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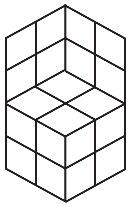

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CHAPTER I

General Introduction

1. Importance of village chicken production

The world poultry population has been estimated to be about 14 billion heads (FAO, 2000). Chickens are the most important poultry species. Poultry production in tropical countries is based on the traditional scavenging system. The share of family poultry to total poultry population in developing countries (in general and in Africa in particular) is not well documented, but estimated to reach 70 to 80% (Guèye, 1998; Sonaiya et al 1999; Guèye, 2000). A review of available literature from eight Sub-Saharan African (SSA) countries showed that village poultry on average accounts for 78%, ranging from 30 to 99%, of the total poultry population, and the largest proportion of eggs and poultry meat are produced in the village system (Tadelle, 1996). Despite the fact that village poultry are more numerous than commercial ones and provide the largest proportion of products in developing countries, little research and development work has been carried out to characterise, understand and develop the system (Cumming, 1992).

Although indigenous birds have a number of adaptive traits and genes with special utility in the tropics (Horst, 1989), the real value of indigenous chicken breeds is often under-estimated mostly due to their poor appearance, relatively low productivity and alleged low "commercial" values. To this effect, they have been neglected and little attention has been given from researchers, development workers and policy mkers to put them in the research and development agendas. As it is stated by Hodges (1990), developing countries in most cases opt for high performing commercial breeds from developed countries to increase animal productivity through crossbreeding or if conditions allow by breed substitution without properly investigating the production system and potential of the indigenous birds. Although poultry are an important sources of food, both meat and eggs, and a means of investment that is important to the welfare of women and children in traditional and low-input systems, an alarming 34% of all avian breeds in Africa are at risk of being lost (FAO, 2000).

Currently there is an understanding (Seré and Steinfeld, 1996) that introducing high-yielding breeds of animals and specialised modes of production can lead to loss in genetic diversity among indigenous animals. In developing countries, the less intensive production systems are the mainstay of the existing genotypes. More over there exists a strong and close relationship between native breeds and non-intensive systems of production.

Village poultry production, however, is regaining importance in smallholder agricultural systems, wherever low external production inputs are demanded (Sonaiya *et al.,* 1999). According to Delgado *et al.* (1999), the dramatic increases in consumer demand for poultry products, mainly in urban areas, will have major implications for demand, in availability and prices of concentrate feeds, that will, in turn, affect intensive poultry production activities in most developing countries.

2. Chicken production in Ethiopia

Chicken production systems in Ethiopia show a clear distinction between traditional, low input systems and modern production systems using relatively advanced technology (Alemu, 1995). There is also a third up coming "small scale" intensive system with small number of birds (from 50 to 500) as an urban and peri-urban household income source using exotic birds and relatively improved feeding, housing and health care (Alemu and Tadelle, 1997). The village chicken production systems in the country is characterised as including small flocks, nil or minimal inputs, low outputs and periodic devastation of the flocks by disease. Birds are owned by individual households and are maintained under a scavenging system, with little or no inputs for housing, feeding or health care (Tadelle and Ogle, 2001).

The chicken population of Ethiopia is estimated to be about 65 million heads (FAO, 2000). The country has about 60% of the total chicken population of East Africa (Mekonnen, *et al.,* 1991). Rural small holder farmers keep more than 95% of this population and typically, the flocks are small in number (an average of 7-10 mature birds) in each household consisting of 2 to 4 adult hens, a male bird and a number of growers of various ages (Tadelle, 1996). The AACMC (1984) gives an average of six indigenous birds per household. According to Sonaiya (1990), the average flock size in Africa ranges from 5-10 birds.

Ethiopia has a short and long term plan of food self sufficiency and poverty alleviation program launched in 1995. This plan gives more attention to local resources, among which indigenous chicken is one. Poultry production is an important economic activity in Ethiopia. Beside its social and cultural benefits it plays a significant role in family nutrition. Village poultry occupy a unique position in rural communities through their contribution to the supply of valuable protein food to the families of the smallholder farmers. This is particularly true in Ethiopia, because there are few alternative animal protein sources and no cultural or religious

taboos of any kind relating to the consumption of eggs and poultry meat as that of pig meat (Teketele, 1986; Tadelle, 1996 and Kitalyi, 1998).

