14
BW_{15}	0.47	0.27	0.25	0.13
L	0.56	0.32	0.20	0.15
K	0.47	0.01	-	-
T_i	0.47	0.01	-	-
BW_i	0.40	0.01	-	-

BW_0, Hatch weight; BW_5, BW_{10}, BW_{15}, body weights at weeks 5, 10 and 15, respectively; *L*, initial specific growth rate; *K*, exponential rate of decay; T_i, age at point of inflection; BW_i, weight (g) at point of inflection

Table 7.9. Genetic correlation coefficients between live weights (BW_0, BW_5, BW_{10} and BW_{15}) and growth curve parameters (*L, K,* T_i *and* BW_i)

	K	T_i	BW_i	BW_0	BW_5	BW_{10}	BW_{15}
L	0.84	-0.66	-0.17	-0.24	0.59	0.67	0.73
K		-0.92	-0.61	-0.12	0.41	0.42	0.44
T_i			0.75	0.09^{ns}	-0.28	-0.30	-0.32
BW_i				0.16	0.14	0.25	0.36
BW_0					0.14	0.23	0.22
BW_5						0.72	0.64
BW_{10}							0.89

BW_0, Hatch weight; BW_5, BW_{10}, BW_{15}, body weights at weeks 5, 10 and 15, respectively; *L*, initial specific growth rate; *K*, exponential rate of decay; T_i, age at point of inflection; BW_i, weight (g) at point of inflection, ns, not significant (p>0.05)

7.5 Discussion

7.5.1 Growth performance

Body weights and daily weight gains are comparable with results of scavenging local chickens obtained in other countries (Dessie and Ogle, 2001; Mwalusanya et al., 2001; Pedersen, 2002b; Demeke, 2003). No comparable data for EGR were published. Sexual dimorphism was expressed for body weights for birds older than 10 weeks, but not for EGR and absolute daily gains. Under intensive management, Tadelle et al. (2003c) reported sexual dimorphism as early as six weeks in Ethiopian chickens for both body weights and daily gains. Pedersen (2002b) also observed sexual differentiation in body weights, which were significantly apparent by 10^{th} week. Body weights and daily gains were increasing with hatch number up to third hatch. Effect of season of hatch was not clearly expressed. The changing trends of live weights and daily weight gains between seasons after 10 weeks shows effect of season on the chicken performance at that particular period and not necessarily due to seasonal effect at hatch. For example, chickens that hatched during hot-wet season had higher early growth performance, which reduced as they entered into cold-dry season. Body weights and growth rates of chicks that hatched during hot-dry season were constantly high up to 30 weeks. This is probably because most of their growth took place before the chicks are exposed to cold-dry season. Hatching during hot-dry season is better in terms of growth performance. However, since chickens displayed aspects of compensatory growth for delayed growth during the unfavourable cold-dry season, seasonal effect is not an important issue to worry about. Season and hatch number did however, not affect EGR.

7.5.2 Growth curves and parameters of growth function

Both observed and Gompertz growth curves (Figures 7.1 and 7.2) fitted to each other well. Curves of females fitted better than males after 20 weeks. Goodness of fit, determined by coefficients of determination, were higher for on-station than for on-farm chickens. Mignon-Grasteau et al. (1999) observed similar pattern with better fit of Gompertz curves to observed growth curves for females than for males after 20 weeks in different lines of chickens selected for the form of growth. Other growth functions used in fitting growth data for poultry include the 4-parameter Richards function (Knizetova et al., 1991; Hyankova et al., 2001), the Weibull growth curve (Maruyama et al., 2001) and the reparamaterised Janoschek growth function (Gille and Salomon, 1998). These functions fit data that, according to growth of local chickens, would need weights at over 30 weeks and were therefore, not tested in this study. The authors generally agree on using growth curve functions to summarize growth using few parameters and that these could be used as a tool to improve livestock by management and genetic. The better fit of Gompertz curve to local chickens data provides a tool to use the parameters in predicting growth of chickens in our local situation where data collection is difficult. The sigmoid shapes were flat compared to those reported by above authors on selected lines of chickens and this shows room for improving these local chickens.

L, K and T_i were similar ($p>0.05$) between on-station and on-farm local chickens while BW_i were significantly ($p<0.05$) higher on-station. Sex also influenced ($p<0.05$) L and BW_i. Unlike body weights and daily gains, it appears growth curve parameters were less sensitive to systematic effects, thus better expressing growth of local chickens.

T_i and BW_i estimated age and body weight, respectively, of local chickens at point of inflection. According to Brody (1945) this is an important age because it signals the point at which growth rate is maximized; the point of puberty (sexual maturity); and the point where survival equals mortality due to resource competition. Brody (1945) reported that body weight at point of inflection is 33 % of mature weight. According to Gompertz function, body weight at point of inflection is 36.8 % of the asymptotic body weight (Knizetova et al., 1991). This translates to estimated mature weights (Lsmeans) of 1609.6 (SE=58.6) g, 1211.5 (SE=79.3) g on-station and on-farm ($p<0.05$), respectively. Males had significantly ($p<0.05$) higher mature weights (1494.2 SE=56.9 g) than females (1326.9 SE=51.5 g). Horst (1989) and Gueye (1998) compiled literature on mature weights of local chickens in different countries. Ranges of those empirical data compare well with the estimated weights of this study. The body weights at point of inflection determined in the study also imply that local chickens reach peak growth rate at lower body weights. In broiler chickens, selection has focused at age or weight at point of inflection, that has been reduced to eight weeks and this coincides with slaughter periods (Knizetova et al., 1991). The potential to improve growth of local chickens through selection is, therefore, great. Most literature (Dessie and Ogle, 2001; Mwalusanya et al., 2001; Pedersen, 2002b) reported that local chickens reach sexual maturity after 25 weeks of age, which is about 9 –10 weeks higher than the ages estimated from growth curves. However, their estimations are based on age at first egg, a common indicator of age at sexual maturity in poultry (Ayorinde, 1995; Kerr et al., 2001), that may not necessarily be the age at sexual maturity if there is time lag between these two physiological states (Sorensen and Ducro, 1995). While reproductive organs could start working at the point of inflection, egg production could start later in local chickens due to environmental, especially feed constraints. Kerr et al. (2001) reported that there is a lower (threshold) age and body weights for females to reach sexual maturity. Interpreting point of inflections, local chickens have higher age but lower body weights as thresholds to sexual maturity.

The effect of place (on-station vs on-farm) was of special interest regarding future studies and their applicability on-farm when done on-station. Sensitivity was observed mainly on directly measured parameters while estimated parameters were less affected. Continuous supplement feeding on-station, unlike sporadic supplementation on-farm could have contributed to the effect. Generally, it appears results for growth traits obtained on-station under similar scavenging conditions could be utilized on-farm.

7.5.3 Heritability and correlation between traits

Heritability estimates for hatch weight, body weights at different ages and parameters of the growth curve function were all moderate to high. The results for growth curve parameters agree with those reported by Barbato (1992) and Mignon-Grasteau et al. (1999), all working on selected lines of chickens. Barbato (1992) reported heritability estimates for body weight at week 14 of 0.49, which is equivalent to the estimated value for week 15 in this study. Chambers (1990) reviewed several studies and reported an average heritability estimate of 0.4 for body weight obtained under intensive management. He also reported that growth traits for chickens have moderate to high heritability, thus supporting the current findings. The estimated heritabilities could be theoretically utilised in breeding programmes of local chickens.

Maternal effects were prominent for body weights and *L* but not for other parameters of growth function. Maternal value for hatch weight was similar to that reported by Mignon-Grasteau et al. (1999) and reflects the pre-oviposition (egg size, weight and quality) and pre-hatch post-oviposition (incubation) effects (Prado-Gonzalez et al., 2003). The increase in maternal effects from hatch weight to body weights at week five is logical but in contrast to the order reported by Prado-Gonzalez et al. (2003), who also reported lower heritability estimates (0.07 to 0.21) for growth for intensively managed Creole chickens. This shows presence of post-hatch maternal effects, which were common environment effects for the chicks belonging to one hen. This means maternal effects in subsequent body weights were more of common environmental effects since hens brood their chicks naturally even up to higher ages. It was not possible to separate maternal from common environmental effects in this study. Studies quoted above reported low maternal effects for *L* and subsequent body weights to week 10, because, unlike in this study, chicks were raised independent of the dam hens. Prado-Gonzalez et al. (2003) reported no maternal and common environmental heritabilities from eight weeks body weights of intensively managed Creole chickens. Chambers (1990) reported that maternal components are not important in body weights of chickens at later ages. This supports the fact that observed maternal effects were due to common environment. As in this study, Mignon-Grasteau et al. (1999) did not observed maternal effects in K, T_i and BW_i.

The magnitude and trend of genetic and phenotypic correlations were similar in most growth and growth curve parameters. Similar and closer correlations were observed by Mignon-Grasteau et al. (1999) for growth curve parameters. The high and positive correlations between *L, K* and body weights at weeks 5, 10 and 15 shows that the traits have common genes influencing them. Selecting for *L* and *K* in local chickens under scavenging conditions would simultaneously alter the shape of the growth curves and improve body weights during juvenile growth phase in populations where these parameters are determined. This will lead to reduced burden of prolonged recording on growth performance of local chickens under scavenging conditions. Performance recording and pedigree determination are a difficult task under the conditions of the production system. These pose limitations to implementing practical breeding programs. Body weights at weeks 5, 10 and 15, and *L* characterize the juvenile growth phase of local chickens, which has been utilized to improve body weights in broiler industry (Kerr et al., 2001). Either body weight at week 15 or *L* appear suitable traits to select for in local chickens. These are highly heritable, have high genetic correlations to other traits and appear to characterize point of inflection where selection is commonly done (Kerr et al., 2001). Selecting at this age has advantages that the selected birds will survive, unlike at earlier ages when mortality is still high. The higher genetic than phenotypic correlation coefficients for body weights were also reported by Saatci et al. (2003) for juvenile weights in quails and Ayorinde (1995) for body weight and reproductive traits in guinea fowls.

The genetic improvement for local chickens is not intended to be like for commercially oriented strains but just adequate under scavenging conditions without compromising for extra resource needs and having deleterious effects on important reproductive and adaptive traits. Selecting breeding males among community flocks seems the more likely initial targets where the results of this study could be utilized. Under such situation, the current findings suffice in addition to providing guiding clues that when farmers select their chickens based on phenotype, they are assured of some genetic improvement.

7.6 Conclusion

Through this study, growth characteristics have been described in terms of body weights, growth rates and growth functions under scavenging conditions. Growth form of local chickens has been better described using growth curve parameters that are less sensitive to environmental (including maternal) influence, hence, appears to have advantages over physical growth parameters as useful potential tools and indicators of improving the species. All traits studied are moderately to highly heritable under scavenging conditions and this provides opportunity for genetic improvement in local chickens through selection. Improving either body weight at week 15 or *L* will desirably improve the shape of growth curve and juvenile and adult body weights in local chickens.

8.1 Reproductive performance and survival of local chickens under scavenging conditions in Malawi

8.1 Abstract

A study was conducted to evaluate and compare reproductive performance of local chickens and chick survival raised on-station (n=151 hens) and on-farm (n=378 hens) under scavenging conditions in Lilongwe, Malawi from June 2002 to October 2003. On-station, deep litter and free-range management systems were used during laying and brooding. On-farm, all hens were on free-range. After hatching, all hatchlings were raised under free-range system. Survival of hatchlings was monitored up to 20 weeks of age. Cumulative mortality was calculated. Hen reproductive efficiency estimated as return from offspring per annum was calculated as annual weight of chicks per hen while reproduction ratio was calculated as annual weight of chicks per unit hen or metabolic hen weight, all measured at hatch and weeks 5, 10, 15 and 20.

Egg production was mostly interfered by changes in management and human handling, especially in deep litter system on-station. Significantly ($p<0.05$) more and heavier eggs, and longer laying periods were observed on-station under deep litter system than on-station and on-farm under free-range system. Hatchability was significantly ($p<0.05$) higher on-farm (93%) than on-station (61 %) under free-range; while was least ($p<0.05$) on-station under deep litter (49 %). Age at first hatch was significantly higher on-station (37 weeks) than on-farm (30 weeks). Hatching interval and number of hatches per annum were similar ($p>0.05$), while annual hen reproductive index was significantly ($p<0.05$) higher on-farm (30 chicks hatched) than on-station (22 chicks). There was higher early chick mortality (43 % on-station) than on-farm (29 %) observed during the first five weeks. By 20 weeks over 50 % of chicks hatched had died, both on-farm and on-station ($p>0.05$).

Returns per hen and reproduction ratios were significantly ($p<0.05$) higher on-farm than on-station. Coefficients of variation for returns per hen were high (≥50 %), mostly influenced by genetically unrelated reproduction traits such as hatching rates, hatching interval and survival of chicks. On-farm, survival of chicks was the main influencing factor, whereas on-station, low hatching rates and low early chick survival influenced low annual values.

It is concluded that under scavenging conditions, local chickens have good hatching performance but poor chick survival. A holistic intervention management of confining and supplementing chicks and selection for survival approaches especially during the first five weeks of chick life are required.

Keywords: scavenging chickens, reproduction, mortality, survival, reproductive efficiency

8.2 Introduction

The scavenging village chicken production provides food, income, socio-cultural outputs to people. Flocks sustain themselves through chicks hatched from the flock, purchasing breeding stock and acquisition through gifts from friends and relatives (Missohou et al., 2002; Tadelle et al., 2003b). However, acquiring breed stock is relatively less significant compared to replacement from own flock (Gondwe et al., 1999a). Between 50 and 100 % of eggs laid by local hens are used for natural incubation (Dessie and Ogle, 2001; Missohou et al., 2002). Flock hatchlings are a primary source of birds constituting flocks. The importance of hens to reproduce is evidently displayed as a household capital asset. Quantitative reproductive parameters of reproduction such as age at sexual maturity, eggs laid, hatchability and hatching frequency are therefore vital information needed to improve flock productivity. Local chickens are described to be poor egg layers but good hatchers (Branckaert and Gueye, 1999).

Survival of chicks to mature hens determines flock off-take for utilization, replacement and selection. Highly variable mortality rates have been reported as a major constraint in local chicken production under scavenging conditions in different countries in Africa (Mwalusanya et al., 2001; Pedersen, 2002b; Kondombo et al., 2003) and elsewhere (Kyvsgaard et al., 1999). This high mortality is observed mainly between hatch and eight weeks of age (Gueye, 1998). Diseases and predation are major causes of losses in chicks.

Under prevailing farming conditions, efficiency of production based on output per unit resources or per bird, which combine reproduction and growth performance has not been investigated in local chickens. Reproduction efficiency parameters have been used in commercial broiler and layer production and other livestock to compare differences between managements, among different breeds or species, and to assist in modelling a production system and make selection decisions (Shalev and Pasternak, 1989; Weller, 1994).

The objectives of the study were: (i) to evaluate reproductive parameters for local chickens under scavenging conditions; (ii) to evaluate chick mortality (survival); (iii) to evaluate annual productivity of local chickens based on hen reproductive rate; (iv) to compare these parameters between on-farm and on-station raised chickens under scavenging conditions.

8.3 Materials and methods

8.3.1 Study area

An on-station study was carried out at Bunda College of Agriculture (BCA), while an on-farm study was carried out on 134 Village Poultry Project (Gondwe et al., 2003) participating households in 27 villages of Mkwinda and Mitundu Extension Planning Areas (EPA) of Lilongwe Agricultural Development Division (LADD). Farmer demography and other details of the study area are outlined in Chapter 3.

8.3.2 Study animals

8.3.2.1 Reproduction performance

Local hens were monitored for reproductive performance on-farm (n=378 hens) and on–station (n=151 hens). On-farm, these were individual participating farmers' hens. On-station, hens and cocks were randomly bought from different villages (Chapter 3). Table 8.1 shows eggs recorded during the study period June 2002 to October 2003.

8.3.2.2 Management

All chickens, both on-farm and on-station, were raised under free-ranging, scavenging condition. On-farm, farmers managed their flocks traditionally. Natural, uncontrolled mating was practised, hens laid and incubated their eggs, and brood the hatchlings. Weaning and return-to-lay was natural. Supplement feeding of local chickens and health management were as described in Chapters 3 and 8.

Table 8.1. Frequency distribution of different factors on egg records

Factor		Number of eggs	Frequency (%)
Place of study	On-station	3467	75.35
	On-farm	1134	24.65
Season of study	Hot-wet	1575	34.23
	Cold-dry	2370	51.51
	Hot-dry	656	14.26
Clutch number	1	602	34.90
	2	460	26.67
	3	296	17.16
	≥ 4	367	21.28
Management	Deep litter, on-station	2429	52.79
	Free-range, on-station	1038	22.56
	Free-range, on-farm	1134	24.65
Colour of eggs	Brown	1736	66.95
	White	857	33.05
Phenotype of hens[1]	*Chiphulusa*	258	17.49
	Kawangi	122	8.27
	Mawanga	246	16.68
	Yakuda	514	34.85
	Yofira	234	15.86
	Yoyera	101	6.85

[1]Local names described by Gondwe et al. (1999a)

A similar management was used on-station to imitate farmers' practice. However, during laying, a mating design on-station followed a procedure described in Chapter 3. The purpose of this design was to determine pedigree for chicks hatched in order to determine genetic parameters of growth for local chickens (Chapter 7). However, hens that did not have space in pens reproduced under free-range.

For all birds outside pens, maize bran (10.1 % CP, as fed) was regularly supplemented because it was the major feed supplement to local chickens by households on-farm.

8.3.2.3 Chick growth and survival

Chicks hatched from these hens (at hatch, n=2430 on-farm; n=1119 on-station) were monitored for their growth performance (Chapter 7), both on-farm and on-station. These hatchlings were individually monitored for survival. For each hen, number of chicks hatched, and weekly mortality of chicks were recorded. Attempts were made to record causes of death or loss of chicks. However, most of chick deaths could not be specified.

8.3.3 Data collection and analyses

8.3.3.1 Reproduction performance

Primary data on reproduction included number of eggs laid per hen per clutch, individual weight of eggs, colour of eggs, dates at first and end of lay, dates at brooding and at hatch, number of eggs brood, number of chicks hatched, hen weight at hatch, and weekly live weights of chicks. On-farm, both farmers and research assistants recorded the data. From these data, number of days in lay per clutch and number of days for laying and egg incubation were calculated. Hatchability was calculated as number of chicks hatched divided by number of eggs set for incubation.

Preliminary analyses showed that most parameters departed from normal distribution due to human intervention (both on-farm and on-station) and changes in management (on-station). As such, most of these parameters were only analysed for means and their standard deviations. Weight of eggs and hatchability were statistically analysed to test effect of place of study and management during laying using the following model

$$y_{ijkl} = \mu + p_i + m_{ji} + c_k + s_l + \beta(x_{ijkl} - xl) + \varepsilon_{ijkl} \qquad (8.1)$$

where

y_{ijkl} is the observed measure for hen (egg weight or hatchability); μ is the overall mean common to all hens; p_i is the fixed effect of place of production (i = on-station, on-farm), considering birds on free-range only; m_j is the fixed effect of management within place during laying (j = deep litter, free range); c_k is the fixed effect of clutch number of the bird (k = 1,2,3,4); s_l is the fixed effect of season of lay (l = hot-wet, cold-dry and hot-dry); β is the linear regression coefficient of the measure on hen weight; $(x_{ijkl} - xl)$ is the observed weight of the l-th hen adjusted from the overall mean weight (xl), taken as a covariate; ε_{ijkl} is the residual error assumed NID (0, $\sigma^2\varepsilon$).

Hen reproduction history data included dates between hatches (n=529, 226, 114, 57, 34 hens in first, second, third, fourth and fifth hatch, respectively). For hens that hatched for the first time and whose dates of hatch were known, age at point of first hatch (POH, n=118 hens) was calculated. Hatching interval (HI, n=100 hens) was calculated by calculating period between subsequent hatches. Number of hatches per annum was calculated by dividing 365 days by average of three HI per hen (n=100 hens). Reproductive index (RI, n=93 hens), defined as number of chicks hatched per hen per annum, was calculated by multiplying number of hatches per annum by average number of chicks hatched per hen per hatch (averaged from four hatches per hen).

These parameters were statistically analysed for fixed effects using the following model

$$y_{ijk} = \mu + p_i + c_j + \varepsilon_{ijk} \quad (8.2)$$

where

y_{ijk} is the observed measure for hen reproductive history; μ is the overall mean common to all hens; p_i is the fixed effect of place of production (i = on-station, on-farm; c_j is the fixed effect of phenotype of the hen (j = 1,2,3,4, 5,6); ε_{ijk} is the residual error assumed NID (0, $\sigma^2\varepsilon$).