3 Past research and development efforts

3.1 Commercial production system

Development and research in poultry started in the early 1950's with the establishment of higher learning agricultural institutes. The activities of these institutions mainly focused on the introduction of exotic breeds to the country and the distribution of these genotypes to farmers with recommendation on appropriate feeding, housing, health care and other husbandry practices (Alemu and Tadelle, 1997). This was expected to have a considerable positive influence for the expansion of large-scale commercial farms in the country. However, after 40 years of effort the contribution of exotic birds in terms of egg and meat production is less than 10%. A number of factors can be sited as causes for this low rate of adoption. First, one should recognise that poultry, particularly exotic birds, are food converters' not food producer. The foodstuffs used to feed chicken are often of a quality that could be fed directly to humans. Thus, in grain deficient countries like Ethiopia, adopting intensive poultry industry will be frustrated by the severe shortage of grain to feed the animals and shortage of foreign exchange to import breeding stocks and other associated inputs. Unless the grain production and foreign exchange reserve in the country is improved, such a system cannot be economically sustainable and socially acceptable.

3.2 Village production system

"Upgrading" the blood level of local birds using exotic birds through distribution of cockerels to farmers was considered as the most important strategy to effect improvement by policy makers (Alemu and Tadelle, 1997). The extension system of the Ministry of Agriculture has promoted schemes in which cockerels from selected strains (mainly White Leghorn and Rhode Island Red) are reared up to 15 to 20 weeks of age and given out to subsistence farmers in order to "upgrade" the genetic potential of local birds. In addition, exotic pullets and fertile eggs were distributed to individual farm households in rural Ethiopia (Tadelle *et al.,* 2000). This approach has been practised in the last 40 or more years (Alemu and Tadelle,

1997). Although the impact of this strategy in the genetic structure of indigenous birds has not been assessed carefully, the empirical evidence suggests that these approaches were met with a limited success due to the high mortality rate of the exotic breeds (Tadelle *et al.*, 2000). The mortality rate of exotic birds was high because the birds were not well suited to the poor management and disease conditions in the new environment. The low impact of exotic birds distributed to rural areas could be due to their inability to brood, their lack of alertness to predators, poor colour camouflage against predators, and their short legs which are unsuitable for fast running (Smith, 1990). The study by Tadelle and Ogle (1996), in the central highlands of Ethiopia shows that there has been an introduction of exotic breeds to the three study villages at various times and in different forms, such as through the introduction of cockerels, pullets, and fertile eggs, but their impact in upgrading the village chicken has been minimal. This is because the programs were usually planned without the participation of the farmer, with no parallel improvement in feeding, housing and health care and usually lasts for short time. Usually the farmers were asked to remove all remaining local cockerels. However, throughout the country, success has not been achieved, mainly because chances are very high that the exotic bird will die, leaving the farmer with no cockerel at all.

4. Rationale of the study

The development of innovative ideas for improving rural poultry production requires a complete understanding of the system and its operators. Furthermore, research directions and strategies should be geared to addressing farmers' real problems and constraints so as to help them expand and become self sufficient. As summarised by Röling (1988), the development and transfer of appropriate technologies should be a function of the farmers' socio-economic and management practices at the field level. An on-farm investigation of poultry systems and poultry ecotypes aimed at description of indigenous chicken in their respective production environments and characterisation of the associated village production systems was the first module of this study. A better understanding of the rationale underlying smallholders' objectives of keeping chicken and use patterns of chicken and chicken products is necessary to guide research and development programmes supporting village chicken producers through focusing on local breeds and traits of importance to meet smallholders' production objectives. Understanding the roles and function of local chicken as well as production problems/constraints is of considerable relevance in view of envisaging future research and development directions and strategies. Phenotypic diversity of different indigenous chicken

ecotypes in Ethiopia aim at understanding the phenotypic differences between and within the different populations which provide the basis for genetic improvement was the second module of this study. This requires a system oriented characterisation and evaluation of the different chicken ecotypes form different regions and corresponding market sheds of the country. Genetic characterisation which is essential to estimate the relatedness between and within the different ecotypes using microsatllite markers was the last and the third module of this study. The identification and understanding of local chicken genetic resources and the prevention of further loss of genetic variation in the face of the rapidly increasing demand for animal protein and related economic and market forces is an important task to improve livelihood and alleviate poverty.

5. Objectives of the study

The main objective of this study is: to advance the methodological approach for a system oriented evaluation of chicken ecotypes with the aim to establish a poultry breeding policy.

Within this main objective, the study defines the following specific objectives:

1. To asses functions and importance of chicken production systems of different agro-ecological regions in Ethiopia
2. To identify and analyse constraints and opportunities for sustainable improvement of chicken production under smallholder systems in the divers agro-ecological regions of the country
3. To valuate performance and other traits under village production conditions in the faces of low input-output levels
4. To understand production objectives and selection criteria of farm households
5. To evaluate the quantitative performance of five different ecotypes of birds for their growth potentials
6. To asses the feed utilisation and growth potential of the different ecotypes from different ecological regions of the country.
7. To estimate the genetic distance between and within the different chicken ecotypes

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Teketel Forssido, 1986. Studies on the meat production potential of some local strains of chicken in Ethiopia. Ph.D Thesis, J.L. Giessen University

CHAPTER II

Literature review

This chapter is based on papers:

1. Tadelle D., Alemu.Y., and Peters K.J. 2000. Indigenous chicken in Ethiopia: genetic potential and attempts at improvement. *World's Poultry Science Journal Vol. 56, 45-54.*
2. Tadelle D., Nigusie D.; Alemu Y and K. J. Peters. 2002. The feed resource base and its potentials for increased chicken production in Ethiopia. *World's Poultry Science Journal Vol. 58, 73-83.*

1. The evolution of chicken domestication

The process of domestication of animals began about ten thousand years ago and the different stocks were distributed in the course of domestication and human migration to the north, east and west, which means domesticated animals have been carried by migratory humans to various regions of the earth. In each region and local area, domestic populations adapted and evolved in response to wide range of selection pressures. In each case the primary factors contributing to the final population were complex and included founder effects, migration, mutation, natural selection and selection by man. The current genetically diverse animal populations are the result of this long term evolutionary process which have adapted to different environmental conditions and to a wide range of human needs (Clutton-Brock, 1999).

The domestication of chicken took place between 8000 to 3000 BC. Archaeological findings indicate that chicken were domesticated in the Indus River Valley (presently Pakistan) as early as 3250 BC (Moiseyeva, 1998). The wild species of *Gallus*, which may have contributed to the present domesticated fowl, include the Red jungle fowl (*Gallus gallus*), Grey Jungle Fowl (*Gallus sonnerrati), Ceylon Fowl (Gallus lafayettei)* and the *Green Fowl (Gallus varius)*. Studies on morphological characteristics such as comb and feathers characteristics have shown similarities between the Red Jungle Fowl and domestic fowl. Geneticists therefore generally accept the Red Jangle fowl, which is currently in wild form in Asia as the common ancestor of the domesticated chicken (Crawford, 1990a; Horst, 1991). Therefore, there is no doubt that the domestic fowl originated in Asia, so its distribution throughout the world has to be traced from there.

As it is outlined by Skinner, (1974); Crawford, (1984); Crawford, (1990b), the evolutionary process of chicken domestication in the world has four distinct stages: The first evolutionary stage was by use of these animals in religious, cultural and traditional purposes which resulted in the selection of colour and different morphological features. During the second stage chickens were moved from centres of domestication to other countries, continents, other cultures and other environments. The major forces of genetic changes were genetic drift, migration and natural selection for adoption to new environmental conditions. The third stage was epitomised by the 'hen crazy' of the 19th century. At this stage most of the breeds and varieties known at present were developed. The fourth stage belonged to the 20th century,

which grew out of the cultural 'hen crazy' into the vast chicken meat and egg industry of today. The industry has been very quick to adopt new advances in genetics and breeding and new advances in technology. In the due course the number of breeds, varieties and strains used in food production have declined to the very few which now dominate the breeding and products industry.

Most commercial birds are results of crossing of several purebred lines being selected on the basis of desirable traits. With ever increasing production intensities and desire to improve performance levels the breeding industry began to specialize in either egg or meat type birds. The genetic base was reduced, only few breeds were used in this system and in their breeding programs. For example, nearly 100% of the commercial chicken broilers in most parts of the world are descendants of White Plymouth Rock females. The sire side in this case is a synthetic breed, combining genetic material from the Cornish, New Hampshire and Barred Plymouth Rock varieties (Hawes, 1986). The loss and potential loss of genetic variability in poultry may be a cause for concern in the industry due to the disproportionate concentration of breeding materials and programs under the control of just a few large companies (Ponsuksili *et al*, 1996).