Cumulative mortality was calculated at five weekly intervals by subtracting number of chicks that survive at particular age from number that hatched, then dividing by number of chicks hatched. Statistical analyses was done using the following model

$$y_{ijkl} = \mu + p_i + s_j + c_k + h_l + w_m + (wp)_{im} + (ws)_{jm} + \varepsilon_{ijkl} \quad (8.3)$$

where

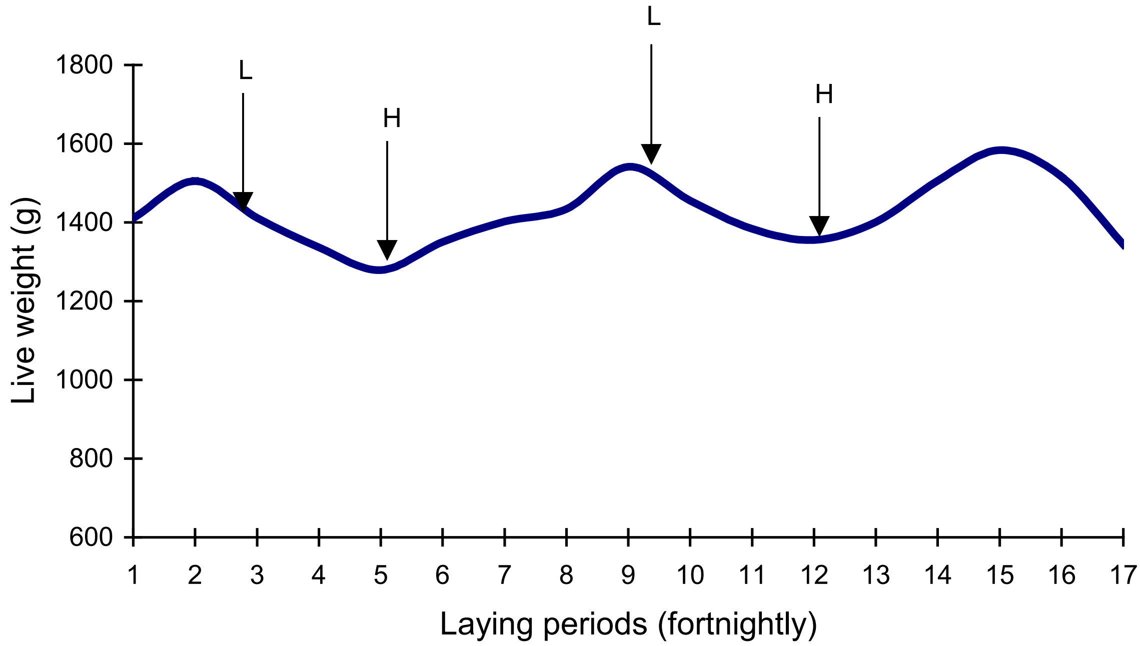
y_{ijkl} is the observed chick mortality for hen l in week m; μ is the overall mean common to all hens; p_i is the fixed effect of place of production (i = on-station, on-farm); s_l is the fixed effect of season of hatch (l = hot-wet, cold-dry and hot-dry); c_k is the fixed effect of phenotype of the hen (k = 1,2,3,4,5,6); h_l is a random effect of hen; w_m is the fixed effect of week (m = 5,10,15,20); ε_{ijkl} is the residual error assumed NID (0,$\sigma^2\varepsilon$). Parameters in brackets represent two-way interactions.

All analyses used proc Mixed procedure of SAS (SAS, 1999). Least square means were computed and significant differences were determined by least significant difference (LSD). Correlation coefficients between various parameters of egg production were determined using proc Corr procedure of SAS (SAS, 1999).

8.3.3.2 Reproduction efficiency

Reproduction efficiency was evaluated using hen or hen weight as a unit. However, during laying, hen live weights were undulating according to periods of laying, egg incubation and chick brooding (Figure 8.1). Live weights of hens used in this study were therefore, averages of all weights per hen. Number of chicks per hen was the sum of all chicks hatched during subsequent hatches. Average live weight per chick per hatch was calculated. This was multiplied by number of chicks per hen to give total weight of chicks per hen.

All parameters were annualized as follows: Annual number of chicks per hen at hatch, weeks 5, 10, 15 and 20 (A) = number of chicks per hen x number of hatches per annum, divided by number of hatches per hen during the study period; total weight output of chicks per hen per annum at hatch, weeks 5, 10, 15 and 20 (B) = average weight per chick per hatch X A.



L = week of starting to lay eggs; H = week of hatch.

Figure 8.1. Live weights of scavenging hens between subsequent laying and egg incubation periods (n = 85 hens)

Based on annualized values, reproductive ratio (R) was calculated at hatch, weeks 5, 10, 15 and 20 as follows (Weller, 1994)

$$R = \frac{B}{W_h} \qquad (8.4)$$

where W_h is the average live weight of the hen; B as defined and calculated above. Actual live weights of hens and metabolic live weights ($W_h^{0.75}$) were used as denominators. In order to normalise the distribution and homogenise the variances, *R* values were natural log transformed. To test for effect of place of study, analysis of variance was done on the transformed *R* values for using the following model

$$y_{ij} = \mu + p_i + \varepsilon_{ij} \qquad (8.5)$$

Where

y_{ij} is the observed reproductive ratio per hen per annum; μ is the overall mean common to all hens; p_i is the fixed effect of place of production (i = on-station, on-farm; ε_{ij} is the residual error assumed NID (0, $\sigma^2\varepsilon$). General linear model procedure of SAS (SAS, 1999) was used. Significant differences were determined by least significant difference (LSD) t-test.

8.4 Results

8.4.1 Egg production and hatching performance

Table 8.2 shows egg production parameters, hatchability and live weights of hens at hatch by place and management of hens during laying. There were more days in lay and number of eggs laid for hens under deep litter, intensive management than for chickens laying under free-range system. This also meant longer periods of laying and incubation (egg brooding) for chickens under deep litter system. Egg weights were significantly ($p<0.05$) heavier for chickens under deep litter system and free-range on-farm than those under free-range on-station (Table 8.3). Number of eggs brood was smaller than number of eggs laid. Hatchability as percentage of eggs brood that hatched was significantly ($p<0.05$) higher on-farm than on-station compared within free-range. On-station deep litter managed chickens during lay had significantly ($p<0.05$) least hatchability. On the other hand, live weights of hens at hatch were significantly ($p<0.05$) higher under deep litter (lsmeans 1764.69 g, SE 27.1) than on-station under free-range (lsmeans 1567.99 g, SE 21.3). Live weights for on-farm free-range hens (lsmeans 1189.28, SE 20.2) were the least ($p<0.05$). Egg weights were significantly ($p<0.05$) lower in clutch one and three, while hatchability was highest ($p <0.05$) in clutch three.

Table 8.2. Egg production, hatchability and hen live weights at hatch for local chickens by place and management system per clutch

Trait	On - station						On - farm		
	Deep litter			Free - range			Free - range		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Laying period, days	2101	18.0	10.2	972	11.1	4.3	981	10.5	3.1
Laying and incubation period, days	1238	36.6	6.2	725	32.8	3.4	808	31.3	2.5
Number of eggs laid per hen	2418	15.5	9.3	972	9.9	2.2	1047	10.7	2.0
Number of eggs brood per hen	1958	9.9	3.2	1019	9.2	2.2	1112	9.1	2.4
Egg weight at lay, g	2407	48.3	6.0	1011	45.9	5.0	1039	49.5	7.6
Number of chicks hatched per hen	1477	4.8	2.8	916	5.7	2.7	1081	8.3	2.3
Hatchability (% of eggs incubated)	1466	48.5	25.1	905	61.1	23.2	1070	92.5	16.4
Hen weight at hatch	986	1547.0	376.7	648	1522.1	324.5	412	1271.8	262.1

n = number of eggs recorded; SD = Standard deviation

Table 8.3. Effect of management within place, season and clutch on egg weight and hatchability of local chickens

Effect	Egg weight (g)		Hatchability (%)	
	Lsmean	SE	Lsmean	SE
Management within place				
Deep litter on-station	51.69[a]	0.50	44.3[c]	1.8
Free range on-station	48.67[b]	0.38	64.0[b]	1.3
Free range on-farm	51.23[a]	0.45	88.9[a]	1.4
Clutch of lay				
One	49.30[c]	0.42	69.2[b]	1.3
Two	53.36[a]	0.48	69.8[b]	1.6
Three	49.39[c]	0.57	79.1[a]	1.7
Four and above	50.75[b]	0.42	68.1[b]	1.4

[abc]Means within column in a category with different superscripts differ significantly ($p < 0.05$); SE = standard error

Table 8.4 shows correlation coefficients of parameters by management system. The coefficients between hatchability, laying period, number of eggs laid per clutch, number of eggs incubated, egg weight and hen weight tended to differ in magnitude and direction between free-range and deep litter managed laying hens.

8.4.2 Hen reproductive history

Age at first hatch (POH), hatchling interval (HI), number of hatches per year and reproductive index (RI) was used to describe the reproductive history for the hens (Table 8.5). Chickens on-farm had significantly ($p<0.05$) lower POH and higher RI than chickens on-station. Number of hatches per year and HI were similar between places ($p>0.05$).

8.4.3 Chick survival and mortality

Figure 8.2 shows chick survival per hatch per hen (based on hens with survival records) between on-station and on-farm raised chickens up to 20 weeks of age. The curve of chick survival for on-farm raised chickens was higher than that for on-station raised chickens. This statistical difference is demonstrated by mortality rates (cumulative and overall, Table 8.6). High chick mortality and losses was observed during the first five weeks, being significantly higher on-station than on-farm ($p< 0.05$). This is also shown by the sharp fall of the survival curves during the early chick life (Figure 8.2). Cumulative mortality remained significantly ($p<0.05$) different between two places up to 15 weeks. After week five, mortality rates were small in both places. As shown in Figure 8.2 and Table 8.6, less than 50 % of chicks that hatched survived after 20 weeks of age. Season of hatch did not affect ($p>0.05$) chick mortality.

Table 8.4. Phenotypic correlation coefficients between reproduction traits in local chickens by management system (deep litter above, free ranging, below diagonal, number in brackets is number of observations)

	Laying period	Eggs laid	Eggs brood	Egg weight	Chicks hatched	Hatchability	Hatch weight	Hen weight
Laying period		0.83 (2101)	0.39 (1731)	0.14 (2080)	0.06 (1306)	-0.19 (1295)	-	0.31 (812)
Eggs laid	0.73 (1953)		0.30 (1958)	0.15 (2396)	-0.09 (1477)	-0.23 (1466)	0.14 (582)	0.46 (986)
Eggs brood	0.46 (1931)	0.63 (1997)		-	0.38 (1466)	-0.15 (1466)	0.18 (580)	-
Egg weight	-0.16 (1929)	-	-0.10 (2020)		0.07 (1463)	-0.12 (1454)	0.56 (581)	0.58 (979)
Chicks hatched	0.21 (1808)	0.44 (1874)	0.54 (1975)	0.15 (1884)		0.82 (1466)	0.06 (576)	-0.07 (702)
Hatchability	-0.09 (1797)	0.07 (1863)	-0.13 (1975)	0.25 (1873)	0.74 (1975)		-0.05 (574)	-0.13 (702)
Hatch weight	-	-	-0.07 (1361)	0.19 (1291)	0.18 (1372)	0.30 (1353)		0.40 (303)
Hen weight	-0.25 (929)	-0.20 (961)	-	0.09 (1001)	-0.07 (999)	-0.08 (999)	0.05 (647)	

Table 8.5. Effect of place of study on hatching coefficients of local chickens

Effect	POH (weeks)		HI (days)		Hatches per year		RI	
	Lsmean	SE	Lsmean	SE	Lsmean	SE	Lsmean	SE
Place of study								
On-station	37.4[a]	1.3	107.8	2.8	3.6	0.1	21.7[b]	0.8
On-farm	29.8[b]	1.3	107.5	2.7	3.7	0.1	30.4[a]	0.7

[ab]Means within column in a category with different superscripts differ significantly ($p<0.05$); POH = age at first hatch, HI = Hatching interval, RI = Reproductive index (number of chicks hatched per hen per annum)

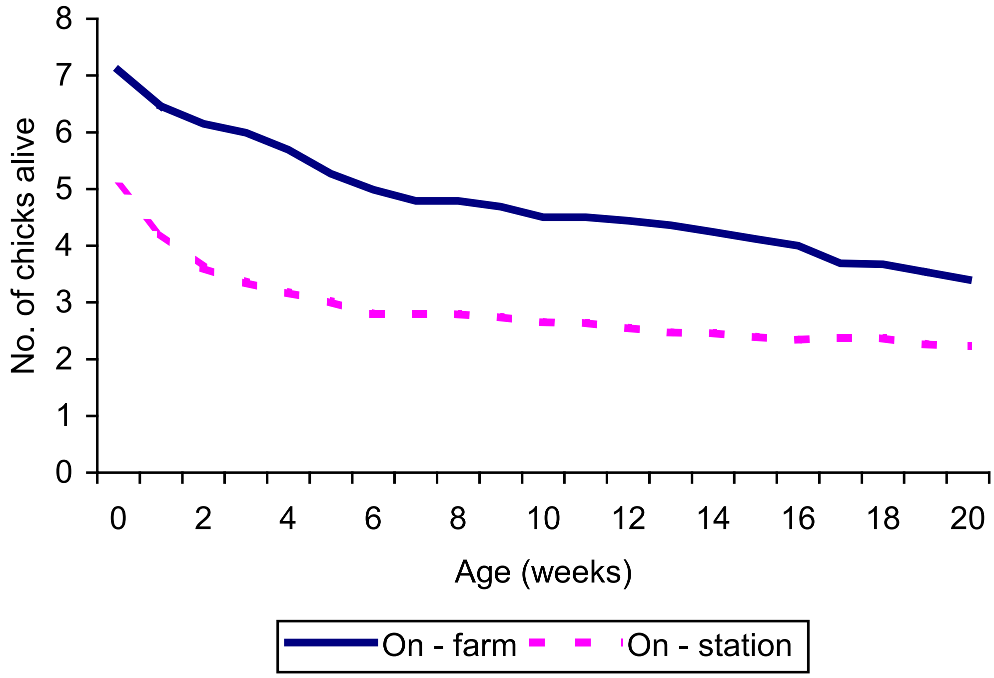


Figure 8.2. Number of chicks surviving per hen by age

8.4.4 Annualized output from chicks per unit hen

Table 8.7 shows number of chicks and their total live weights per year per hen at hatch, 5, 10, 15 and 20 weeks, plus live weights and metabolic weights of hens. Hens from on-farm had more chicks per hen than hen from on-station. The difference was 33.5 % at hatch, 48.9 %, 58.1 %, 52.3 % and 58.3 % at weeks 5, 10, 15 and 20, respectively, using on-farm numbers as base. Coefficients of variation (CV) were high and increasing with age. CV for hen weight and metabolic weights were small (<20). Hen live weights during reproduction period showed undulating pattern (Figure 8.1). Weight loss of 12.5 % (SD, 6.3 %, Max, 26.6 %) and weight regain of 11.8 % (SD, 8.6 %, Max, 33.3 %) were observed from start of lay to hatching, and from hatching to next laying, respectively.

8.4.5 Reproductive efficiency

Female reproductive rates per live hen weight or per metabolic hen weight (Table 8.8) were significantly higher ($p<0.05$) on-farm than on-station. This difference was observed to be true for all ages. The difference was constantly high at over 50 % for both per hen live weight and per hen metabolic live weight. These reproductive ratios were increasing with age of chicks.

Table 8.6. Effect of place of study on chick mortality (percent of chicks hatched) by age

Effect	Age (weeks)									
	5		10		15		20		0 – 20	
	Lsmean	SE	Lsmean	SE	Lsmean	SE	Lsmean	SE	Lsmean	SE
Place of study										
On-station	43.3[a]	2.5	49.1[a]	2.9	53.7[a]	3.2	55.5	3.4	50.4[a]	1.5
On-farm	29.4[b]	2.2	38.4[b]	2.7	43.2[b]	3.2	52.2	3.3	40.8[b]	1.7

[ab]Means within column in a category with different superscripts differ significantly ($p<0.05$); SE = standard error

Table 8.7. Annualized number of chicks and their total live weights per unit hen, and per live and metabolic weights for hens

Factor	On-farm				On-station			
	n	Mean	Median	CV %	n	Mean	Median	CV %
Number of chicks at								
Hatch	289	23.3	21.6	45.5	132	15.5	14.0	53.1
Week 5	261	17.8	17.1	54.5	105	9.1	7.0	70.8
Week 10	180	14.8	13.7	60.6	75	6.2	4.8	63.8
Week 15	128	13.0	10.3	63.6	75	6.2	4.8	85.8
Week 20	79	10.3	8.8	65.9	59	4.3	3.8	68.4
Overall live weight (g) of chicks at								
Hatch	286	706.7	641.2	49.3	132	466.0	457.9	54.2
Week 5	261	2145.0	1945.5	68.3	105	1082.3	839.3	83.8
Week 10	180	3984.2	3303.5	70.3	75	1778.5	1590.5	74.1
Week 15	128	5996.6	5077.3	69.1	75	3305.7	2660.3	102.5
Week 20	79	7135.2	6276.9	75.7	59	3447.8	2800.0	90.7
Live weight (g) of hens	160	1321.2	1278.8	19.5	110	1384.6	1370.7	19.6
Live weight$^{0.75}$ of hens	160	218.5	213.8	14.1	110	226.2	225.3	14.6

Table 8.8. Reproductive ratio of local chickens at different ages in weeks

Place	5		10		15		20	
	lsmean	SE	lsmean	SE	lsmean	SE	lsmean	SE
Per hen weight								
On-farm	1.56	1.07	2.63	1.08	3.87	1.09	4.57	1.12
On-station	0.60	1.09	1.00	1.10	1.85	1.10	1.91	1.11
Significance (p-value)	0.0001		0.0001		0.0001		0.0001	
Per hen weight$^{0.75}$								
On – farm	9.39	1.07	15.80	1.08	23.20	1.09	27.30	1.12
On - station	3.65	1.09	6.12	1.10	11.30	1.10	11.65	1.11
Significance (p-value)	0.0001		0.0001		0.0001		0.0001	

8.5 Discussion

8.5.1 Reproductive performance

Local chickens show characteristic brooding behaviour. Eggs are laid in clutches, which are demarcated by a clearly marked laying, incubation and brooding period. The observed average number of eggs laid per clutch compares well with the mean range of 9 to 18 compiled from different countries by Gueye (1998) and a range of 6 – 28 eggs per clutch reported by Mwalusanya et al. (2001) in Tanzania under scavenging conditions. Using a recall survey in Ethiopia, Tadelle et al. (2003b) reported higher number of eggs per clutch than those observed in this study. Egg weights were higher than 42, 44, 38 g reported by Gueye (1998), Mwalusanya et al. (2001) and Missohou et al. (2002), respectively for local chickens in different African countries. The egg holding time of 10.5 days reported by Farooq et al. (2003) agrees with laying period reported in this study for hens under free-range. All authors above reported high hatchability of between 60 and 90 % of eggs set by local chickens, agreeing with results found here under free-range conditions but not for deep litter conditions. While local chickens are reportedly low egg producers (Gueye, 1998), hatching performance was good.

By placing hens in pens under deep litter system, laying behaviour changed, resulting into long laying periods, more eggs laid and significantly ($p<0.05$) heavier eggs than for hens under free-range on-station. On the other hand, hatchability was severely reduced compared to free-range laying chickens. The lower hatchability of hens under free-range on-station than those on-farm could probably be explained by human handling during brooding, such as frequent weighing of hens and eggs, and counting eggs. All on-station hens were significantly ($p<0.05$) heavier than on-farm hens due to feeding of breeders mash *ad lib* while confined in pens during laying period. Correlation coefficients reflect probably the effect of change in management and human handling between deep litter and free-range management during laying (Table 8.4). This emphasizes the influence of management on hen reproduction. Under deep litter, hatchability was negatively influenced by laying period, number of eggs laid and brood and egg weight. Under free-range, only laying period and eggs brood negatively influenced hatchability. Laying period and number of eggs laid are associated with length of storage for eggs before a hen incubates, which is negatively correlated with hatchability (Meijerhof, 1992; Farooq et al., 2003; Petek et al., 2003). The positive correlation observed between egg weight and hatchability under free-range hens is expected and is probably due to availability of nutrients in the egg. Smaller eggs have relatively insufficient essential nutrients that might result to pre-hatch chick mortality (Petek et al., 2003). Based on results from free-range, local chickens have an efficient reproductive capacity demonstrated by laying suitably sized fertile eggs that hatch well. Putting hens in deep litter and feeding breeders mash prolonged egg-holding periods, increased hen live weights and therefore, negatively affected egg quality, leading to observed low hatchability.

Farooq et al. (2003) observed poor hatchability during summer and winter compared to spring and fall, respectively. Hatchability in this study was similar between seasons ($p>0.05$). The clutch influence on hatchability might be related to age of birds, with older birds laying eggs that have better embryonic development than young hens (Meijerhof, 1992).

On-farm, the difference between number of eggs laid and number of eggs set for incubation was due to farmers consuming or selling some of the eggs. This represents mean of 1.48, SD 2.20 eggs per hen per clutch, or 13.6 % of eggs laid. About 3.3 % of eggs laid were lost through breakages. The setting of large proportion of eggs for hatching confirms the report by Gueye (1998) that farmers allow most of the eggs to be incubated in order to hatch into chicks. Farmers therefore, recognize the value of their hens to reproduce in the flocks.

Chicks hatched and raised on-station took a longer time to reach age at first hatch (POH) than those on-farm. This is possibly the effect of flock size on-station, where birds were scavenging together as one big flock size of over 50 birds. On-farm, flocks sizes were less than 20 and had larger free-range areas. The lower RI on-station compared to on-farm is a reflection of poor hatching performance of hens on-station. Taking the on-farm POH of 30 weeks, subtracting laying and incubation period gives age at first lay of 25.5 weeks. Gueye (1998) reported age at sexual maturity (defined as age at first lay) ranging from 24 – 32 weeks in village chickens from different countries in Africa. Through recall surveys, Mwalusanya et al. (2001) in Tanzania and Tadelle et al. (2003b) in Ethiopia reported higher ages at start of laying of over 42 weeks. The differences basically reflect inaccuracies from farmers to recall actual ages of their chickens when a survey approach is used. Number of hatches per year depended upon the hatching intervals, which were slightly over 100 days both on-station and on-farm ($p>0.05$). These similarly influenced RI between places. Overall, the results showed that reproductive performance for local chickens is superior under village scavenging conditions.

8.5.2 Chick survival

Chick survival or mortality was mostly age related, with high mortality of chicks observed during the first five weeks of age. Cumulatively, over half of chicks were lost by week 20. Dessie and Ogle (2001) reported chick mortality of 61 % by eight weeks in Ethiopia; Mwalusanya et al. (2001) reported survival rate of 60 % by 10^{th} week in Tanzania; Missohou et al. (2002) reported death rate of 43 % in chicks in Senegal; while in Zimbabwe, Permin and Pedersen (2000) observed 50 % chick mortality in Newcastle disease vaccinated free-range flocks by 12^{th} week, being highest during the first three weeks. The high early chick mortality reported in this study agrees with the reported observations. High chick mortality of 20 % per month was also reported in Newcastle disease vaccinated flocks in Nicaragua (Kyvsgaard et al., 1999). After week five of age, low subsequent mortality rates observed were also reported by Kondombo et al. (2003) in Burkina Faso (8.8 %) and Demeke (2003) in Ethiopia (4.6 %). The results showed that rearing losses due to chick mortality were high despite disease intervention using conventional veterinary treatment on-station and on-farm. The higher early chick mortality on-station than on-farm could also be related to increased number of chickens scavenging together, and hence competition of feed resources. Permin and Bisgaard (1999) reported that nutritional related diseases dominate among the causes of early chick mortality. Though not quantified, common causes of chick losses included various unspecified diseases, external parasites (especially fleas), weather conditions and predation. Some of above cited authors also reported these causes. While Newcastle disease is acknowledged as a major disease contributing to chicken mortality (Gueye (1998), other diseases, parasites and predation contribute to high chick mortality according to findings of this study. Permin and Bisgaard (1999) reported that while NCD may kill up to 80 % of chicken flocks, it is not expected to account for the high early chick mortality rate. The results show that viability is a problem early after hatching. High early chick mortality is therefore an important component of rearing losses in scavenging local chickens. Also, as per Permin and Pedersen (2000), preventing rearing losses by controlling diseases appears to be just part of the solution because of multiple infection and management complex. Lesson learnt is that it is not possible to single out one factor, which appears to be a major constraint and neglect the others. This calls for a holistic approach to intervene losses especially during the first five weeks of chicks' life. Use of baskets to confine chicks during early life was implemented in Bangladesh and lowered early chick mortality to 3 % (Ahamed, 2000). Enclosing chicks using baskets were attempted in a DANIDA project in Central Malawi (DAHI, 2001) and by Ahlers (1999) in Northern Malawi. However, this requires to feed chicks and the mother hen during enclosure, an issue that needs further investigation if the technology is to be adopted by farmers in Malawi.

8.5.3 Live weights of laying hens

The loss and regain of live weights for hens during reproduction (Figure 8.1) was also reported by Pedersen (2002a) in Zimbabwe. Summarising postnatal growth of native chickens from Nigeria and Ethiopia, Horst (1989) observed that after 25 weeks of age, growth curves showed loss and regain of weights, most likely coinciding with laying phases. The loss in weight during laying is probably due to relocation of nutrients to egg formation. Hens mobilise nutrients to lay fertile and hatching eggs. During incubation (brooding) of eggs, local hens have limited access to scavenging feed. This means hens have to depend on nutrient reserves, thus, contributing to weight loss that is regained post hatch. This loss and regain of weights show prioritisation of nutrient allocation towards reproduction. Indicated by high hatchability of eggs reported in many studies, local hens supply adequate nutrients to provide good shell quality and support embryonic development. On the other hand, the loss of weights probably suggests qualitative and quantitative deficiencies in scavenging feed to support body maintenance, production and reproduction. Farrell (2000) reported that laying hen of 1.2 kg body weight requires 689 kJ/day ME and 6 g/day protein for body maintenance and egg deposition, and that these were limiting from the scavenging feed resource base of 250 kg per household of 13 hens per year. In Bangladesh, Huque (1999) reported that protein, energy and phosphorus were limiting nutrients in scavenging feeds for family poultry. Dana and Ogle (2002) reported that scavenging feed resource in Ethiopia appeared to be poor in terms of both energy and protein nutrients that affected reproductive performance of Rhode Island Red and Fayoumi scavenging chickens. The weight loss and regain is an adaptable feature for local hens to reproduce.

8.5.4 Hen output from chicks and reproductive rate

Evaluation of hen or dam output is usually done at market weight or age of the offspring (Shalev and Pasternak, 1989; Weller, 1994). Ages 15 and 20 weeks were taken as market or consumption points, while earlier ages were included for comparison purposes in this study.

Results from literature are not available for comparison. Total hen output (Table 8.6), which measures return from offspring per year, was influenced by number of chicks surviving and their growth performance. Number of chicks was determined by reproductive traits such as number of eggs laid, hatchability, hatching interval and chick mortality rates. The observed lower output on-station than on-farm is due to differing performance of these reproductive traits. There were fewer chicks per hen per annum on-station, with subsequent high mortality during the first five weeks, compared to those on-farm. In Kenya, Upton (2000) estimated that a hen rears 5.8 chicks to adult age per year, which was lower than number of chicks reared to 20 weeks on-farm, but higher than those reared on-station in this study. In addition to reproductive traits, reproduction ratios, a measure of output per unit hen weight (Table 8.7), were also determined by live weights of hens. Metabolic hen weights were significantly higher ($p<0.05$) on-station than on-farm, hence negatively affected reproductive efficiency. Since absolute live weights were not different between on-farm and on-station hens ($p>0.05$), output per live hen weight was only influenced by reproductive traits.

There is therefore, potential to improve output per hen through increasing number of chicks surviving to market or slaughter age, and / or increasing growth rates for chicks. Increasing number of chicks surviving depends on traits, all of which are related to natural fitness and viability. These have low heritabilities (Falconer, 1989; Weller, 1994) and thus difficult to improve through selection. Live weights per offspring can be increased through selection since the trait is influenced by growth rate and has moderate to high heritability (Chapter 7). It appeared reproductive (fitness related) traits were more important determinants of returns from offspring than chick weights. This is also shown by the low ($r<0.30$) correlations between annual returns from chicks and average chick weights except for those at five weeks ($r = 0.47$). With this in mind, the variation observed in Table 8.6 is therefore, non-genetic. The on-station environment and management therefore, affected fitness traits of hatchability and survival, leading to low output. Large number of chickens scavenging together on-station meant the flock biomass exceeded the carrying capacity of the scavenging feed resource, leading to low chick survival rates (Gunaratne, 1999). The on-farm conditions (with small household flock sizes of 12 chickens, Chapter 4) were favourable for reproduction, only need to improve on chick survival.

8.6 Conclusion

Scavenging chickens start reproducing after 30 weeks of age, determined by age at first hatch. With hatching interval of about 15 weeks, they hatch on average, four times per annum. While they lay few eggs per clutch, hatchability is high under their natural, undisturbed incubation environment as is the case under village conditions. However, despite high reproductive rate, rearing losses due to mortality of chicks before week five are extraordinary high. Results from on-station were not desirable compared to those from on-farm, especially on hatchability and early chick losses. This probably disqualifies attempts to improve local chickens through nucleus flocks kept on-station, hence supporting an alternative community based approach while each farmer manages own flock.

9. Valuing functions and losses, and input – output efficiency of scavenging chickens in rural communities of Malawi[1]

9.1 Abstract

A participatory monitoring study was conducted on household flocks of scavenging chickens in 27 villages in central Malawi. The objective was to identify and value functions and losses of growing and adult chickens from household flocks, and to determine input-output efficiency. Farmers and researchers recorded household flock dynamics and their causes. Annual flock values were quantitatively determined based on monthly flock sizes and outputs, live weights and farm-gate prices. Input-output efficiency was estimated based on rate of return on breeding chickens in a flock.

Annualised values were MK958 (1US$ = MK85.00) for home consumption, MK636 for ceremonies, MK403 for sales, MK66 for breeding and MK43 for gifts per household flock (average flock size of 12.9, SD 8.4). Losses due to diseases and predation were valued at MK567 and MK420 per flock, respectively. These losses accounted for 37 % of total output. The value of breeding flock averaged MK781.28. Rate of return, a measure of input-output efficiency, was 247 % when losses were included, 153 % when only functional outputs were included. For all parameters, variation was large, influenced by season of observation, flock size and village effect. High positive correlation coefficients were obtained between flock size and total annual values, and between flock size and loss due to diseases.

Value of losses due to diseases and predation signals health and management constraints. The production is highly efficient. Values of functions and losses provide information for the development of breeding goals and guidance for appropriate community based management programs.

Keywords: flock migration, economic and social functions, values, rate of return, community based

9.2 Introduction

Rural or village poultry production, chickens in particular, plays an important role of providing cheap animal protein, income, socio-cultural values to majority rural people including the vulnerable poor and aged in societies of Malawi (Gondwe et al., 1999a) and other developing countries within and outside Africa (Panda and Mohapatra, 1993; Branckaert and Gueye, 1999;). The non-descript local chickens are raised in small flock sizes of 5 to 20 per household (Gueye, 1998). Their production is regarded as a supplementary enterprise since it does not compete with other farming activities for scarce resources (Upton, 2000). The 60 – 90 % of production costs encountered in commercial poultry sector due to feed is avoided by local chickens' dependence on scavenging, with very little supplementary feed in form of wastes products from household consumption (Gunaratne, 1999). The use of simple housing materials (where housed), limited or no veterinary health care and use of non-cash traditional means (gifts, loan, entrustment) of acquiring breeding stock results in low cost or even negligible cost of production (Aini, 1990; Upton, 2000). Cost-efficiency of

[1] Paper to be submitted to Livestock Research for Rural Development

production, therefore, is high despite their low output (Aini, 1990). Upton (2000) estimated high rate of return per hen (226 %) for village chickens in rural Kenya. Tadelle et al. (2003a) estimated gross return per year of 68 % of the initial value in local chickens in Ethiopia. The authors valued output functions from local chickens but could not attach values to socio-economic functions. All these economic parameters, and studies on input-output relationships are important to contribute to complete understanding of village poultry production system, evaluate losses and justify investment in village chicken development programs. The current study aimed at: (i) economically valuing household flocks, their output and losses based on flock dynamics; (ii) assessing the input-output relationship and rate of return on flock.

9.3 Materials and methods

9.3.1 Study area

An on-farm monitoring study was carried out on 134 Village Poultry Project (Gondwe et al., 2003) participating households in 27 villages of Mkwinda and Mitundu Extension Planning Areas (EPA) of Lilongwe Agricultural Development Division (LADD). These villages surround Bunda College of Agriculture, and demography of farmers, climatic conditions and livestock distribution are described in Chapter 3.

9.3.2 Source of data

Data was obtained by monitoring and recording dynamics and management of household flocks of local chickens in the study area from August 2002 to August, 2003 (for details, see Chapter 4). Age of birds moving out were calculated from their hatch dates when known.

9.3.3 Annualised and weighted valuing of primary flock outputs

Annual flock outputs were quantitatively determined from information of monthly flock sizes and outputs; proportions of migrants out for each specific output by season of migration; seasonal live weights and farm gate price per unit live weight of chickens sold by farmers. For other output functions, farm-gate price was used to compute the values as an opportunity cost (Panin, 2000). The objective was to value outputs that involved physical exit of chickens and compare the outputs on single unit basis weighted by factors used to calculate monthly values presented in equation 10.1

$$A = f * o * r * w * p \qquad (9.1)$$

where

- *A* is monthly value of a specific output
- *f* is household flock size for a particular month of study
- *o* is the proportion of flock size (%) as migrants out of flock for the month of study
- *r* is ratio of migrants out of flock (O) that is due to a specific output in the season of migration (i.e. ratio taken as seasonal average)

w is average live weight of each migrant due to a specified output in the season of migration
p is the seasonal average farm-gate price in Malawi Kwacha (1US$ = MK85.00) per kg of live local chicken

Total output per flock was determined by adding specific outputs, while annual flock output was determined by multiplying monthly output by 12. Value of eggs was not included based on assumption that most households leave eggs for hatching by hens as also reported elsewhere (Upton, 2000).

9.3.4 Valuing breeding flocks

Flock value was based on breeding stock that was assumed to be the only investment (capital) and a limiting resource (Panin, 2000). This meant valuing hens and cocks per household that were breeding. These were multiplied by seasonal average live weights and farm-gate prices to obtain flock value.

9.3.5 Input – output relationship and efficiency

The main input into the production was assumed to be breeding stock, comprising of hens and cocks in a household flock. The value of household breeding flock was considered as capital in this analysis (Panin, 2000). Variable costs of feed, labour and house construction were negligible and assumed to be zero as also observed by other authors (Gunaratne, 1999; Upton, 2000). On diseases, only the cost of NCD vaccine was included as a variable cost. Farmers shared the cost of vaccine by contributing MK0.50 per bird regardless of size. All farmers were assumed to have administered three vaccinations to their flocks per year. With this, the gross output per flock less cost of vaccine was the gross margin per flock.

Efficiency of production was measured by rate of return on breeding flock (R, % of capital value, a measure of return on capital) as follows

$$R = \frac{O}{I} * 100 \qquad (9.2)$$

where *O* = gross output (gross margin) per flock per year; *I* = average breed stock value. R was defined as rate of return for total output (including losses) and for utilisable output (excluding losses). Breed stock values and rates of returns were natural log transformed to normalise the distribution and homogenise the variance for statistical analysis.

9.3.6 Data analysis

Output partitioned into different functions and losses were analysed for means and their standard deviations (SD). Gross output (O), breed stock value (I) and return per flock (R) were subjected to analysis of variance using the following model

$$y_{ijk} = ų + s_i + v_j + \beta(x_{ijk} - xI) + \varepsilon_{ijk} \qquad (9.3)$$

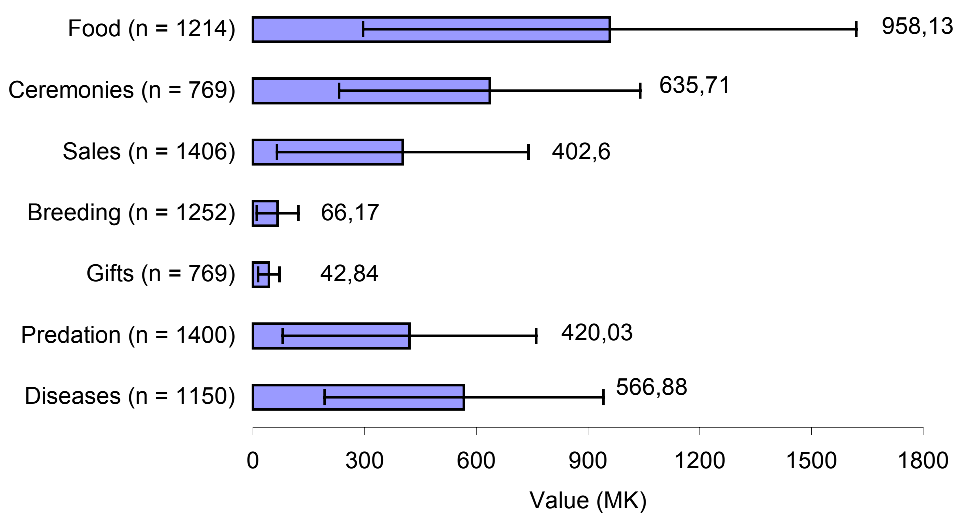
Where

y_{ijk} is the observed value; ų is the overall mean; s_i is the fixed effect of season when output was observed; v_j is the effect of village; β is the linear regression coefficient of the measure on flock size per household; (x_{ijkl} - xl) is the observed flock size of the l-th household adjusted from the overall mean flock size (xl), taken as a covariate; ε_{ijk} is the residual error assumed NID (0, $\sigma^2\varepsilon$). General linear model procedure of SAS (SAS, 1999) was used. Significant differences were determined by least significant difference (LSD).

9.4 Results

9.4.1 Annual values for output and losses per flock

Weighted and annualised values for each output per household flock (average flock size of 12.9; SD 8.4) are shown in Figure 9.1. Home consumption of chickens had more value, followed by ceremonies, then sales, with least value for exchange of breeding stock and providing gifts to friends and relatives. Combined value of losses due to diseases and predation was about MK1000.00. This loss represents 37.23 % (SD 7.7; Range of 20.14 – 47.41 %) of the annual value of outputs from the flock per household.



n = month flock observations used in the calculation of value of a function; MK = Malawi Kwacha (US$1 = MK85.00); bars represent standard deviations from the means; figures in front of bars are mean values

Figure 9.1. Annualised flock output of primary products and losses based on functions involving chicken dynamics

Season, village of study and household flock size significantly ($p<0.05$) influenced annual flock output (Tables 9.1 and 9.2). Due to large number of villages, only Lsmeans for effect of season of observation were computed (Table 9.3). As shown in Table 9.1, Pearson correlation coefficient between flock size and total output was positive, high and significant ($p<0.001$). Correlation coefficients between flock size and specific output values were positive and significant from zero but below 50 % except for diseases.

Table 9.1. Pearson correlation coefficients between household flock size and valued flock outputs involving migration of chickens

	Total value	Specific values						
		Food	Sale	Breed	Gifts	Ceremonies	Diseases	Predation
r	0.74	0.28	0.49	0.23	0.36	0.42	0.67	0.44
n	1150	1427	1427	1427	1427	1427	1150	1427

r = Pearson correlation coefficient between flock size and the respective functions; n = number of observation included in the relationship; coefficients were significantly different from zero (p<0.001)

9.4.2 Input – output efficiency

Rates of return on breeding flock based on season of observation are shown in Table 9.2. The value of breeding flock was MK781.28 (SE, 1.67). Return based on gross output were on average, more than 200 %. The rates dropped by approximately 100 % when output due to losses were excluded. Observations during hot-wet season gave higher returns than observations from the other seasons (p<0.05). Rates of return were least during the cold-dry season.

Table 9.2. Least square means and SE for gross flock output per annum and rates of return per flock by season of observation

Season	Gross output (MK)		Return (%) per gross output[1]		Return (%) per functional output[2]	
	Lsmean	SE	Lsmean	SE	Lsmean	SE
Hot-wet	3198.38[a]	83.4	327.10[a]	1.1	215.02[a]	1.1
Cold-dry	1845.12[c]	82.0	191.10[b]	1.1	99.45[c]	1.1
Hot-dry	2155.13[b]	96.1	208.17[b]	1.1	149.08[b]	1.1
Overall (Mean & SEM)	2556.14	936.9	247.28	1.9	153.16	1.9

[abc]Means within a column with different superscripts differ significantly (p< 0.05); MK = Malawi Kwacha (1 US$ = 85 MK); SE = standard error of the mean. [1] = absolute return including losses due to disease, predation and theft; [2] = output excluding losses

9.5 Discussion

Functions of chickens for home consumption, ceremonies and for income were important and show the multiple role local chickens play in rural households and the society. The 37 % of annual output due to loss through diseases and predation demonstrates the importance of animal health related constraints in village chicken production. This is a significant waste to households, which, when prevented would turn into usable output and contribute to food security. The low values for breeding stock exchange and gifts suggests that most of replacement stock is derived from within the flocks through reproduction. No costs are incurred when replacement is through reproduction. This limited breed stock exchange has advantages of reducing risk of transmitting diseases due to migrating breeding birds. However, continuous use of existing breeding stock has probable consequences of inbreeding and lack of genetic progress (Chapter 5).

Correlation coefficients were low between flock size and specific outputs, except diseases. The need to fulfil specific household and social obligations regardless of the flock available is reflected through low correlation coefficients. In contrast, the high and positive correlation between flock size and disease value shows the high association between the variables. The disease and flock size relationship may also indicate competition of resources from scavenging among chickens. Without preferential feeding to certain groups such as chicks, as is the case in the study area, young and weaker ones are likely to die (Ramlah, 1996; Gunaratne, 1999). According to Permin and Bisgarrd (1999), nutritional diseases significantly contribute to early mortality in chickens (chicks and growers) due to shortage of supplementary feed. Overall, variation in outputs was huge. This was also reported by Upton (2000) to be due to influence of season and flock characteristics.

The rates of return on capital (value of breeding stock) were high and positive, showing that the village poultry production system is highly efficient. This confirms what other authors reported (Aini, 1990; Gunaratne, 1999). Considering functional outputs only, rates of return were higher than those reported in Ethiopia (Tadelle et al., 2003a) but lower than those estimated by Upton (2000) in Kenya. The estimated values reported by Upton (2000) were similar to rate of return obtained in this study when losses are part of output. Apart from country differences, estimation procedures could contribute to the differences. This high rate is basically because the major costs of production such as feeds are avoided through use of scavenging feed resource or feed supplements, which do not have a market value (Gunaratne, 1999; Tadelle et al, 2003b). Pedersen (2000a) reported a negative gross margin of 28 US$ for local chicken flocks under improved feeding management in Zimbabwe. The difference between returns per gross output and return per functional output shows the gross importance of loss in returns from flocks due to disease, parasites, predation and theft. The findings support the fact that the production system is cost-effective and economically efficient, and a supplementary enterprise to households that provides meat, income and other functions to local populations without competition of resources with other principal enterprises (Aini, 1990). This remains to be recognised since currently village poultry production is still considered secondary to other farming activities (Gueye, 1998). While productivity is low, the low input into the system makes it efficient. The high variation in output means potential to increase the production while maintaining cost effectiveness of the production. The output, and subsequent rate of return would be higher if such functions as value of chicken manure, eggs consumed or left after brooding would be included in the evaluation.

This high value to the breeding flock shows importance farmers place on reproduction. This is an indirect investment since there is little or no cash involved in establishing or replacing a flock.

According to Weller (1994) and Panin (2000), efficiency can be increased by either minimising costs or increasing output per enterprise. As per above discussion, costs of inputs for local chickens are already minimal, thus, leaving the option of increasing output per flock by reducing losses due to diseases and predation through improved management. However, any management intervention will be associated with increased costs of production that may limit adoption of technologies by farmers (Kitalyi, 1999, Permin and Bisgaard, 1999). A community based disease management intervention may help to reduce costs and overcome the within and between flocks interaction on the complex and poorly understood disease situation in local chickens. This dual benefit could be achieved since when drugs or treatment is done communally, unit cost declines. At the same time, the community will have health flocks, thus reducing inter-flock infections. Knowledge of farmers on how to reduce disease burden and predation is critical and could only be incorporated through this community approach (a training aspect). Studies on disease tolerance are needed in order to look at possibilities of breeding for disease resistance in local chickens. It is also important to note that an increase in flock output will directly or indirectly be associated with an increase in flock size. Increase in flock size is limited by carrying capacity of the scavenging feed resource (Gunaratne, 1999), necessitating the need to feed local chickens. This option of feeding, even suggestions to use locally available feeds is currently not viable due to scarcity of ingredients without other human value apart from those currently used to supplement feed chickens, and needs further investigation. The option touches the main cost of production that is avoided in local chicken production and most likely absorbs the output due to small scale of production and low productivity for local chickens.

9.6 Conclusion

Results from the current study have provided an estimate of the annual values of output per household that involved migration of chickens from flocks and the importance of each output. The current production system is highly efficient and has opportunities to improve production in a community-based approach. Based on the valuation, establishing community based breeding and management programmes to improve village chicken production has economic justification.

10. Growth potential of local chickens in Malawi[1]

10.1 Abstract

A study was conducted to evaluate growth potential of local chickens in Malawi by comparing their growth performance under cage-fed and free-range management conditions. Chicks (n = 151) were collected from 64 farmers in 19 villages and individually raised in cages at Bunda College of Agriculture from an average age of 9 weeks to 20 weeks. On-farm made growers mash (17 % CP) was fed and birds were treated against common diseases and parasites. Hatch mates (n = 196) of cage-raised chicks remained on farmer household flocks and were raised by their dam hens under scavenging conditions. These birds were raised in three batches (that also represented seasons), between August 2002 and June 2003.

Batch of production, sex of chickens, village, management and management x batch interaction significantly ($p<0.05$) influenced growth traits. The values for birds under cage-managed conditions were significantly ($p<0.05$) 35 %, 39 %, 42 %, 25 % and 41 % higher than for birds under scavenging conditions, for weight at 20 weeks, overall daily weight gains, specific growth rate and growth efficiency, respectively. Phenotypic variance for daily weight gains and specific growth rates were 17 % and 21 %, respectively lower for cage-fed than for free range birds. Correlation coefficients of growth traits measured between cage-fed and scavenging conditions were low ($r = 0.26 – 0.33$, $p<0.05$), indicating possible within breed genotype by environment interaction. Gross margin over feed costs was MK18.00 per bird (SD, MK25.00). This was 25 % rate of return on feed costs (SD, 43 %) or 17.5 % rate of return on initial bird value plus feed cost (SD, 28.5). It is concluded that growth potential of local chickens is not exploited under scavenging conditions primarily due to feed constraints.

Keywords: growth potential, cage fed, scavenging, local chickens

10.2 Introduction

The recognised importance of local chickens in providing meat, cash income, socio-cultural values to rural people and their efficient scavenging system has led to increased research on the species during the past decade. However, most of these studies have been in form of baseline surveys (Pedersen, 2002b). These studies have generated information on local chicken production, their functions to rural households and demonstrated that the system is complex with many constraints such as low productivity of meat and eggs, and high mortality (Gueye, 1998). Because of little or no financial input invested into the system, production of local chickens is low cost, makes use of by-product resources and thus is efficient (Aini, 1990).

Growth is a compound trait influenced by genetic and management, especially nutrition and health. The village scavenging condition is variable, without standard husbandry system (Kitalyi, 1999). Performance of local chickens is thus also variable under traditional production system. While it is important to know how chickens perform under scavenging conditions, knowledge of their production potential is also

[1] Paper accepted for publication in International Journal of Poultry Science

essential (Pedersen, 2002b). This knowledge can guide proper formulation of strategies to improve local chickens. Trials under controlled environments can help to determine production potential, especially when compared to the scavenging village conditions. Such comparative trials on growth of local chickens under improved feed with those on free-ranging (scavenging) are scarce. This study objectives were to determine growth potential of local chickens under cage-managed system; and to compare their growth with contemporary local chickens under free-ranging system in the villages. The hypothesis to be tested was that the village free-ranging system limit expression of growth potential for local chickens.

10.3 Materials and methods

10.3.1 Experimental site

This study was conducted at Bunda College of Agriculture (BCA) located 30 km west of Lilongwe. Fifty (50) metabolic cages of 34 x 33 x 33 cm size (Figure 3.9, Chapter 3) were constructed locally from welding wire and placed inside the Small Animal Unit (SAU) at BCA.

The trial on scavenging conditions was conducted in the surrounding villages on households of farmers who participated in the village poultry project as described in Chapter 3.

10.3.2 Experimental chickens in cages

Fifty growing chicks collected from farmers in the study area were individually allocated into the cages at random. From each farmer, up to three chicks from the same hen were randomly chosen. The hatch dates of these chicks and their mother hens were recorded. Chicks were of an average age of eight and half (8.5) weeks when introduced to cages. Chicks were tagged, sexed and phenotypically characterised. Initial weight was taken for each bird. In total, 64 farmers from 19 villages in the study area participated in the study. The periods for the pre-trial and batches 1 to 3 were, respectively, August – September 2002; October – December 2002; January – March 2003; April – June 2003.

10.3.3 Feeding in cages

During the study period, chicks were offered on-farm formulated growers' mash (Table 10.1). Growers' mash is fed locally to commercial layer chicks during growing phase. Feed and water were offered *ad lib* in the cages.

10.3.4 Health management of chicks in cages

Birds in cages were treated against helminths (Piperazine from CAPS, Zimbabwe), coccidiosis (Amprolium from Netherlands) and other prophylaxis (Triple Sulfa from Antec healthcare Africa Ltd, South Africa). Those that had external parasites were dusted and smeared with tick greeze (Cooper Ltd, Zimbabwe). Other treatments were administered upon noticing a problem on individual birds. Treatment was, however, administered to all birds to prevent possible infection to other birds.

If birds died during the study, it was arranged to return to farmers a replacement bird of similar age taken from the stock at BCA.

Table 10.1. Ingredients and nutritive contents of Growers' mash ration fed to chicks (on as fed basis)

Ingredient	Amount (kg)
Maize	67.61
Soybeans, full fat, roasted	26.12
Fish meal	3.67
Vitamin and Mineral premix	0.30
Iodised salt	0.30
DL-Methionine	0.01
Lime	2.00
Total	100.00
Cost per 50 kg bag (Malawi Kwacha, US$1 = MK85.00)	1200.00
Nutrient contents[1], as fed	
Dry matter, % (analysed)	95.34
Crude Protein % (analysed)	17.95
Calcium % (calculated)	1.00
ME, kcal per kg (calculated)	3233
Phosphorus % (calculated)	0.83
Crude Fibre, % (calculated)	2.43
Lysine % (calculated)	0.93
Methionine % (calculated)	0.32

[1]Analysed means nutrients were analysed in the lab; calculated means nutrients were calculated based on nutrient values of ingredients as determined from lab analysis

10.3.5 Experimental chickens under free-range

The clutch mates of chicks (offspring from same hatch) brought to cages remained at the farmers' home in the villages. These were on free-range (scavenging) with their dam-hens. Their growth was monitored during the same period as their contemporary counterparts in cages. Weighing of all birds was on the same day. Management followed what farmers practiced except for the participatory communal Newcastle disease vaccination (Chapter 3).

10.3.6 Data collected

Birds were in the cages until they reached 20 weeks of age. Altogether there were four batches of chicks introduced in the cages. However, the first batch was on pre-trial basis and was not included in the final analysis. With three batches 151 chicks were observed. Of these, 69 % were female and 31 % males. Distribution in terms of colour[2] were 7.33 % *Chiphulutsa,* 21.33 % *Kawangi*, 14.00 % *Mawanga,* 28.00 % *Yakuda,* 14,00 % *Yofira* and 15.33 % *Yoyera*. On a weekly basis, live weights of

[2] Local names reported by Gondwe et al.(1999a).

chicks were taken using a digital scale (Ohaus CS5000, Ohaus Corp, Pine Brook, NJ, USA; maximum of 5 kg, graduated to 2 g).

Data on free-range birds (n = 196) were combined with data from cage birds and subjected to similar calculations described for cage-managed chickens pertaining to growth traits. Altogether, there were 347 birds included, 43 % in cages and 57 % under village management. Female birds constituted 72 %. Distribution by batch is shown in Table 10.2.

Table 10.2. Distribution of chicks allocated into cages and on-farm with number of their hens

Batch	Number of hens	Number of chicks		
		Cage	On-farm	Overall
1	22	50	79	129
2	24	50	68	118
3	24	51	49	100
		151	196	347

10.3.7 Data calculation and analyses

Growth performance was determined using live weights and growth rate parameters weight gains, specific growth rates and growth efficiency. These were calculated as follows

$$WG = \frac{(LW_{ti} - LW_{to})}{t_i - t_o} \quad (10.1)$$

Where, *WG* is weight gain (daily, weekly or overall) per time period in g; LW_{ti} is live weight at particular week = t_i; LW_{to} is live weight for the previous period = t_o measured on weekly intervals or interval between start and end of the trial.

$$SGR = \frac{\ln(LW_{ti}) - \ln(LW_{to})}{t_i - t_o} * 100 \quad (10.2)$$

Where, *SGR* is the specific growth rate in percent growth per day at a particular time; $ln(LW_{ti})$ is natural log of live weight at week = t_i; $ln(LW_{to})$ is natural log of live weight at previous week = t_o; $(t_i - t_o)$ is the period of weighing converted to days (Brody, 1945).

$$GE = \frac{WG_{ti}}{LW_{to}} \quad (10.3)$$

Where, *GE* is growth efficiency per time period = t_i; WG_{ti} is weight gain at time = t_i; LW_{to} is live weight at time = t_o

All measures and calculated parameters were tested for normality using proc univariate, normal and plot procedure of SAS (SAS, 1999). Normality was considered at over 90 % using Shapiro – Wilk (W) test for normality ($n_{obs} < 2000$). All parameters were normally distributed and data analyses proceeded without transformations.

10.3.8 Model of analysis

The model of analysis included the management effect to compare growth variation among birds between cage-managed and free-range managed systems. Effects of colour, two-way (except batch x management) and three-way possible interactions were not significant (p>0.05) and were hence dropped from the model. Initial weight was more important as a covariate than initial age and hatch weights. The final model fit to data was

$$y_{ijklmn} = \mu + b_i + m_j + s_k + v_l + h_m + \beta x_{ijklmn} + \varepsilon_{ijklmn} \qquad (10.4)$$

Where, y_{ijklmn} is the observed measure for bird n; μ is the overall mean to all birds; b_i is the fixed effect of batch of production (i = 1,2,3); m_j is the fixed effect of management (j = cage, scavenging); s_k is the fixed effect of sex of bird (k = 1,2); v_l is the fixed effect of village (l= 1,2 …, 19); β is the linear regression coefficient of the measure on initial weight of bird; x_{ijklmn} is the observed initial weight of the n-th bird adjusted from the overall mean initial weight, taken as a covariate; h_m is the random effect of hen; ε_{ijklmn} is the residual error assumed NID (0, $\sigma^2 \varepsilon$).

Batches of production were confounded with season. Batch one was during hot-dry season, batch two in hot-wet season, and batch three in cold-dry season. Batch / seasonal effects will be used interchangeably.

General linear model procedure of SAS (SAS, 1999) was used during the analysis of variance for the various parameters. Least square means were separated into significant differences by the least significant difference procedure (LSD).

Genotype x environment (G X E) interaction was estimated by correlating performance of local chickens between two management systems based on dam hen REML BLUP values obtained using proc mixed procedure of SAS (SAS, 1999). The dam hen random effect was adjusted for the fixed effects in Model 10.4 in order to estimate within breed G x E interaction.

10.3.9 Economic evaluation of feed costs

Feed costs (FC) during cages were calculated by multiplying total feed intake (TFI) by price per kg feed. Revenue (RV) was calculated by multiplying weight at 20 weeks per bird by farm-gate price of MK142.79 per kg live weight of chicken. Initial value of chicken was calculated by multiplying initial weight per bird by farm-gate price per kg live weight. Gross margin over feed cost (GMOFC) was calculated by subtracting FC from RV. Return on FC was calculated as GMOFC as a percentage of FC, while return on bird and FC was calculated as GMOFC as a percentage of initial bird value plus FC. These parameters were normally distributed and were analysed for their means and standard deviations. Analysis of variance was performed to test effect of batch and sex using general linear model procedure of SAS (SAS, 1999).

10.4 Results

10.4.1 Fixed effects of growth performance

Table 10.3 shows fixed factors and their effects on growth traits. Batch of production, sex of birds, management and management x batch interaction significantly (p<0.05) influenced growth performance for all traits studied. Village effect was important for all traits except GE, while initial live weight was not significant (p>0.05) for overall weight gain.

Table 10.3. Effects of fixed factors on overall growth characteristics of local chickens

Effect	Weight at 20 weeks	Overall weight gain	Daily weight gain	SGR	GE
Batch of production	***	***	**	**	**
Sex of birds	***	***	**	**	**
Village	**	**	***	*	ns
Management	***	***	***	***	***
Batch x management	***	***	***	***	***
Initial weight	***	ns	**	***	***

SGR = specific growth rate (% growth per day); GE = growth efficiency (g final weight gain / g initial weight); Significant levels (F – Test), * = p<0.05; ** = p<0.01; *** = p<0.001; ns = not significant (p>0.05)

10.4.2 Growth performance between cage-fed and scavenging chicken mates

Birds under cage-fed condition were superior to clutch mates under free-range village conditions (Table 10.4). The difference was significant for all traits in batches 1 and 2. Batch 3 only showed numerical difference. Stress of the birds due to observed predation followed by disease outbreak masked the effect of management in batch 3. When only batches 1 and 2 are considered, birds under cage-fed management had significantly (p<0.05) 34.99 %, 39.01 %, 41.57 %, 25.24 % and 41.17 % higher values than birds on free-range for live weights, overall weight gains, daily weight gains, SGR and GE, respectively.

10.4.3 Variance components and G X E interaction

Effect of management was compared on behaviour of variance components as shown in Table 10.5. Management did not affect phenotypic variance for final weight and weight gains. Phenotypic variance for daily weight gains and SGR were 16.9 % and 21.3 %, respectively, lower for cage-fed than for free-range birds. On the other hand, phenotypic variance for GE was 7.8 % higher in cage-fed than in free-range birds. The between dam-hen variance was larger in free-range birds than in cage-fed birds. The between dam-hen variance was also larger than the within bird variance comparing within free-range birds.

Correlation coefficients between cage-fed and free-range local chickens (Table 10.6) were significantly (p<0.05) different from zero but lower than 50 % for all traits. Daily weight gains had lowest coefficient while weight at week 20 had highest value.

Table 10.4. Overall productivity of local chickens under cage-fed and free-range village conditions (lsmeans and standard errors)

Trait	Batch	Management			
		Cage-fed		Free-range (villages)	
		Mean	SE	Mean	SE
Live weight (g) at 20 weeks	1	1142.98[a]	45.12	856.34[b]	48.11
	2	1030.20[a]	39.53	871.56[b]	44.75
	3	766.53	48.31	721.23	51.66
	Overall	979.91[a]	28.30	816.37[b]	29.08
Weight gain (g/period)	1	875.90[a]	45.12	589.25[b]	48.11
	2	763.12[a]	39.53	604.47[b]	44.75
	3	499.44	48.31	454.14	51.66
	Overall	712.82[a]	28.30	549.29[b]	29.08
Daily weight gain (g/day)	1	10.57[a]	0.59	6.58[b]	0.63
	2	10.56[a]	0.51	8.41[b]	0.59
	3	7.30	0.63	6.81	0.67
	Overall	9.48[a]	0.36	7.27[b]	0.37
SGR (% / day)	1	1.698[a]	0.095	1.213[b]	0.100
	2	1.944[a]	0.084	1.694[b]	0.093
	3	1.590	0.101	1.533	0.108
	Overall	1.744[a]	0.061	1.480[b]	0.062
GE (g/initial weight)	1	3.415[a]	0.208	2.398[b]	0.223
	2	3.248[a]	0.181	2.350[b]	0.208
	3	2.133	0.223	2.091	0.240
	Overall	2.932[a]	0.128	2.280[b]	0.132

[ab]Means within a row with different superscripts differ significantly ($p<0.05$); SGR = specific growth rate (% growth per day); GE = growth efficiency (g final weight gain / g initial weight)

Table 10.5. Variance components by management of local chickens for growth traits

Component		Weight at 20 weeks		Weight gain		Daily weight gain		SGR		GE	
		σ^2	SE	σ^2	SE	σ^2	SE	σ^2	SE	σ^2	SE
Between dam hen ($\sigma^2 b$)	Cage	12109	7114	12109	7114	0.8388	0.846	0.0366	0.022	0.2764	0.150
	Free - range	25107	9404	25107	9404	4.2914	1.891	0.0835	0.050	0.5320	0.203
Within birds ($\sigma^2_{residual}$)	Cage	24416	4426	24416	4426	4.9720	0.841	0.0956	0.017	0.5844	0.102
	Free - range	11832	2206	11832	2206	2.7045	0.522	0.0845	0.017	0.2666	0.050
Total (σ^2_p)	Cage	36525		36525		5.8109		0.1322		0.8608	
	Free - range	36939		36939		6.9959		0.1680		0.7986	

SGR = specific growth rate (% growth per day); GE = growth efficiency (g final weight gain / g initial weight)

Table 10.6. Correlation coefficients between BLUP values of dam hens for cage fed and free-range managed local chickens

Trait	Weight at 20 weeks	Weight gain	Daily weight gain	SGR	GE
Coefficient	0.325	0.325	0.261	0.311	0.316
Significant level	**	**	*	**	**

SGR = specific growth rate (% growth per day); GE = growth efficiency (g final weight gain / g initial weight); Significance levels , * = p<0,05; ** = p<0,01

10.4.4 Economic evaluation of feed costs in cages

Economic evaluation of feed costs (Table 10.7) showed a positive mean gross margin with a wide variation. Similarly, both rate of return on feed costs and on feed and bird costs showed wide variation. Batch 3 was significantly ($p<0.05$) inferior to the other two batches (Table 10.8). Males had significantly ($p<0.05$) higher values for the three parameters than females.

Table 10.7. Descriptive statistics for economic parameters of feed costs for chickens under cage management

Parameter	n	Mean	SD	Minimum	Maximum
Total feed intake, g	161	3346.6	863.5	1048.0	5536.0
Feed cost per bird, MK	161	80.32	20.73	25.15	132.86
Income per bird, MK	141	98.57	35.94	23.42	194.19
GMOFC per bird. MK	140	18.03	28.52	(48.42)	90.08
Return on feed cost, %	140	25.20	43.54	(62.04)	227.07
Return on bird & feed cost, %	140	17.52	28.55	(40.42)	128.41

n = number of birds; SD = standard deviation; GMOFC = Gross margin over feed cost; MK = Malawi Kwacha (1US$ = MK85.00); Values in brackets are negative

Table 10.8. Least square means and SE for gross margin over feed cost and rates of returns by batch and sex of birds

Factor		GMOFC, MK		Return on feed cost, %		Return on bird & feed cost, %	
		Lsmean	SE	Lsmean	SE	Lsmean	SE
Batch	1	29.77[a]	4.02	41.91[a]	6.33	28.96[a]	4.12
	2	23.87[a]	3.93	29.72[a]	6.19	20.94[a]	4.03
	3	2.24[b]	4.19	5.03[b]	6.60	3.74[b]	4.30
Sex	Female	15.68[b]	2.71	23.16[b]	4.26	15.93[b]	2.78
	Male	21.57[a]	4.14	27.94[a]	6.52	19.83[a]	4.24

[abc]means within a column in a category with different superscripts significantly differ ($p<0.05$); GMOFC = Gross margin over feed cost; MK = Malawi Kwacha (1US$ = MK85.00)

10.5 Discussion

10.5.1 Growth potential

Demeke (2003) observed higher live weights (1300g, intensive; 985 g, free-range) in Ethiopian local chickens at 20 weeks of age than the results from this study. The difference could in part be due to different initial live weights which were not adjusted for in Demeke's study. Due to missing of comparative data on genetic characterisation, genetic differences could not be discussed. In this study, feeding started from 9 weeks while in Demeke's study, feeding started from one day old, thus a management difference. However, daily weight gains are comparable. On the other hand, the trend for live weights and daily weight gains agree with those in this study, whereby their birds under intensive system were 24 % heavier than birds under scavenging conditions. The status and limitation of scavenging feed resource base is the main area of research in most parts of Africa (Roberts, 1999; Olukosi and Sonaiya, 2003). In their prediction, Olukosi and Sonaiya (2003) calculated a daily feed intake of 20 g per bird per day under scavenging condition, which was lower than feed intake observed in the study (45 – 59 g per day) under cage management. The findings support views that scavenging feed resource base is often inadequate quantitatively and qualitatively (Huque, 1999; Ndegwa et al., 2001; Dana and Ogle, 2002), depending on flock size, environment and season (Gunaratne, 1999; Roberts, 1999). Kitalyi (1998) reported that scavenging feed is a constraint to local chicken growth and reproductive potential, and emphasised on the need to provide supplement feeds to birds. The major input to birds under cage management was feeding a balanced ration (grower's mash). Disease intervention may have differed in intensity (between cage-fed and village chickens) but was also taking place in the villages. The difference in growth performance observed in the study was therefore due to feeding management. The significant superiority of birds under cage managed conditions over village free-range birds shows that feed constraint limits expression of growth potential in local chickens.

Batch effect is mainly due to confounding effect of season, predation and disease stress during batch 3 and mainly affected birds under cage management. Birds under free-range were consistent between batches for most traits. Village influence is probably due to differing in flock structure, management, scavenging biomass and nutritional pressure under free-range, and disease challenges that vary from village to village. Village effect was more pronounced in birds under free-range than those fed in cages. This is obvious since birds in cages were exposed to village conditions only before they were brought to cages.

10.5.2 Variance components

The larger between dam-hen variance for free-range than for cage-managed birds is expected since free-range birds continued with their dam-hens, and hence had more common influence from their dam-hens. Nature of data in this comparison did not allow for determining the between bird variance due to missing sire pedigree. Hence, the dam-hen variance includes all genetic, maternal and common environment effects. Since village effect was taken care of, the common environment in this case was flock of the birds. Birds under cage management were separated from their dam-hens, and hence the low between dam-hen variance that was in this case, a carry over effect.

Hu et al. (1999) reported that maternal effects are moderate in poultry, only contributing less than 10 % of total variance and depend on traits. Falconer (1989) reasons that maternal affects are more important in mammals. Pinchasov (1991) reported that maternal effects in chickens disappear within the first three weeks of life. Prado – Gonzalez et al. (2003) observed significant effect of maternal effect for weights at hatch and fourth week of Creole chickens in Mexico and not thereafter. The variances in this study show potential maternal effects that are high and persist for long time in chickens (see also Chapter 7). Maternal effects from literature arose from the dam-hen influence on the egg (size, weight, shell quality and yolk composition) that is described as the only vehicle for maternal effects in poultry (Selewant and Johansson, 2000). This is true when birds are raised under intensive system and are separated from their dam-hens at hatch. In free-ranging chickens, a dam-hen controls chicks till weaning; hence post hatch maternal effects are expected. The observed variance and the difference show possible post hatch maternal influence on the birds under free-range system. The magnitude of such maternal effect is however, trait and management specific.

By separating chicks from their dam-hens, post hatch maternal and common environmental effects are minimised. This also depends on the age when chicks become independent of their dam-hens. Together with improved feeding, the between dam-hen variance was reduced under cage managed conditions.

10.5.3 G x E interaction

In general, genetic parameters could be better estimated under these conditions of improved feeding. However, there is need to check if local chickens express some genotype by environment (G x E) interaction, if the results determined under improved feeding could be applicable to local free-ranging environment. In absence of sire pedigree, a mere estimate of individual by environment (within breed) interaction was derived by correlating the BLUP values of dam-hen effects (genetic and maternal) under cage fed and free-range conditions. In genetic analysis, genetic correlations between 0.9 and 1.0 suggest that two traits are the same (Kerr et al., 2001).

Lower correlation coefficients imply small covariance between the two observations. This indicates presence of a stronger interaction (Lin and Togashi, 2002). The dam-hen effect and ranking was expected to be similar in the two management systems and hence show high correlation coefficients. The results obtained showed correlation coefficients ranging from 0.26 – 0.33. Common covariance in these correlations was due to genetic and maternal effects. Their low values shows possibility of G x E interaction being expressed in growth traits for local chickens. This means local chickens are sensitive to environmental changes. Use of parameters determined under improved feeding in this case is only to show potential performance of local chickens under free-ranging environment (Prado – Gonzalez et al., 2003).

10.5.4 Economic evaluation of feeding local chickens

While feeding improved production performance of local chickens by over 30 %, gross margins and rates of returns on feed costs were positive but lower than 30 %. High costs of feed and poor feed conversion efficiency are probable reasons for low rates of returns. This return declined even more when initial value of birds was included. When all costs, such as labour involved with intensification and treatment are taken into consideration, it would not be economically justifiable to improve feeding of local chickens, as observed by Demeke (2003). Pedersen (2002b) found negative gross margins for intensively managed local chickens of US$28 in Zimbabwe. Local chickens are appropriate for the low input scavenging system. This poses a challenge to utilise the advantages of the low-input system while at the same time attempt to achieve their genetic potential.

10.6 Conclusion

The growth potential of local chickens is not fully exploited under free-range (scavenging) conditions due to inadequate feeds. Feeding management contributes to about 30 % of their growth potential. Productivity of local chickens can be enhanced through improved management under free-ranging conditions. The option of improved feeding of local chickens under confined conditions is, however, economically not attractive enough to warrant farmers adopting it.

11. Feed intake, metabolism and utilisation efficiency of local chickens under cage managed conditions in Malawi

11.1 Abstract

A study was conducted to determine feed intake, feed and nutrient utilisation efficiencies and metabolism of local chickens under cage managed conditions. Per batch, 50 growing chicks (about 8.5 weeks old on average) were collected from farmers and were randomly allocated into cages. In cages, they were fed on-farm made growers mash (17 % CP) till they were 20 weeks old. Feed was weighed when offered to chicks while residual feed was weighed the following day. Droppings were collected underneath the cage and weighed weekly. Three batches of 151 chicks altogether were used in the analysis. Metabolic parameters were determined from a sample of 53 chicks by collecting droppings from each bird for 14 days.

Feed intake per bird ranged from 38 to 56 g per day by beginning of the study and a range of 42 to 66 g per day when birds were 20 weeks old. Dry matter intake was 13 % of body weight at beginning, and declined to 6.6 % of body weight at 20 weeks old. Feed conversion efficiencies were high (4.5 to 6.0 g feed per g gain) and increasing with age of birds. Efficiency of protein utilisation was better at young age (1.313 g weight gain per g protein intake) than at old age (0.824). A similar trend was shown for metabolised protein. Season, sex, initial weights and random effect of hen significantly ($p<0.05$) influenced the parameters. Fifty-two percent of feed intake and 30 % of protein intake were metabolised. Protein intake was 8 g per bird per day. Dry matter content of fresh faecal matter was 52 %. Each bird excreted 21 g faecal matter on dry matter basis, that contained 33 % CP and 22 % ash. It is concluded that local chickens have low feed intake, poor conversion efficiencies but utilise metabolised nutrients efficiently. Droppings are rich in nitrogen and minerals, supporting their potential use in feeding other livestock species and as organic fertiliser.

Keywords: local chickens, feed intake, faecal matter, metabolism, cages

11.2 Introduction

Growth is a compound trait that is directly or indirectly influenced by nutrition. Feeding characteristics, biomass and requirements for local scavenging chickens are not well established. To date, there are no reliable methods of estimating quantity and quality of scavenging feed resource (Kitalyi, 1999). This leads to lack of designed rations and feed supplements for local chickens in Malawi and elsewhere. However, this does not underscore the importance of feeding and nutrition of the scavenging feed resource in local chickens (Gunaratne, 1999). In some cases, there are attempts to estimate quantity of scavenging feed resource base and their nutritional status through crop contents, household refuse estimation and prediction equations (Dessie and Ogle, 1996; Gunaratne, 1999; Huque, 1999; Olukosi and Sonaiya, 2003).

Currently rural poultry improvement programs include introducing commercial rations to improve chicken production (Kitalyi, 1999). Some authors (Rodriguez and Preston, 1999; Tadelle et al., 2003c) reported that scavenging feed resource is limited and a constraint to growth and reproduction in local chickens. To further pursue on the scavenging feed resource base and potential growth of local chickens, there is need to determine optimal feed consumption and feed utilisation in local chickens. Knowledge of this will enable to estimate the input-output relationship and efficiency of local chickens. The results will be used to develop improved feeding management to improve local chicken productivity among smallholder farmers. The current study was therefore, conducted to determine feed intake (consumption), feed and nutrient utilisation efficiencies, and metabolism in local chickens under cage conditions.

11.3 Materials and Methods

11.3.1 Metabolic cages and chicken management

Fifty metabolic cages were used in this study (see Figure 3.9, Chapter 3). Source of chicks and health management are described in detail in Chapter 10.

11.3.2 Feeding management

During the study period, chicks were offered locally (on-farm) formulated growers mash (Table 10.1, Chapter 10). Growers' mash is locally fed to commercial layer chicks during growing phase. Feed and water were offered *ad lib* in the cages. Feed offered was weighed in the morning and put in feed troughs. Additional feed was continuously provided to birds that consumed all feed. On the following day, residual feed was weighed before supplying new feed to the chicks. This weighing was used to determine the amount of feed consumed by the bird.

11.3.3 Data collected

Per batch birds were in the cages until they reached 20 weeks of age. Feed offered and feed residuals were weighed daily. On a weekly basis, live weights of chicks were taken using a digital scale (Ohaus CS5000, Ohaus Corp, Pine Brook, NJ, USA; maximum of 5 kg, graduated to 2 g). Droppings (faecal matter) for each bird were collected on a metal plate (7 cm deep) below the cage and were weighed on weekly interval as air-dried. Droppings that were contaminated with water were discarded.

Altogether there were four batches of chicks introduced in the cages. However, the first batch was on pre-trial basis. With three batches (1, 2 and 3), 151 chicks were observed and their results will be reported.

11.3.4 Data calculation and analyses

Data on feed intake was determined as follows

$$FI = F_o - F_i \tag{11.1}$$

Where *FI* is feed intake per bird per day in grams; F_o is amount of feed offered for per day; F_i is amount of feed residuals and measured the following morning.

To match with live weight data, daily feed intakes were added for seven days. The two files were merged in order to calculate parameters that required both growth and feed data. These included feed conversion ratios and dry matter intake.

Feed conversion ratio was calculated from

$$FCR = \frac{FI}{WG} \qquad (11.2)$$

Where *FCR* is the feed conversion ratio (g feed / g weight gain); *WG* is the weight gain per unit period.

Weight gains and FCR were calculated on weekly basis and for overall study period. Overall weight gain was calculated by subtracting initial weight from the final weight. Overall FCR was calculated by dividing overall feed intake by overall weight gain.

Dry matter intake as an indicator of stomach capacity was calculated as

$$DMI = \left(\frac{FI}{WT_t}\right) * 100 \qquad (11.3)$$

Where *DMI* is the daily dry matter intake in percent; *WT* is the live weight in grams per bird at a particular period $_t$; FI was converted to dry matter basis (95.3 % DM).

All measures and calculated parameters were tested for normality using proc univariate, normal and plot procedure of SAS (SAS, 1999). Outliers were checked and edited. Normality was considered at over 90 % using Shapiro – Wilk (W) test for normality (n_{obs} < 2000). All parameters were normally distributed and data analyses proceeded without transformations.

11.3.5 Model of analysis

Effects of colour of birds, sex and batch of study were tested in the model building on the parameters using normal GLM procedure of SAS (SAS, 1999). The final model included hen as a dam random effect. Of the possible covariates (hatch weight, age at cage and initial weight at cage), the initial weight was most important and others were dropped from the analysis.

The following mixed linear model was used to test effect of factors on different parameters in chicks during the cages

$$y_{ijklm} = \mu + b_i + s_j + p_k + a_{ijkl} + w_m + \beta(x_{ijkl} - xl) + h_n + \varepsilon_{ijklm} \qquad (11.4)$$

Where y_{ijklm} is the observed measure for bird l in week m; μ is the overall mean; b_i is the fixed effect of batch of production (i = 1,2,3), that also reflects seasonal effect; s_j is the fixed effect of sex of bird (j = 1,2); p_k is the fixed effect of phenotype by colour of bird (k = 1,2,3,4,5,6); a_{ijkl} is the random effect of bird within hen; w_m is the fixed effect of period in weeks of the birds on feeding (m = 1,2 …, 10), 1 taken to approximate 10 weeks of age; β is the linear regression coefficient of the measure on initial weight of bird; (x_{ijkl} - xl) is the observed initial weight of the l-th bird adjusted from the overall mean initial weight (xl), taken as a covariate; h_n is the random effect of hen; ε_{ijklm} is the residual error at particular period m, assumed NID (0, σ^2 ε).

The GLM repeated measures analysis showed correlations among observations on the same subject that were reducing the further the measures are apart. Chi-square test for orthogonal components (Mauchly's Criterion Sphericity Test for within subject effect) were significant (P<0.0001) for most parameters except dry matter intake and feed conversion ratios, showing differing variances between measures and thus existence of a covariance structure among repeated measures. Proc mixed procedure of SAS (Wolfinger and Chang, 1995; Littel et al., 1998; SAS, 1999) was used to model the covariance structure and test for the effects adjusted for the covariate structure among measures. The mixed procedure (REML) was used to allow for flexibility in mean model fitting and to have standard errors that are adjusted for the variance-covariance structure. Compound Symmetry (CS) was used as a within subject (bird/henid) covariance structure since it generally provided a better statistical fit than other structures at convergence. Week, sex and batch of study were included as between-within factor interaction, while bird as subject was included as random effect.

The model for protein efficiency ratio and metabolic protein efficiency ratio omitted effect of sex, initial weight since they were not significant. Weight gain was included as a covariate instead.

11.3.6 Nutrient metabolism in local chickens

In order to determine metabolic feed intake, fresh droppings were collected and analysed. The droppings were collected from individual birds randomly sampled from within the batch every day for 14 days. No acclimatization period was needed since birds were already on feed. Data from 174 samples collected from 53 birds were finally used.

Nutrients (dry matter, crude protein and ash) were determined on faecal matter in the Animal Nutrition Laboratory at BCA using proximate method of analyses (AOAC, 1981). Additional feed and faecal samples were collected from birds on free-range at BCA and from the villages. These samples were included in the analysis of protein.

Apparent metabolisability (metabolic coefficients) of the feed was determined for dry matter intake and crude protein for each observation using the formula

$$AM_t = FI_n - FC_n \qquad (11.5)$$

Where AM_t is apparent metabolisable nutrient t = dry matter or protein; FI_n is gross value of nutrient n (dry matter or protein) in feed; FC_n is gross value of nutrient n (dry matter or protein) in the droppings. All values were converted to dry matter basis.

Endogenous loss was determined using a regression method described by Sibbald (1975), Askbrant and Khalili (1989) and Brand et al. (2000). For each observation, gross nutrients output (dry matter and crude protein) (y) were regressed on gross nutrient intake (x) in a simple linear regression

$$y = \alpha + \beta x \qquad (11.6)$$

where y is the total gross nutrient excreted in faeces; x is the gross nutrient intake from feed (FI_n); α is the endogenous nutrient loss; β is the proportion of gross nutrient in feed that is in the excreta (not metabolised).

True metabolisable (TM_t) nutrient of the feed was the proportion of the gross nutrient in feed (x_n) that was metabolised

$$TM_t = X_n(1-\beta) \qquad (11.7)$$

11.4 Results

11.4.1 Feed intake and dry matter intake

Least square means for different parameters under cage-fed management (combined for sex) are presented in Table 11.1. Batch (season) of production, week and sex and their interaction were all significant ($p<0.001$) factors affecting feed consumption in birds. Random effect of hen ($p<0.05$) and initial weight as a covariate ($p<0.0001$) contributed significantly to feed consumption (up to five and nine weeks of feeding, respectively).

FI for birds in batch one (hot-dry season) was higher for all weeks and for the overall FI, seconded by batch two (hot-wet season) though differences were not significant ($p>0.05$) at weeks 5 and 10. FI for birds in batch three (cold-dry season) were significantly lower ($p<0.05$) than FI for birds in the two batches. The trend showed that FI was increasing by week, an average increase of 25.68 % during the period. The pattern of sex was similar across weeks and batches. Males had significantly ($p<0.05$) 10.39 % higher FI than females (Figure 11.1).

Dry matter intake (DMI) measured by dry matter FI as a percent of body weight is presented in Table 11.1 and Figure 11.2. DMI is used as an indicator of stomach capacity of the animal in relation to its body weight. Except in the first week, batch and sex of the bird did not affect DMI ($p>0.05$). DMI was, however, significantly ($p<0.05$) declining linearly with week of production, while live weights for chickens were linearly increasing. Random effect of hen and initial weight (covariate) were significant ($p<0.05$) throughout the period.

11.4.2 Feed and protein conversion efficiencies

Feed utilisation efficiency for local chickens was measured by feed conversion ratio (FCR), protein efficiency ratio (PER) and efficiency of protein metabolism (EPM), all shown in Table 11.1. Week had significant effect ($p<0.05$) on FCR while batch effect was observed significant ($p<0.05$) in weeks 5, 10 and overall FCR. Birds in batch 1 were significantly ($p<0.05$) better in utilisation of feed than birds in batches 2 and 3. In general, FCR were increasing with age of birds while sexual dimorphism was not significant ($p>0.05$).

Table 11.1. Overall and weekly feed intake, DMI, FCR, SGR, PER and EPM in chickens adjusted for age and initial weight of birds (lsmeans and standard errors (SE) in grams)

Trait	Batch / Season	n	Week of study							
			1		5		10		Overall	
			lsmean	SE	lsmean	SE	lsmean	SE	lsmean	SE
Feed intake, g / day	1	51	55.81[a]	2.12	57.95[a]	2.18	66.09[a]	2.28	59.17[a]	1.59
	2	53	38.00[b]	2.18	56.07[a]	2.20	60.45[a]	2.35	53.21[b]	1.58
	3	47	40.98[b]	2.20	46.32[b]	2.23	42.86[b]	2.34	44.54[c]	1.59
Dry matter intake, DMI (%)	1	50	15.98[a]	0.68	7.94	0.71	6.45	0.73	7.58	0.64
	2	51	11.37[b]	0.69	9.87	0.70	6.65	0.76	9.01	0.59
	3	47	11.98[b]	0.68	9.54	0.69	6.71	0.76	8.97	0.59
Feed conversion ratio, FCR (g feed / g weight gain)	1	32	4.23	0.51	3.92[b]	0.43	4.89[b]	0.45	4.54[c]	0.33
	2	40	3.56	0.48	5.55[a]	0.41	6.12[a]	0.46	5.36[b]	0.18
	3	39	4.67	0.42	5.96[a]	0.45	5.57[ab]	0.50	6.03[a]	0.20
Protein Efficiency ratio, PER (g weight gain / g protein intake)	1	42	1.241[b]	0.05	1.026	0.05	0.599[b]	0.18	0.960	0.05
	2	47	1.427[a]	0.05	1.026	0.05	0.835[b]	0.06	1.039	0.04
	3	41	1.272[b]	0.05	1.119	0.05	1.037[a]	0.06	1.088	0.04
Efficiency of protein metabolised, EPM (g weight gain / g metabolised protein)	1	42	4.362[ab]	0.19	3.661	0.19	1.381	0.84	2.216[b]	0.18
	2	47	4.788[a]	0.18	3.403	0.18	1.003	0.21	2.775[a]	0.13
	3	41	4.182[b]	0.19	3.513	0.18	0.969	0.23	2.770[a]	0.13

[abc]Means with different superscripts within a column in a trait are significantly different ($P<0.05$); n is number of birds

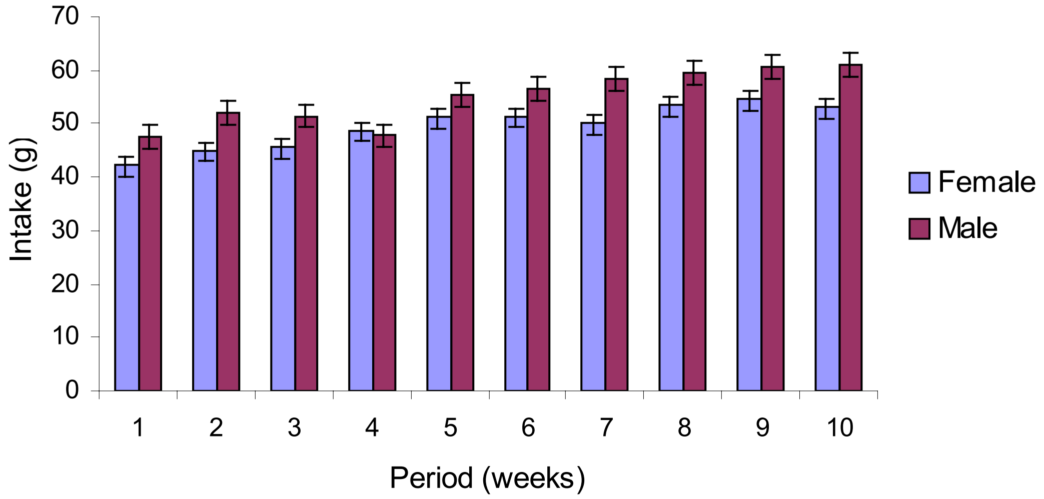
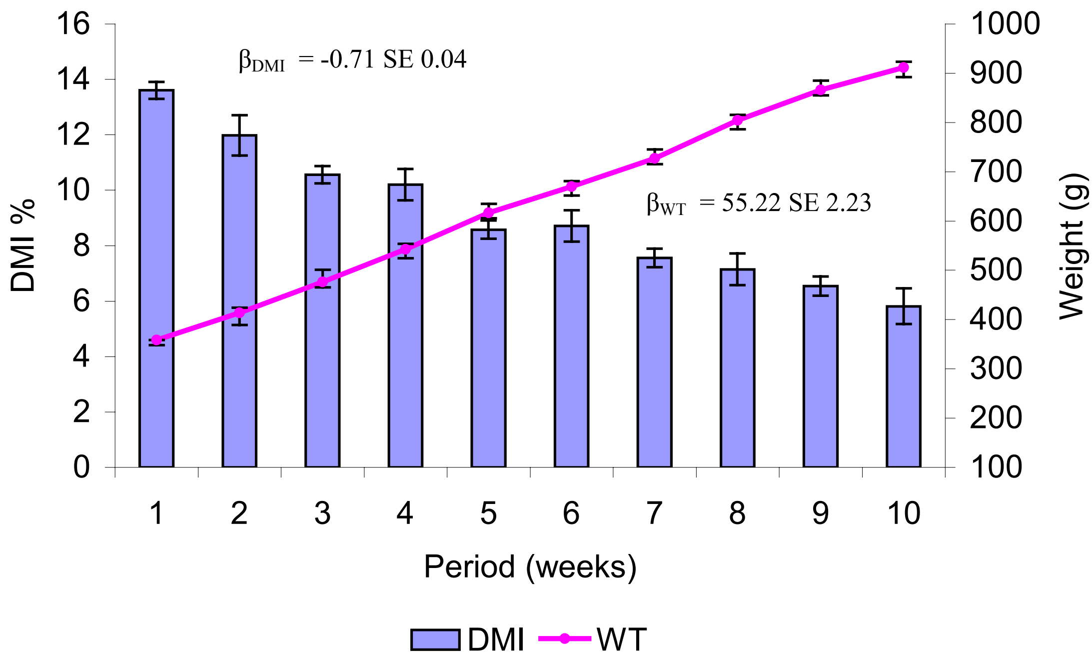


Figure 11.1. Feed intake of birds by batch, week and sex of bird (lsmeans and standard errors)



DMI = Dry matter intake (%), WT = live weight (g), slopes (β_{DMI} and β_{WT}) are regression of DMI and WT, respectively on age (weeks)
Adjusted correlation between WT and DMI = -0.25; WT and FI = 0.30

Figure 11.2. Dry matter intake (%) and live weights in chickens (lsmeans and standard errors)

Effects of week and the interaction between week and batch were significant on PER ($p<0.05$), so was weight gain as a covariate ($P<0.05$). Birds in batch 2 had higher ($p<0.05$) gain per unit of protein intake at week 1, while batch 1 and 3 were similar

($p>0.05$) at week 1. Batch 3 had significantly ($p<0.05$) higher PER at week 10 than the two batches. Overall PER were similar between batches ($p>0.05$). PER was declining with age. A similar trend was observed in EPM except overall EPM where batch 1 had significantly ($p<0.05$) lower value than the two batches.

11.4.3 Determination of nutrient metabolism

Metabolic regression coefficients of feed nutrients for local chickens are presented in Table 11.2 while estimates of nutrients in feed and faecal output are shown in Table 11.3. Based on endogenous loss (α) calculated true metabolisable dry matter feed and crude protein were correlated with the predicted values. Correlation coefficients were high and significant ($p<0.0001$) for both nutrients.

Table 11.2. Metabolic coefficients estimated by linear regression of faecal output on feed intake and crude protein

Nutrient	Endogenous loss (α)	SE	Slope (β)	SE
Dry matter feed intake	7.4826	1.783	0.3004	0.039
Crude Protein	2.0886	0.583	0.5610	0.067

Pearson correlation between observed and predicted true metabolised feed = 0.813 ($p<0.0001$, 168 observations); Pearson correlation between observed and predicted true metabolised crude protein = 0.810 ($p<0.0001$, 128 observations)

Table 11.3. Estimated daily nutrients in feed and faecal output and apparent and predicted true metabolisability of feed and crude protein

Variable per bird per day	n	Mean	SD
Faecal nutrient value			
Faecal dry matter, fresh %	174	52.00	15.73
Faecal dry matter, air dried substance %	174	91.70	0.56
Crude protein, % on dry matter basis	174	32.47	1.87
Ash, % on dry matter basis	174	21.87	1.23
Daily feed intake, faecal output and feed metabolism			
Feed intake, as fed, g	172	45.82	15.66
Feed intake, on DM, g	172	43.68	14.93
Faecal output, on DM, g	174	20.57	8.75
Apparent metabolised feed, g	168	23.72	12.31
True metabolised feed, g	172	30.56	10.45
Percent feed metabolised, %	168	52.16	15.44
Daily protein intake, output and metabolism			
Crude protein in feed, g	172	8.22	2.81
Crude protein in faecal, g	174	6.69	2.92
Apparent crude protein metabolised, g	128	2.74	1.78
True crude protein metabolised, g	172	3.61	1.23
Crude protein metabolised, % of protein intake	128	30.14	12.57
Crude protein metabolised, % of feed intake	128	5.41	2.26

DM = dry matter; n = number of observations

Dry matter content of fresh droppings for local chickens was high (52 %). When air dried, dropping dry matter was 91 %. On dry matter basis, each bird (between 10 – 20 weeks old) excreted an average faecal weight of 21 g per day that contained 33 %

crude protein (5.2 % nitrogen) and 22 % ash. Dry matter and crude protein of fresh faecal samples from free-ranging chickens were compared from those in cages and there were no significant differences (p>0.05). Phenotype by colour and sex of birds were not significant (p>0.05).

Fifty-two percent (52 %) of feed intake was apparently metabolised while metabolised protein constituted 30 % of protein intake (5 % of protein in the feed). Protein intake was on average 8 g per bird per day.

11.5 Discussion

11.5.1 Feed intake and stomach capacity

Results of FI are closer to feed consumption reported by Tadelle et al. (2003c) on indigenous chickens of Ethiopia raised under deep litter management conditions, on-station. Olukosi and Sonaiya (2003) estimated amount of scavenging feed consumed by a local chicken to be 32.2 g per day, which was lower than estimates from this study. The authors used an equation based on flock size and energy requirements for each bird but overlooked age of the birds in a flock. FI in local chickens is equivalent to FI of a Ross broiler chicken at two weeks and weighing about 422 g (Aviagen, nd) and FI for Cobb broiler strain by 4th week weighing 540 g in Ethiopia under intensive management (Tadelle et al., 2003d). Demeke (2003) reported an average FI of 48 g in growing local chickens when feed to appetite in Ethiopia. The results of FI agree with findings from other similar studies for local chickens. FI shows that local chickens have low stomach capacity.

Live body weights and its correlation to age influenced the stomach capacity (Figure 11.2). To make results comparable, DMI has to be calculated. DMI declined with age while body weight increased. Tadelle et al. (2003c) did not include DMI determination in their study but calculations from their intake and body weights provide values that are similar to DMI determined in this study. Similar calculations from the study by Demeke (2003) gave DMI of 20 % at nine weeks and 6.5 % at twenty weeks of age. Results are also comparable with Ross broiler breed whose data showed DMI of 15 % of body weight at about week one of age and 6.0 % at week eight (Aviagen, nd). Stomach capacity is well established during early ages of the bird and it increases at a declining rate in relation to an increase in body weight. DMI found in the study could be used to estimate amount of dry matter feed a bird could consume per day from live weight of the bird and the need to meet all daily energy and nutrient requirements within that amount.

11.5.2 Feed and protein utilisation efficiencies

Results found in the study agree with those obtained by Tadelle et al. (2003c) who found average FCR ranging from 4.5 to 6.4 for different ecotypes of local birds under deep litter management conditions. Roberts (1999) reported FCR of 4.5 for village chickens when given free access to feed under intensive management. Demeke (2003) reported higher FCR (11.1 to 13.4) for local chickens fed to appetite than that of Tadelle et al. (2003c) and those in this study. However, Tadelle et al. (2003c) found higher FCR in young birds than in old one, which disagree with the findings of the current study. Since birds were group fed and on deep litter system in their experiments (Tadelle et al., 2003c), it is possible there were feed spillage, especially when birds were young. Under deep litter system, spill over feed is considered consumed, thus, resulting in high FCR in young birds. Kingori et al. (2003) reported similar FCR to this study when indigenous chickens were fed 16 – 18 % CP diets, but reported higher FRC (7.6 – 15.6) for local chickens fed 10 – 14 % CP diets. Compared with improved breeds and broiler strains (FCR ranging from 0.85 to 2.50, increasing with age) under intensive management (Tadelle et al., 2003d; Awoniyi et al., 2003), FCR for local chickens were high. Local chickens are, therefore, poor in converting feed into body mass.

Literature is scanty on values of PER and EPM for local chickens to compare the results of this study with. Awoniyi et al. (2003) reported PER ranging from 1.52 to 1.88 in broilers under intensive management. The authors did not specify method of determining PER. Roberts (1999) reported PER of 1.02 (gain /unit protein intake) for village chickens in Sri Lanka. The results of this study are comparable to those reported by Roberts (1999) and Awoniyi et al. (2003). This shows that despite poor feed conversion, local chickens utilise absorbed nutrients efficiently for their growth. The higher EPM than PER values showed that birds were able to utilise efficiently all the proteins that were available for metabolism. Generally both PER and EPM were declining with age, indicating decreasing efficiency of utilisation of protein. This may be related to increased requirements for maintenance as birds grew older.

11.5.3 Dry matter and protein metabolism

Endogenous loss represents amount of dry matter and crude protein that can be sacrificed from the body when fasted (i.e α when x = 0). Based on intake, these would represent 17.1 % and 25.4 % of dry matter feed and protein intakes, respectively. These could be used to indicate level of adaptation to feed shortage in local chickens. The high faecal dry matter content suggests that birds reabsorbed most of the water in faeces. Under scavenging conditions, metabolised feed and nutrients may be lower than the reported values due to high fibre content (up to 10.3 %) in scavenging feed resource (Huque, 1999). CP in droppings were similar to the 30.6 % content analysed by Bayemi et al. (2001) for poultry droppings supplemented to growing cattle in Cameroon. The high CP and ash contents of faecal matter support use of chicken droppings as organic fertilizer or as feed supplements to other species such as dairy cattle and pigs.

11.6 Conclusion

The study has found that local chickens are characterised by relatively low feed intake and poor feed conversion efficiency when comparing to performance of commercial breeds or strains. Metabolised nutrients are however, efficiently utilised. Droppings have high dry matter content, probably indicating recycling of water from droppings into the body. These plus the high endogenous nutrient contents need further investigation since they indicate potential adaptation of local chickens to feed or nutrient shortages.

12. Comparative growth performance of Black Australorp and local chickens under free-ranging village conditions in Malawi

12.1 Abstract

Growth performance of Black Australorp (BA) and local chickens (LC) was compared under free-range conditions in a farmer participative study. Maximum of three BA chicks (n=125) per farmer were distributed at random in the villages at nine (9) weeks of age. Contemporary LC chicks (n = 124) hatched and mothered by a local hen were used for comparison. Other BA chickens (n = 63) were kept on-station. Live weights were collected weekly till birds reached 30 weeks.

At 29 weeks of age, BA fed commercial ration (CR) on-station were 18 % ($p<0.05$) heavier than BA and LC on free-range in village flocks. In the villages, LC performance was not different ($p>0.05$) to BA on free-range for live weights, daily weight gains and growth efficiency. In the villages, cumulative mortality by week 5 was 14.4 % in BA, 11.3 % in LC on free-range and 4.7 % in BA kept on-station. The current study has demonstrated to farmers that BA is not a suitable breed to be used to substitute LC. BA seems to be preferred due to its exotic image, which is not supported by actual performance under village conditions. In feedback discussion, farmers appreciated the findings of the study, correcting common perceptions.

Key words: Black Australorp, local chicken, free-range

12.2 Introduction

Local chickens dominate in smallholder farms in Malawi. These local chickens (LC) are deemed less productive but appear to be adapted to local harsh free-ranging rearing environment. In an attempt to improve their productivity, an exotic dual-purpose Black Australorp (BA) breed was introduced to crossbreed with LC in Malawi since 1960 (Upindi, 1990). The objective was to produce crossbred chicken that would provide more meat and lay more eggs while at the same time, be adapted to local environment. The assumption was to utilise heterosis effects at various levels of crossbreeding. Since inception, no programme evaluation has been conducted to determine achievements of the programme (Safalaoh, 1992; Malawi Government, 1999a). Localised survey studies on prevalence of BA in the villages of Central and Southern Malawi (Gondwe, 1994 unpublished; Sankhulani, 2003 personal communication) and reviews (Safalaoh, 1992; Safalaoh, 2001) concluded that the crossbreeding program has had no impact on improving local chicken productivity. The programme, however, continues and farmers like the BA breed due to ‘exotic is good’ image. Several Non-Governmental Organisations (NGO) that promote food security distribute BA to resource poor farmers following participatory rural appraisal (PRA) study reports in Malawi.

Recently studies to compare productivity of BA and LC and their crosses were initiated at Bunda College of Agriculture (BCA) and Chitedze Agricultural Research Station (CAR) (Kadigi, 1996; Jere et al., 1996). These studies observed less than 20 % differences in growth performance between the two breeds and their crosses. All these studies were conducted under intensive feeding on-station. At present there are no data from on-farm studies. These would be important to demonstrate to farmers the impact of the BA. A better approach would be to run a participatory research programme jointly by farmers, researchers and extension workers. Farmers could assist through providing their own birds as well as data recording to identify possible genotype x environmental interactions that may interfere with application of results obtained on-station. It was against this background that the breed comparison study was initiated, in addition to act as an incentive to encourage farmers to compare their local chicken resources directly. Growth performance of BA and LC chicken was compared on-farm under existing village free-range production system. It is hypothesised that performance of BA is similar to that of LC under village scavenging conditions.

12.3 Materials and methods

12.3.1 Study area

This study was conducted among farmer households in the villages of Mkwinda and Mitundu Agricultural Extension Planning Areas (EPA) of Lilongwe Agricultural Development Programme (LADD). This is an area where the researchers introduced an FAO Village Poultry Improvement Project in 1999 (Gondwe et al., 2003) with the aim to promote indigenous poultry production and utilisation. Farmer demography and climatic conditions of the area are described in Chapter 3.

12.3.2 Study birds and their management

Farmers demanded to introduce BA at village poultry group discussions. The goal (crossbreeding or substitution) of introducing BA to farmers is not defined and explained to farmers (Gondwe, 1994 unpublished). Consequently, 300-day-old BA chicks were bought from Bwemba Poultry Centre, which was the governmental BA multiplication centre for the Central Region of Malawi. These were raised at BCA till they were about 9 weeks using intensive system of management. The birds were fed an on-farm mixed chick starter mash (22 % CP) during the first four weeks, and thereafter grower's mash (17 % CP) *ad lib*. This is the same practice as in distribution centres managed by the government (Upindi, 1990; Safalaoh, 2001). Therefore this study intended to simulate the chicken improvement program that was instituted decades ago. One hundred and twenty-five BA chickens of mixed sex were distributed at random to farmers in the villages in December 2002. These farmers were chosen in such a way that they had contemporary local chicks (n = 124) hatched and mothered by a local hen. Each household had up to three BA (one at least a male) provided for comparison with the local chicks from a hen. While on farmer household, both BA and LC were raised on free-ranging (scavenging) system. Farmers were supplementing their chickens with household by-products and wastes. Newcastle disease (NCD) was prevented through community vaccination of local chickens using La Sota live oral vaccine (1000 doses, cloned, Lohmann Animal Health GmbH, see Chapter 3). Some BA chicks (n = 63) continued under intensive deep litter management. Table 12.1 shows the design structure. For the purpose of this study, therefore, it was not necessary to keep LC under intensive conditions on-station.

Table 12.1. Design of the study by breed and management

Breed	Management		
	Free range (on-farm)	Deep litter (on-station)	Total
	n	n	n
Black Australorp (BA)	125	63	188
Local (LC)	124	-	124
Total	249	63	312

12.3.3 Data collection and analysis

Individual birds were weighed weekly till they were 30 weeks old. Growth performance was determined using live weights (LW) and growth rate parameters daily weight gains, specific growth rates and growth efficiency. These were calculated as follows

$$DWG = \frac{\left(LW_{ti} - LW_{to}\right)}{t_i - t_o} \qquad (12.1)$$

Where, *DWG* is daily weight gain per time period in g; LW_{ti} is live weight at particular week = t_i; LW_{to} is live weight for the previous period = t_o.

$$SGR = \frac{\ln\left(LW_{ti}\right) - \ln\left(LW_{to}\right)}{t_i - t_o} * 100 \qquad (12.2)$$

Where, *SGR* is the specific growth rate in percent growth per day at a particular time; $ln(LW_{ti})$ is natural log of live weight at week = t_i; $ln(LW_{to})$ is natural log of live weight at previous week = t_o; $(t_i$-$t_o)$ is the period of weighing converted to days.

$$GE = \frac{WG_{ti}}{LW_{to}} \qquad (12.3)$$

Where, *GE* is growth efficiency per time period = t_i; WG_{ti} is weight gain at time = t_i; LW_{to} is live weight at time = t_o.

All data were analysed using proc mixed procedure of SAS (SAS, 1999) to determine effects of breed and management on growth traits, and model the covariance structure. Breed effect was compared separately by considering BA and LC under scavenging conditions. Similarly, effect of management was compared within BA breed under intensive and scavenging conditions. Least square means, adjusted for initial weights, were separated into significant difference using least significant difference (LSD) test.

The following model was used for data analysis:

$$y_{ijk} = \mu + b_i + s_j + a_k + w_l + (bw)_{il} + (sw)_{jl} + \beta(x_{ijk} - xk) + \varepsilon_{ijk} \qquad (12.4)$$

Where, y_{ijk} is the observed growth parameter for bird k in week l; b_i is the breed effect under village management , *i* = BA, LC; s_j is the effect of sex of bird, $_j$ = male, female; w_l is the fixed effect of week, *l* = 1, 2, … 30; β is linear regression coefficient of the measure on initial weight for the bird; ($x_{ijk} - x_k$) is the observed initial weight of the *k*-th bird adjusted from overall mean initial weight (xk); a_k is the random effect of bird k; e_{ijk} is the random error at particular week l, assumed NID (0, σ^2 ε).

In brackets are two – way interactions. Due to the design, which did not include testing of LC under intensive management, comparisons were done at two levels for breed and management. Breed x management interaction was not possible.

12.4 Results

12.4.1 Live weights and weight gains

Figure 12.1 shows live weights for BA and LC under village management system, and BA under intensive management. Live weights for BA and LC under village management were not different (p>0.05), so was breed by week interaction. LC were numerically superior to BA. By fifth week, BA fed intensive were 14.20 % and 6.12 % superior to BA and LC on free-range, respectively. The trend continued over time where BA fed intensive were 18.54 % and 17.71 % superior to BA and LC on free-range by week 29. Sex and sex by week effects were significant (p<0.05) but not breed by sex effect. Based on female weights, males were 8.1 % heavier than females. LC had significantly (p<0.05) higher daily weight gains (DWG) than BA for week 5 of study (14 weeks of age). DWG at week 10 of study were higher (p>0.05) for LC than BA, while DWG were higher (p>0.05) for BA than LC at weeks 15 and 20 (Table 12.2). Overall DWG were not significantly different (p>0.05) but numerically higher for LC than for BA. DWG for BA under intensive management were higher than for BA and LC under free-range management. Compared within breed, BA under intensive management had significantly (p<0.05) higher DWG than BA under free-range management.

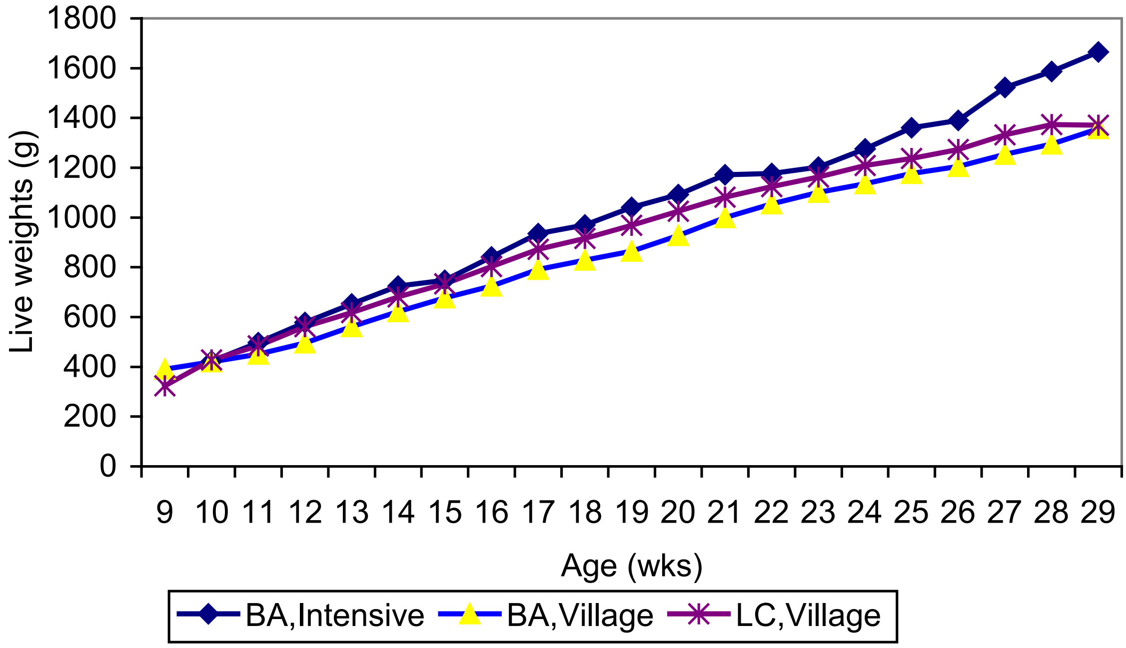


Figure 12.1. Live weights of Black Australorp (BA) and local chickens (LC) under village management system and BA under intensive management

Table 12.2. Least square means (lsmeans) and standard errors (SE) for daily weight gains (g/day) for BA and LC under scavenging system and BA under intensive system

Week of study	Breed by management					
	BA village		LC village		BA intensive	
	Lsmean	SE	Lsmean	SE	Lsmean	SE
5	6.59[b]	0.36	8.18[a]	0.42	8.84	0.50
10	6.97	0.40	7.71	0.46	8.78	0.51
15	7.19	0.41	6.95	0.51	7.61	0.53
20	6.31	0.42	5.49	0.54	9.63	0.54
Overall (1–20)	6.77*	0.22	7.08	0.26	8.71*	0.30

[ab]Means within a row under similar management with different superscripts differ significantly ($p < 0.05$); * significant different between two management compared within breed ($p<0.05$)

12.4.2 Growth efficiency

Table 12.3 shows growth efficiencies (GE) and specific growth rates (SGR) for BA and LC under village and intensive management systems. Except for week 5 of study, breed effect was not significant ($p>0.05$) on GE and SGR for birds under free-range management. Overall GE for LC were numerically higher than GE for BA under both intensive management and free-range. Within breed, GE for BA under intensive management was significantly ($p<0.05$) higher than GE for BA under free-range management at weeks 5 and 20 of study. Male chickens had significantly ($p<0.05$) higher GE than female chickens. GE were declining with age of birds. Similar trend of results were observed for SGR. In addition to breed effect, sex effect was not significant ($p>0.05$) on SGR for BA and LC under free-range management.

Table 12.3. Lsmeans and standard errors for growth efficiencies (GE) and specific growth rates (SGR) for BA and LC under different management systems

Week of study	Breed by management					
	BA village		LC village		BA intensive	
	Mean	SE	Mean	SE	Mean	SE
GE						
5	0.63[b]	0.03	0.95[a]	0.03	0.67	0.03
10	0.42	0.03	0.42	0.04	0.43	0.03
15	0.33	0.03	0.27	0.04	0.28	0.03
20	0.23	0.03	0.16	0.04	0.29	0.03
Overall (1–20)	2.70	0.10	2.99	0.13	2.92	0.11
SGR						
5	0.013[b]	0.001	0.018[a]	0.001	0.015	0.001
10	0.010	0.001	0.010	0.001	0.010	0.001
15	0.008	0.001	0.007	0.001	0.007	0.001
20	0.006	0.001	0.004	0.001	0.007	0.001
Overall (1–20)	0.009	0.000	0.009	0.000	0.010	0.000

[ab]Means within a row under similar management with different superscripts differ significantly ($p < 0.05$)

12.4.3 Mortality

Mortality was 14.4 % in BA, 11.3 % in LC under village free-ranging system by the fifth week of study. Mortality was 4.7 % for BA kept intensive. It was not possible to compare mortality after fifth week (from week 15 of age) since some farmers had started consuming or selling some chickens under observations. This was expected since participating farmers were not restricted to utilise their chickens despite being monitored.

12.5 Discussion

The objective of the governmental policy by introducing BA was to crossbreed with LC in order to improve meat and egg production. For this objective to be achieved, two breeds used in crossbreeding should be distinctly variable on traits under consideration. This will lead to expression of additive (breed complement), heterosis and maternal effects in offspring (Nitter, 2000). The current results show that under village conditions, growth performance of BA is not different from that of LC. Even the difference between BA under intensive management and LC under village conditions is not big enough to warrant exploiting the variation. This challenges the use of BA breed to substitute LC through continuous crossbreeding as far as improving meat is concerned. While investigation of heterosis effects require more detailed studies, the current results therefore, confirms review reports that BA crossbreeding program has had no impact on improving LC productivity among rural farmers (Safalaoh, 2001). Timon (1993) reported that most crossbreeding programs failed due to poor distribution of exotic breeds. While this is true, this study finds also that BA may resemble an inadequate genetic material to use as far as growth performance is concerned.

The higher performance of BA under intensive than that of BA under village conditions show that productive potential of BA is masked by management constraints under scavenging conditions. Also mortality for BA was higher under scavenging than under intensive management. Jensen (2000) reported that traits such as scavenging and survival traits are the most important under free-range and semi-scavenging conditions. Lack of fitness for survival of BA under scavenging conditions likely constrains efficient utilization of limited feed resources. Indeed LC had higher GE than BA, meaning LC were efficient at utilising scavenging feed resources. This implies farmers have to provide surplus feed and prophylactic treatments, which is difficult under smallholder farming conditions with practically non-existent infrastructure. Since LC were not tested under intensive management, it is not possible to judge whether BA were superior to LC under intensive management. However, this comparison was not considered as of practical relevance in this type of farmer demanded study. It should be noted, however, that the study was not planned to investigate possible breed differences between LC and BA in adaptation from intensive on station to scavenging in village conditions.

Growth curves showed continued growing pattern in both BA and LC after week 20 week of the study. DWG, GE and SGR showed that BA had lower values than LC during early weeks of study while BA had higher values than LC towards the end of the study. This may be due to coping mechanism for BA as they were adapting to the environment (feeding under scavenging and disease challenge). These observations suggest that BA was struggling to adapt to the free-ranging scavenging environment in the villages. Currently the Government of Malawi distributes BA to farmers when the birds are over six weeks old. This may pose challenges of adapting to scavenging environment without any acclimatization as they are transferred from intensive fed environment. This system confounds possible genetic effects. Other options such as distributing BA eggs to be hatched by LC hens, or hatching crossbred and distributing them to farmers may have been tested under farmer participation. In this study BA fertile eggs were distributed to farmers to be hatched by local hens during the hot-dry season of 2002. Most chicks that hatched died before eight weeks and this made data to be abandoned for analysis.

The results were presented (feedback discussion, done twice) and appreciated by farmers and Government extension and veterinary agents who participated in the study and discussions. Their “take – home message” was that BA received from on-station was not performing differently from LC under village conditions.

12.6 Conclusion

Up to 29 weeks, BA chickens have larger live weights and growth rates when fed intensive but have similar live weights to LC under village conditions. BA showed problems of impaired growth and reduced survival rates to adapt to free-ranging environment. Under scavenging conditions, performance of LC is significantly ($p>0.05$) not different from that of BA. Under present production and environmental conditions the distribution of BA chicks to smallholder farmers to improve growth performance is not recommended.

13. General Discussion

13.1 Local chicken production system

This study has found that LC are the most widely owned species of livestock with a more even distribution among smallholder rural farmers (Chapter 3). This puts LC as a potential tool to be used to promote human welfare in rural areas with a wider reach of outputs to all gender groups and social strata in the society. LC are an integral component of the smallholder crop-livestock production system in Malawi. To understand this better, their production system was characterised by studying flock structure and sizes, feeding, housing, flock output and health (Chapter 4); breeding system and structure (Chapter 5) and marketing system (Chapter 6).

13.1.1 Flock sizes and structure

Number of chickens per household was small but falling within the range observed for village poultry in African and Asian countries (Aini, 1990; Gueye, 1998; Kitalyi, 1998). Demographic structure of the flock constitutes different age groups (chicks, growers and adults) and sexes, all scavenging together.

13.1.2 Housing, feeding and health

LC mainly roosted inside human dwelling units or in kitchens. Special places within the house were arranged for chickens of different age groups to roost during nights. Mother hens covered their young chicks. Few farmers had purposely built chicken houses locally called *khola.* Security against theft contributed to using houses for night roosting as the optimal strategy adopted by farmers.

Feeding was through scavenging. This is a common characteristic for LC. Majority farmers supplemented their LC with by-products from maize grain. The amount of supplement was not known and difficult to quantify. Supplement feeding was individual household responsibility and depended on availability of the feedstuff. More flocks were provided with supplement feed during the cold-dry season when maize had just been harvested. A similar case was observed in Zimbabwe (Pedersen, 2002b). All supplement feed were of energy source, hence, LC obtained all proteins for their growth and reproduction from scavenging.

Flock health was the main constraint contributing to loss of chickens in terms of numbers and productivity. When timely implemented, NCD vaccination was 100 % effective. However, mortality and loss of condition due to other infections still occurred for all age groups in these NCD vaccinated flocks. Notable causes of losses were infections from helminths, external parasites, infectious coryza and from predation. Possibly nutritional related diseases contributed to chick mortality, especially because of competition during communal scavenging. Young chicks and growing chickens require more nutrients for the growth and maintenance (Roberts, 1999). Weaker ones could not scavenge adequately. Multiple infections were also observed. Treatment using veterinary drugs was administered and was effective but disease recurrence was often. Possible causes of recurrence included re-infection from non-treated neighbouring flocks during scavenging, inconsistent administration of treatment by farmers and the multiple infections, which needed broad-spectrum treatment. Aini (1990) reported that the free-ranging and unconfined type of management makes disease control difficult on local chickens. Since most flocks roosted in human houses, predation occurred mainly during daytime. Because of inter-flock and intra-flock infection, flock health cannot only be dealt with at individual flock alone but needs a community approach as well. A communal approach has dual advantages of acquiring drugs at lower costs and following communal treatment against common infections, thus reducing disease incidences and recurrence. This will lead to health flocks within the community. The communal NCD vaccination approach (Chapter 3) that was also effective in Northern Malawi (Hüttner et al., 2001) should therefore be extended to treatment against other diseases. On the other hand, community cooperation, good management and hygiene of roosting places are the responsibility of individual household flock owners.

13.1.3 Breeding system and structure

Sustainability of the flock mainly depended on the flock to reproduce. Breeding followed an uncontrolled random mating that took place during scavenging. Over 50 % of households did not own a breeding cock (Chapter 5). Hens from cock-free flocks were mate by breeding cocks from neighbouring flocks during communal scavenging. Even though owned by individual farmers, breeding cocks provided genetic material to the community while breeding hens provide genetic material to the household flock. This traditional practice provides opportunities to farmers to utilise male chickens for consumption, sale or for cultural purposes as observed by Gueye (1998). A breeding structure for LC can, therefore, not be defined at household level only but at community level as well. Selection decisions which cock to use for breeding should be transferred from individual household to the community sharing the cock. With this community breeding for LC, conventional method of defining sex ratio at household flock level is not meaningful. Rather a sex ratio should be defined at community of flocks level, as it was done in this study.

Following the community breeding structure, size of the breeding population was defined. The estimated effective populations sizes (Ne) were small and below 50 % of the actual sizes (N). Local chickens breed in small populations, with possible consequences of inbreeding. The estimated inbreeding rate of 4 % per generation was higher than the recommended maximum of 1-2 % (Henson, 1992). Aini (1990) reported occurrence of close inbreeding among indigenous chickens in South-East Asia. Fewer numbers of cocks and variations in mating success of breeding cocks contributed to low Ne. Based on interpolation, it was estimated that breeding cocks should constitute 35 % of the population to maximise the Ne/N ratio at 60 %. To achieve this would require increasing number of cocks within the community, which may not be possible due to potential cock fighting. The number can however, be reached indirectly through a community cockerel exchange approach. Farmers already practice breed stock sharing and exchange. However, this is taking place at random and often within the community only. Long-term monitoring is needed to analyse the impact of breed stock exchange and bottlenecks on effective population sizes. Using this approach, different communities should be exchanging cocks in rotation before the offspring from the cocks become sexually mature. For this approach to be effective, a strong community health management program, including NCD vaccination need to be in place.

13.1.4 Flock output

Flock output was determined based on exit of growing and adult birds from flocks. Local chickens had multiple functions at individual households and at community levels (Figure 13.1). At households local chickens provided animal protein, and were sold for income or direct barter with household items. At community level, local chickens were slaughtered during funerals and wedding ceremonies, presented as gifts to friends and relatives, and were exchanged or shared for breeding. Use of chickens for food during festivities such as Christmas and other entertainments belong to both household and societies’ roles.

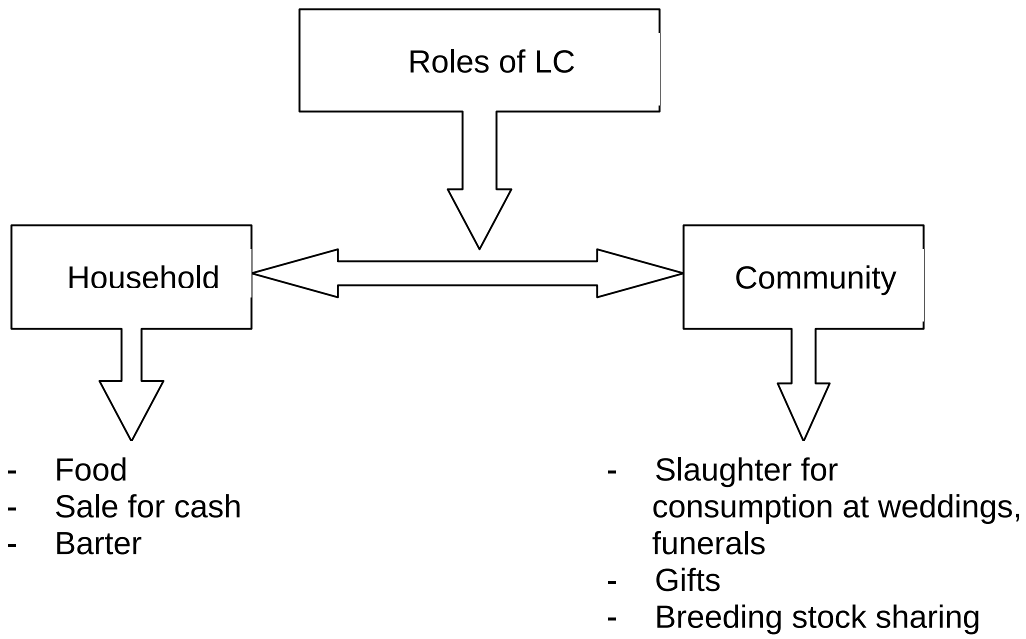


Figure 13.1. Functions of local chickens at household and community level based on flock exit

A significant proportion of flock exit was caused by mortality and predation. Diseases also caused low productivity in LC as demonstrated by lower live weights of birds that died due to diseases and parasites. The lower live weights of chickens predated indicate that young and weak ones were prone to predators. The system operates on survival of the fittest, an aspect of natural selection. This is an area that needs to look at seriously in order to convert these losses into usable output by households and the community.

13.1.5 Marketing

LC were sold at household, trading centres, rural and urban markets. The market is not well structured at farm-gate where transaction takes place in form of cash or barter between farmers and buyers (fellow farmers and middlemen). From rural to urban markets, middlemen played an important role in LC marketing. Low number of chickens sold per household restricts individual farmers from selling their chickens at rural markets due to high transaction costs involved. Prices of LC and profit margins tended to increase from rural to urban markets and this provided a flow of LC from villages to urban. Prices for LC were competitive and unaffected by seasonal forces at urban markets. At household and rural markets, economic conditions and household needs influenced decision to sell LC, pricing and bargaining power. This led to unfavourable farm-gate prices during the wet season (period of food shortage) and better prices during the dry season. Household influencing factors did not seem to affect urban markets, but rather normal market forces. All phenotypes and sexes were available for sale at the markets. The different proportions sold merely reflected prevalence of such phenotypes and sexes of birds. It is concluded that LC have a good market potential, hence it is expected that increased output from household flocks can be sold easily.

13.1.6 LC production system is likely to prevail

Based on the discussed characteristics of the production system, local chickens are produced in a traditional system by traditionally oriented farmers. Aini (1990); Ramlah (1996) and Gueye (1998) reported that the custom of keeping indigenous chickens has evolved for generations from ancient traditional practices and will remain popular in rural communities in Africa and Asia. All aspects of production are geared towards utilising minimal inputs, almost all of which are either obtained at low or zero cost, or are of no other human needs. The same scenario was shown in this study by use of free or low cost feeding, housing, disease management, breeding and reproduction, and marketing strategies. In line with the poor economic structure of the majority of rural people, better parity of distribution, dominance of women looking after the LC, and the link to cultural roles of the society, the production system is well suited and likely to prevail. Their multi-purpose use (Horst, 1989) makes LC to be different from the specialised breeds and strains of commercial production, and can therefore, not be substituted. Because they are mostly neglected compared to other agricultural activities, LC prevail chiefly through continued adaptation to physical and cultural environments. LC and its production system appear to be just one step in the domestication process from wild type and is far from the commercially developed breeds. In this context the application of molecular genetics for genetic characterisation of LC of unknown origin and relationship is strongly recommended.

13.2 Productivity of local chickens

Many authors described LC to be of low productivity in terms of low growth rates, egg production and survival (Horst, 1989; Aini, 1990; Sonaiya, 1990; Gueye, 1998). The observations made by these authors were also noted in this study. Values for hatch weights, growth rates and live weights at different ages agree with mean ranges reported by Dessie and Ogle (2001); Mwalusanya et al. (2001); Pedersen (2002b) and Demeke (2003) for local chickens under scavenging conditions in different countries. Growth in this study was further characterised by specific growth rates and growth curve parameters. These parameters showed that LC are indeed slow growers, reaching sexual maturity and inflection points after 15 weeks at low weights of about 500g, and they continue growing after 30 weeks when mature weights of 1.3 and 1.5 kg are reached for males and females, respectively (Chapter 7). Growth curves were flat (not steep) justifying the observations and showing high theoretical potential to improve the species by manipulating the growth form of local chickens. Fortunately, growth curve parameters *L* and *K* better described the growth curve and had high and positive genetic and phenotypic correlation to juvenile growth parameters.

Growth potential study (Chapter 10) showed that genetic limit of growth for local chickens is constrained by management, especially feeding and health (Chapter 4). Depending on the trait, the values for birds under fed conditions were significantly ($p<0.05$) between 25 and 41 % higher than birds under scavenging conditions. Demeke (2003) obtained similar results in Ethiopia. Birds under fed conditions had reduced phenotypic variation. Kitalyi (1998); Gunaratne (1999); Huque (1999) and Roberts (1999) reported that SFRB is insufficient to provide adequate dry matter intake and nutrients to meet growth and reproductive potential for local chickens.

Despite being suppressed by management and health constraints, growth and growth curve parameters for local chickens were moderately to highly heritable under scavenging system. This means response to a theoretical application of selection criteria will be high. The observed phenotypic variation has a high genetic component expressed. Maternal effects were however, pronounced, especially for juvenile traits including growth parameter *L*. This is because of common environment the mother hens provided to their chicks during brooding till natural weaning. When chicks are raised separate from mother hens, maternal effects are not pronounced and disappear within the first four weeks (Chambers, 1990; Hu et al., 1999; Prado-Gonzalez et al., 2003). The high heritability values for weights at weeks 5, 10, 15 and for *L*; and their high and positive correlations suggest that common genes influence these traits. As discussed in Chapter 7, selection for weight at week 15 or for L would be recommended since it will improve growth by improving the growth form of LC upwards during the earlier growth phase and exploit the point of inflection where growth rate is maximum. Through correlated response, age at point of inflection (T_i) will be reduced while increasing live weight (BW_i). Around this age, most chicks are assured of survival and can be selected without wasteful losses from deaths. Age of selection for body weight is important in commercial poultry breeding because timing of selection influence the pattern of growth (Aggrey, 2004). Kerr et al. (2001) reported that selecting for exponential growth rates at 42 days of meat type chickens had little antagonistic effects on reproductive traits. Aggrey (2004) found that selection for relative growth rates also influences efficiency of growth, while selection for absolute weights or growth rates have negative consequences on correlated traits. This is important to consider since LC production depends on its ability to reproduce within the flock (Chapters 4, 5 and 8), and bearing in mind that reproductive and fitness traits are negatively correlated to growth traits (Reddish et al., 2003).

The heritability values obtained in this study may sound more of theoretical than practical use considering the local infrastructure for development of conventional breeding programmes. However, as discussed in Chapter 7, breeding males may be the first target of selection within the community (Chapter 5). The values could be applied here to judge which to select or to predict and observe the performance of their offspring. On-station, experimental trials aiming at improving dual-purpose potential of LC may utilise the values.

Reproductive performance of LC showed that they are low egg producers, which are of small weights (about 50 g), but have good hatching abilities (Chapter 8). Local hens laid eggs in clutches of less than 20 eggs in four clutches per annum separated by long lying, egg incubation and chick rearing periods. Most of the eggs laid were reserved for incubation, which places the importance of reproduction in household flocks. The high hatching rate also showed that LC laid fertile eggs with good embryonic viability. Because of natural weaning of hens, hatching intervals were long (over 100 days) and contributed to the observed reproductive index (21 – 30 chicks per hen per annum). LC showed to have a generation interval of less than a year considering two hatches. During lay and egg incubation periods, hens lost weights, which they regained after hatching (Chapter 8). This is an adaptation process to reproduce in presence of feed shortage from scavenging. Hens mobilised reserves from the body. Generally reproductive parameters were variable and appeared to have chiefly been influenced by non-genetic factors during laying and brooding. This variation due to management, environment and physiological factors is supported by the observed differences in correlation coefficients between different parameters under different managements (Chapter 8); and the higher CVs for annual number and weights of chicks per hen or hen weights (Chapter 8). After all, reproductive and survival traits are lowly heritable (Weller, 1994; Szwaczkowski et al., 2003).

Hen reproductive efficiency showed low annual output from offspring per hen measured between 15 and 20 weeks (Chapter 8). This was mainly due to high early chick mortality by week 10 (Chapter 8). As with reproductive traits, chick survival measures viability, a fitness trait that is heavily subjected to pressures of natural selection. Without preferential feeding for chicks, they were subjected to competition for scavenging feed. Viability is probably also depressed by inbreeding effects, which was found to exist in LC flocks (Chapter 5). As reported by many authors (Gueye, 1998; Kitalyi, 1998; Dessie and Ogle, 2001; Kusina et al., 2001; Pedersen, 2002b), mortality in local chickens is a major health constraint contributing to low output from hens.

13.3 Input – output relationship and efficiency

Local chickens produce on low or zero-cost inputs (Chapters 4 to 6) and output per unit hen or flock is also low (Chapters 7 to 9). This results in a low input-low output system. Since most inputs are obtained at zero cost, the most limiting resource was assumed to be the breeding stock that sustains the flock. When the breeding flock and the outputs were valued into an aggregate (composite) monetary unit (Chapter 9), it was found that the traditional chicken production system is efficient and cost effective, as reported by Aini (1990) and Gunaratne (1999). The high rates of return per breeding flock observed in this study were in agreement with those obtained by Upton (2000) and Tadelle et al. (2003a). The value of losses due to health and predation contributed significantly to the rate of return as shown by drop in efficiency ratio when only functional outputs were considered. The value of chicken droppings, which are rich in nitrogen and minerals, could increase the rate of return when included. On the other hand, the production system was efficient because of the zero cost of the scavenging and supplement feed. As shown from the growth potential study (Chapter 10) under *ad libitum* feeding, rate of return on feed costs was lower than 30 % due to high feed costs and poor conversion of feed by local chickens. Local chickens are appropriately suited to utilise local resources under scavenging system (Sonaiya, 1990; Pedersen, 2002b; Demeke, 2003).

13.4 On-station versus on-farm performance

Growth performance between on-farm and on-station did not show a significant difference under scavenging conditions for most parameters (Chapter 7). It is therefore, possible to utilise on-station generated growth results for on-farm application. However, when comparison was between different management systems (feeding vs scavenging), growth traits appeared to show G x E interaction (Chapter 10). Developing production technologies based on results from intensively raised LC may not be applicable under real production system on-farm. All reproductive and survival traits were negatively affected on-station, compared to on-farm (Chapter 8). Variation for such traits was higher on-station than on-farm. Unfortunately these are traits that influenced economic efficiency and sustainability of local chickens under scavenging conditions. Management interventions during laying and egg incubation were chief causes of poor fertility and hatching rates on-station. The higher early chick mortality rate on-station than on-farm can be explained by large flock sizes that created higher competition in terms of feed, space and caused an increase in disease load (Ramlah, 1996; Gunaratne, 1999). Similar effects on hatching rates and survival were experienced on nuclear multiplication centres in the villages (data not presented). It appears the household environment provides best conditions for local chickens to reproduce. Under scavenging conditions, creating large nuclear flocks would increase feeding competition, disease and parasite load.

13.5 Is there scope to improve local chickens?

As shown in Chapter 3, and also as reported elsewhere (Horst, 1989; Panda and Mohapatra, 1993; Dolberg, 2001), LC is a species for rural masses that also serves as a starting asset for households, and therefore, an important constituent of poor people’s existence. The production system allows the LC to utilise available but otherwise wasteful resources, making them to be produced at least cost. The system follows traditional customs of rural people that is unlikely to change in the near future. Majority human population lives in rural areas and most of them are poor, illiterate or at low level of education. It is unlikely that urbanisation (estimated at 4.7 % p. a. in Malawi (NSO, 2000)) will change the structure of the traditional rural society in the mid-term. Since these have evolved together (Gueye, 1998), LC and the production system is likely to prevail in rural areas of Malawi.

Chapters 4 and 5 have shown that the production system is low input, with low output in terms of productivity per unit hen or flock. However, the outputs are multiple and variable in terms of nature and functions, in line with society needs. LC is not actually a dual-purpose but a multi-purpose breed. When considered at community level, total output is huge due to multiplier effect. Based on results from Chapter 9, the value of functional outputs is estimated to be more than two million Malawi Kwacha per annum (US$23,500) in the study area alone, which consists of 2000 households. Central Malawi has 3.9 million people living in about 740,000 households in rural areas. Based on the assumption that 82 % of households keep LC, value of functional outputs for the region is estimated to be 1.3 billion Malawi Kwacha per annum (US$15 million).

Despite introduction of commercial broiler and layer production, this sector is restricted to urban and semi-urban areas. No other species or commercial breeds or strains could substitute local chickens in rural areas (Horst, 1989). Local chickens still have market in rural and urban markets (Chapter 6), and are therefore, presently not directly threatened by globalisation of poultry trade and market liberalisation that favour high yielding strains (Malawi Government, 1999b; Resnick, 2004). Aini (1990) reported that price of indigenous chickens is not affected by market price of intensively raised commercial broiler strains because local chickens are preferred to broilers due to their better taste and flavour. A similar situation exists probably in

Malawi. However, price comparisons or testing of preferences with exotic strains were not done in this study.

Chapters 7 and 8 showed that LC productive and reproductive performance were low. This low productivity is a threat to LC, its genetic resource and to the system, which makes farmers to neglect the species in Africa (Gueye, 1998). Government used this to justify introducing exotic BA breed to improve LC through crossbreeding (Upindi, 1990). These crossbreeding programs appear to have failed in rural communities (Timon, 1993). According to results from Chapter 12, failure of crossbreeding is also due to lack of a suitable exotic breed to introduce into rural chickens. On the other hand, phenotypic variation exists within LC for growth (Chapters 7 and 10), reproductive and survival parameters (Chapters 8 and 9). Growth traits showed that this variation is both genetic and management, while management and physiological factors chiefly influenced reproductive and survival traits. Growth potential study (Chapter 10) showed that management, especially feeding constrained LC to achieve their genetic potential on-farm. Despite being described as low output, the production system is efficient (Chapter 9).

Taking a systems approach, considering social, cultural and equity aspects, assessing the production potential and variation of performance traits of LC fulfilling multiple purposes, there is obvious scope to improve LC and its production system. The parameter identified and quantified in this study could be used for small and large scale chicken development programs. This supports the views of Panda and Mohapatra (1993) that LC production should not be ignored development programs.

13.6 A proposed village poultry development model

The study has shown that LC production follows a unique system with complicated characteristics. Biological and socio-cultural factors are interrelated and could not be dealt with in isolation. A similar situation was reported by Dessie and Ogle (2001); Pedersen (2002a) and Kondombo et al. (2003) in different countries in Africa. Because of too many correlated and non-correlated factors involved in the production, improving LC is not straight-forward, simple, and requires a holistic approach as suggested by Branckaert and Gueye (1999). Sonaiya (1990) and Kitalyi (1999) suggested that strategies to improve LC should combine breeding, housing, health and feeding management, and marketing. What has not been clear from most studies is which traits should be improved in LC and up to what level. This question could best be answered by developing a production goal. According to findings of this study a proposed goal would be:

> ‘*To increase contribution of Local Chicken to rural livelihood and food security through increased flock output from existing local resource inputs within the context of the existing crop / livestock production system, while maintaining efficiency of production’*

By looking at the goal, the aim is to exploit the production potential discussed above, mitigate constraints that lead to flock losses, and maintain the dual or multi-purpose nature of LC. The overall objective or strategy would be:

> *'To optimise the production system by increasing flock sizes and productivity up to levels constrained by scavenging and supplement biomass'*.

Flock health, feeding and inbreeding were identified key constraints in the study, thus requiring a holistic approach along these lines that could easily be altered to suit a particular environment in terms of society needs and resource capacity and constraints. The type of housing concerns social factors and scarcity of resources and will be left at discretion of farmers. The strategies will be at individual household and community levels due to complex relationship between human and LC and the society at production and consumption levels.

13.6.1 Flock health strategies

At household level, there is need to improve hygiene and disinfecting where chickens roost and provide preferential roosting treatment for chicks. Strategies to confine chicks during their early life will reduce chick mortality and predation but needs further investigation due to the need to feed the chicks and the hen when enclosed.

All disease treatment and vaccinations should be done at community level. This will encourage farmers to pool resources to buy drugs and vaccines cost effectively. Diseases and parasites should be treated for the whole community since birds scavenge together and flock infection and re-infection takes place during scavenging. Strategic control measures should be followed since diseases and parasites showed seasonal prevalence. There is training need to improve on drug prescription and administration by farmers themselves. Traditional remedies need to be investigated and promoted. Based on the hypothesis that some losses were due to nutritional deficiency and due to effects of inbreeding, feeding (section 13.6.2) and breeding (section 13.6.3) strategies are necessary.

13.6.2 Feeding management

Insufficient feed is the most important constraint to growth and reproduction in health flocks. Cost of feed prevents farmers from providing formulated rations to their LC. At present, there is no sustainable feeding technology for LC. It appears the option to supplement scavenging when available the best chosen by farmers if production efficiency is to be maintained. Trials on effect of supplementing LC have shown positive impact on growth and chick survival in other countries (Gunaratne, 1999; Roberts, 1999). The findings from this study showed that reproductive performance was better during the season of harvest, a season when most flocks were provided supplement feed. The use of energy rich food by-products as supplement is a common tradition for LC production and should be enhanced by making the supplement available throughout the year. This is a difficult task when there is starvation; maize bran is also used as food for households, a typical situation in the study area. If households would be food secure by-products would be available to supplement scavenging chickens. This hypothesis and the mutual relationship between livestock and rural households need direct on-farm experimentation to be conducted by farmers and possibly facilitated by researchers. Feeding strategies are individual households' responsibility but birds scavenge together. For example, frequency of feeding and preferential feeding for chicks (through confined feeding) should be promoted.

13.6.3 Breeding strategies

Breeding activities and plans should not be taken strictly as in conventional breeding programs because LC farmers are not breeders but perform roles of LC keepers, producers, users and breeders. This is a common phenomena for village livestock production systems (Sölkner et al., 1998). Recording and animal identification infrastructures for all livestock are not in place and farmers are not organised into breeding societies. Nucleus multiplication centres need further improvement before being effective. As described by Sölkner et al. (1998) this situation, together with the farming system management and environment is not easily changeable. A formulated breeding goal for LC would be complex and must contain various roles and functions as discussed in this study. To contribute to the production goal, breeding strategies should aim at achieving the objective to increase growth and reproductive performance, and reduce mortality for LC to levels to be sustained under existing production system. Village breeding programmes operate under this condition on a community, with selection decision based on visual appraisal of desirable traits. Based on characteristics observed in this study (Chapter 4), major weaknesses of this village breeding programme are (i) low effective population sizes leading to (ii) inbreeding within breeding populations; (iii) longevity of breeding hens in reproduction; (iv) low levels of breeding stock exchange which usually takes place within the community. A breeding strategy should first aim at alleviating these weaknesses and minimising inbreeding. Inbreeding is hypothesised to contribute to reduced growth rates and survival.

An open single tier breeding system is recommended for LC among farmers to maintain the existing human-livestock interrelationship. Farmers should therefore manage their own flocks and be responsible for the selection criteria for hens to replace old and unproductive hens from within and outside flocks. However, farmers should be encouraged to reduce reproductive period of hens to within a year, thereby reducing generation interval. Preferential treatment of chicks (sections 13.6.1 and 13.6.2) should be combined with early weaning, that will reduce hatchling interval and thus, increase reproductive rates for hens. Decision on choice of breeding cocks should be transferred to the community comprising of households whose flocks comprise a breeding population. In order to increase population sizes and thus reduce inbreeding, a breeding cock exchange programme should be facilitated between communities. For example, based on breeding population of close to 40 hens and cocks (Chapter 5) and that 35 % of this should be cocks to minimise inbreeding and attain an Ne/N rate of 60 %, 14 cocks are required in a breeding population. This could be achieved with cockerel exchange between three communities within a year. When kept open, with young cocks joining the breeding replacing old or dead cocks, the effective population size would even be larger. Assuming one cock enters into breeding per community per annum, number of cocks in a breeding population would increase by at least three if generation interval is reduced to one year. This would raise Ne further, control inbreeding even more and even out sampling variance of mating. Figure 13.2 illustrates a proposed exchange program between communities, assuming equal population sizes.

As different communities share same cocks, the breeding population will get defined at broader level and sampling variance will be reduced due to increased numbers of cocks. All these contribute to reduced inbreeding.

Phenotypic selection of cocks to use for breeding should be based on live weights and other agreed criteria by farmers (such as Mendelian phenotypes, survival traits and mothering ability) within the community. When records are instituted, selection of cocks based on growth curve parameter *L* or weight at point of inflection are recommended in order to improve growth form, thereby increasing juvenile weights, reducing age at point of inflection (and thus age at consumption), with minimal negative effects on reproductive and adaptive traits. Reducing age to consume chickens is beneficial to avoid flock sizes to exceed SFRB biomass that will limit productivity (Roberts, 1999).

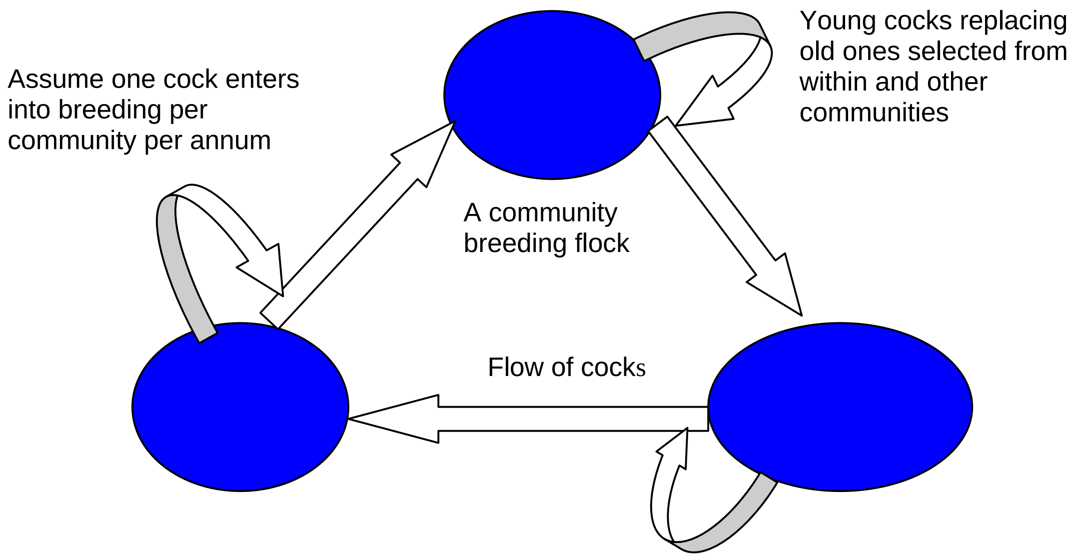


Figure 13.2. A cockerel exchange programme between communities in rural areas

The effect of locally identified phenotypes was not significant on growth, reproduction and survival. All phenotypes could therefore participate in this breeding programme to contribute to genetic resource conservation through utilisation.

Random, uncontrolled mating will most likely continue to be practiced. The selected cocks need to be given opportunity to mate by eliminating unwanted young cocks from flocks. This is already taking place among farmers by consuming male chickens first and could be facilitated by faster growth rates and reaching consumable or marketable size at a lower age. Cooperation among farmers within and between communities, with clearly defined roles is the key to success of the programme. Based on field experiences, record keeping require further campaign and cannot work if there is no research component in the development project. Literacy level of farmers is low and use of records is perceived secondary to immediate benefits they would expect from the project. Farmers could maintain only simple records. This is a major constraint to developing appropriate breeding strategies. Research component in the process is vital, thus calling for a farmer-researcher-extension worker community participatory programme.

In summary, breeding strategies are two folds; management of breeding flocks and selection within community flocks. These strategies are at individual flock as well as at community levels. A well-designed health program is a prerequisite and incentive to farmers to join the program and work as a community. Management and breeding strategies are interrelated. While the programme should follow a step-wise approach (Kitalyi, 1998), the strategies outlined (Table 2.6, Chapter 2) in this approach should be overlapping each other. The model should be flexible and modifiable through close participatory monitoring, evaluation and feedback mechanisms. Village poultry communities should be encouraged and established where they do not exist to run the programme together with government or NGO extension workers and researchers. Extension workers should facilitate in information delivery to farmers while researchers should monitor the implementation and continue investigating new experiences including exploring breeding strategies for chick survival. The model of expert farmer or the introduction of the farmer field school (FAO, 2001) for approach could be used to implement such programs at a larger scale than an individual research project.

14. Summary

This study was conducted to characterise local chickens and their production system in order to test whether there is potential and scope to improve their productivity and for sustainable utilisation of their genetic resources. The study had three approaches, each running concurrently with the other from the cold-dry season of 2002 to hot-dry season of 2003.

Production system characterisation: A monitoring study was conducted among 134 participating households with local chicken flocks in 27 villages of Mkwinda and Mitundu Extension Planning Areas, Central Malawi. Flocks were monitored to determine their flock sizes and structure, breeding system and structure, feeding, housing and health management practices, from August 2002 to August 2003. Through these characteristics, potential and constraints were evaluated. Farmers and researchers jointly observed and recorded local chicken (LC). Data was qualitatively and quantitatively analysed using appropriate procedures of SAS.

A marketing survey was conducted at Mitundu rural market and at two urban markets, Lilongwe and Kawale, all covering the catchments of the study area. The objective was to identify marketing potential for LC, thus complementing to their production system characterisation. Birds sold at the markets, sellers, sources, marketing prices and weights were recorded through direct interviews during the cold-dry season (2002) and the hot-wet season (2003). Sex and phenotypes of birds sold were recorded. Descriptive statistics and general linear model analyses was performed using SAS.

The analysis of the production, breeding and marketing systems could be summarised as follows:

- Household flock size was 12.9 chickens, comprising different age groups that roost and scavenged together. Only 48 % of households owned breeding cocks. For those flocks with cocks, hen : cock sex ratio was 5 : 1.
- Primary functions of LC included consumption by households, sale for cash or barter, exchanging and sharing breeding stock, providing gifts and for households to fulfil socio-cultural obligations, especially during funerals and wedding ceremonies. These functions constituted to 56 % of flock exit of growing and adult chickens.
- Flock dynamics showed that in each flock, there were on average more exits than entry from outside. Replacement through reproduction was important for sustainability of the flock.
- Majority farmers (85 %) used their human dwelling units or separate kitchens for night roosting. During the day, all flocks were released for scavenging. However, 77 % of farmers provided supplement feed to scavenging using energy rich by-products from maize. Maize bran was the most important supplement. Supplement feeding depended on availability of feedstuffs that had no other human use, and hence was more common during cold-dry season following crop harvest. The type of feed supplement meant that LC obtained protein feedstuffs solely from scavenging.
- Losses from diseases, predation and theft constituted 44 % of flock exits, despite an effective NCD vaccination. In these NCD vaccinated flocks, CRD and helminths were important infections to all age groups. Other common infections

included infectious coryza, fleas and lice, and coccidiosis. Other ailments were described by farmers as general weakness and probably included multiple infections and infections related to nutritional deficiencies. All diseases caused death of chickens except coccidiosis. On average, only 32 % of the flocks were observed to be disease free per month, the proportion was higher during cold-dry season and least from the end hot-dry (10 – 30 %) to beginning of hot-wet season (October to January). In most cases, farmers could not follow right dosage and procedure for drug administration to their chickens. Predation was mainly taking place during scavenging by wild cats, hawks, kites and dogs. Birds that died from diseases and predation had significantly ($p<0.05$) lower weights in the range of 800 to 900 g than birds utilised for household and communal functions in the range of 1100 to 1300 g at comparable age.

- Breeding in LC chickens took place in a community of household flocks during scavenging. With this structure, household flock sex ratio was meaningless from a breeder's point of view. On average a breeding population comprised of 38 breeding hens and cocks, with a sex ratio of 10:1. Average effective population size (N_e) was 15.2 using Wright's equation or 13.4 when differences in family sizes and mating success were assumed. The N_es showed that LC breed in small populations and estimated rate of inbreeding per generation was high (4.4 %), leading to possible consequences of inbreeding depression.
- Local chickens were sold at farm-gate and trading centres by farmers; at rural and urban markets by middlemen. Household needs influenced farmers' decisions to sale chickens while market forces influenced selling at urban markets. Due to small number of chickens sold per household, transaction costs limited farmers to selling their chickens within the village boundaries. Both male and female chickens of all phenotypes were offered for sale.

Growth, reproduction and chick survival: A monitoring study was carried out on-farm flocks and on-station between June 2002 and October 2003. Chicks (n=1119 at hatch on-station; n=2430 on-farm) hatched by their dam hens (n=151 on-station; n=378 on-farm) were monitored for their growth and survival through weekly weighing and observations. On-station, mating of hens and cocks was done in pens under deep litter system to facilitate pedigree identification. Dam hens raised their chicks under scavenging conditions. Reproductive performance was observed on the hens pertaining to egg production and hatching traits. Farmers managed their chicks and provided supplement feeding according to their traditional practices. On-station, maize bran was supplement fed to all chickens on free-range. Through community cost sharing, farmers vaccinated their flocks against NCD three times a year between May and December. On-station birds were similarly vaccinated. Treatment of other diseases was by use of conventional drugs, both on-farm and on-station.

Growth analyses included evaluating absolute and specific relative traits of growth and Gompertz growth curve parameters. Mixed procedure of SAS was used to analyse the data. Heritability and genetic correlations were estimated on live weights and growth curve parameters using AIREML. Reproductive traits included analysis of number of eggs laid, age at first hatch, laying periods, hatchling intervals, reproductive rates and efficiencies. Survival analysis included estimating number of chicks surviving at different ages.

The findings referring to parameters of growth and reproduction performance could be summarised as follows:

- Growth productivity results showed that LC had slow growth rates with gentle sloped growth curves, reached point of maturity after 15 weeks at lower body weights of 500 g. Asymptotic live weights of between 1200 to 1600 g were attained after 30 weeks. Live weights and parameters of growth curves were highly heritable (39 – 56 %) and show potential to select for growth under scavenging conditions.
- Reproduction performance showed that LC reached age at first hatch at 30 weeks. Hatching intervals were long with more than 100 days. LC produced about four clutches per annum, resulting in a reproductive index of 22 – 30 chicks per annum. Hatching rate was high (over 60 %) indicating that local chickens lay fertile and viable eggs. Egg production and hatchability were significantly ($p<0.05$) lower on-station than on-farm. Changes in management and interruption during observations were the main cause of this variation.
- High mortality (50 % of chicks that hatched) was observed at 20 weeks of age. Chick mortality by five weeks was higher ($p<0.05$) on-station than on-farm.

Growth potential and feeding trials: In this study, growing chicks of about 9 weeks old were randomly selected from household flocks and individually raised in metabolic cages on-station. Their hatch mates continued under scavenging conditions on-farm. The objective was to compare productive performance of on-farm raised chickens with those under controlled, fed conditions, and to evaluate their feed intake and feed utilisation efficiency. These birds were raised in three batches of 50 birds per batch between August 2002 and June 2003. Growth traits were measured as described above. Feed intake was determined by weighing feed offered and feed left over. Droppings were collected while birds stayed in cages until they were 20 weeks old. After that, they were returned to farmers. By combining growth rates and feed intake data, feed, dry matter and crude protein (CP) utilisation efficiencies were determined. Endogenous metabolic dry matter and CP were determined by regressing nutrients in droppings on nutrients intake. Economic analysis was included to determine margin over feed costs for birds in cages. All data were analysed using proc mixed and general linear models of SAS.

Another auxiliary trial included comparison of growth performance of LC to Black Australorp (BA) chickens on-farm. The aim was to test the hypothesis that growth performance of LC and BA is not different under scavenging conditions to warrant using BA to improve productivity of LC through substitution by continuous crossbreeding. BA chicks at 9 weeks were randomly distributed to household flocks with contemporary local chicks and their weights were measured till they were 30 weeks old.

From the results of these series of studies, output valuation and production efficiency coefficients were computed and analysed. The findings from these experiments are summarised below.

- Growth potential study showed that LC under fed conditions had significantly ($p<0.05$) higher performance than counterparts under scavenging conditions. A within breed G x E interaction for growth traits was expressed. For all traits, males were significantly ($p<0.05$) superior to females. Phenotypic variation was high with potential for both genetic and non-genetic improvement.

- LC chickens had low feed intake (42 to 66 g feed per bird per day at 20 weeks), poor conversion of feed and CP (4.5 to 6.0 g feed per g weight gain), but were good at utilising metabolised nutrients (1.3 g weight gain per g protein intake). Endogenous CP and DM constituted 25 % and 17 % of CP and DM intake. Droppings had high DM content (52 %) and each bird excreted an average of 21 g droppings, on dry matter basis that contained 33 % CP and 22 % ash.
- Rates of returns per hen or per unit hen weight were significantly ($p<0.05$) higher on-farm than on-station. Overall, returns per hen weight or metabolic hen weights were low and variable. This variation was mainly non-genetic.
- Based on breeding stock per flock, LC production system showed that it is efficient, with close to 250 % return on input. However, disease and predation losses contributed significantly to output. The return was 153 % based on functional outputs. Annual values of outputs constituted home consumption (MK958, 1 US$ = MK85), ceremonies (MK636), sales (MK403), breeding stock sharing (MK66) and gifts (MK43). Output due to diseases and predation valued MK567 and MK420, respectively.
- There was no difference in growth performance of BA and LC under scavenging conditions on-farm to warrant using BA as a dual-purpose exotic breed to improve LC through crossbreeding or substitution through continuous crossbreeding.

Scope to optimise local chicken production

Based on the characterised parameters, phenotypic and genetic variation exists that could be exploited for improving local chickens to desirable levels to be sustained under scavenging conditions. This variation, with the wide distribution of LC among all social strata of rural households who still form majority in Malawi and the estimated overall economic value and marketing potential for local chickens lead to the fact that the production system is likely to prevail in Malawi. This creates the need to improve LC production and productivity. Through utilisation, their genetic resource will be sustained. The presented has clearly shown that there is scope to optimise local chicken production and hence, the need to develop appropriate strategies leading to sustainable and optimised production of local chickens.
A community based approach to improving LC and the production system is the most viable approach, while individual flocks operate on a single tier production basis. This approach will create combined and synergetic influence on combating constraints that could not be handled individually at household level such as health and breeding interventions that require the whole community. For example, communal breeding will increase effective population sizes through rotating cocks, thereby increasing number of cocks without running into problems of cock fighting, minimising inbreeding and subsequent consequences on viability and reduced growth rates. Community health interventions will lead to healthy flocks when all birds from differerent households that mix during scavenging jointly receive treatment obtained efficiently through group purchase. The approach will also make sure that all existing but uncharacterised phenotypes are well distributed among all households, hence assuring their survival without threats of diversity loss. Future studies should pursue the theory of community participatory approach described in the thesis with detailed follow up on finding the impact of cockerel exchange on inbreeding levels, viability traits of survival and comparing growth performance with populations without interventions. The impact of selecting cocks should be evaluated on important traits such as growth. A community health monitoring and treatment programme should be instituted for most common diseases (not only Newcastle disease) and parasites to

evaluate the effect on flock re-infection, productivity and mortality. Evaluation and selection for helminth resistant strains of local chickens should be initiated when proper recording is instituted among smallholder farmers. Genetic structure of local chicken populations should be studied using molecular techniques to explain possible variation between and within populations at a national or regional scale.

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