2. Fowl domestication and importance in Africa

Clutton-Brock (1993), as cited by Williamson (2000) has summarised the Archaeological findings for the domestic fowl in Africa: the earliest evidence is a sketch of a cockerel on an ostracon from the tomb of Rameses IX (1156-1148 BC). Chickens were not common in Egypt until the Ptolemaic period (332-330 BC). In West Africa they have been excavated from the Iron Age site of Jenne-jalo in Mali, dated to about AD 500-800. In east Africa they are recorded from two Iron Age sites in Mozambique, and in Southern Africa from eighth century Iron Age sites; Plug (1996) confirms that they are found in early Iron Age sites, but were not apparently common. It is likely that, as suggested by MacDonald (1992), chickens may have been present in Africa well before the earliest date yet attested by Archaeological findings. Williamson (2000) concludes that there is a basic conflict between Archaeological findings to date and the apparently deep embedding of the chicken in many African cultures in addition to the linguistic and ethnographic evidences suggests that the chicken was

probably in Africa much earlier than is currently believed and chicken is deeply embedded to an African culture. The association of chicken to an African culture is illustrated in the following examples, "In Congo a girl should finish eating the whole chicken flesh without breaking a single bone to show the family that she is ready to get married (Minilek Magazine, July 2001, page 21). In Ethiopia the cultural, social and religious functions of indigenous chicken types are important, despite the variations from region to region (Table, 1). The very important features are the colour, sex, comb type and age of the bird used for a given cultural, social and/or religious functions, as was the commitment of an individual to a particular spiritual being or a cosmic force (Tadelle, 1996; Leulseged, 1998).

Table 1 Colour and sex of birds * used for sacrifice and other cultural purposes in the highlands of Ethiopia.

	Village				
Sex and colour of birds	Derek Wonz	Gende Gorba	Awash	Purpose	Remarks
White cock	---			Good harvest and good rains	October and May
Red cock		---	---	Good harvest and good rains	October and May
Red and black spotted cock	---	---	---	Ethiopian new year	Middle of September
White and black spotted cock *(Gebsema*)	---	---	---	Protection from evil things such as disease	Any time if needed
White pullet	---	---	---	To keep in the house	Any time if needed
Red pullet (*Attete)*	---	---	For ancestors		June or May

* This in addition to the prescription by "traditional" doctors
(Source: Tadelle and Ogle, 2001)

Birds of exotic origin are not accepted for any of the above functions. Most Ethiopians slaughter chicken at home during religious, cultural and social festivals; and invite special guests to partake of the popular dish *" doro wat"*, which contains both chicken meat and eggs and is considered to be one of the most exclusively preferred national dishes. Ethiopians have

a special chicken meat cuts. Traditionally there are 12 meat cuts from one bird. Most of the households in Ethiopia slaughter chicken at home during religious festivals. The religious practice at present could be related to the verses from old testament: *"If he cannot afford a lamb, he is to bring two doves or two young pigeons to the Lord one as a sin offering and the other for a burnt offering. He is to bring them to the priest, who shall first offer the one for the sin offering and he will be forgiven ". Lev. 5: 7-8* and the 12 meat cuts to the last super (personal communication with religious clergies).

As is the case with other livestock species chicken also could have been introduced into Africa through the Isthmus Suez, the Horn of Africa and through direct Sea trading between Asiatic countries and coastal Eastern Africa. The advent of DNA-level analyses in biodiversity studies provides powerful tool for elucidating the genetic relationships.

3 Genetic inheritance in chicken

The science of genetics is concerned with determining the modes of inheritance or the transmission of biological properties from generation to generation. The particulate that determines the modes of inheritance are called hereditary factors (genes) which are contained in bodies called chromosomes. Genes that determine specific characteristics are segments of DNA molecules. The manipulation of genes is the basis for all breeding programs, and DNA may be considered as building blocks of the genetic foundation of an animal. As the chromosomes exist in pairs, the genes also exist in pairs. For example, in chicken there are 38 pairs of autosomal chromosomes and one pair of sex chromosome (EZW, ΓZZ) (Bitgood and Somes, 1990). The size of the chicken genome is estimated at $1.2X10^9$ base pair (bp), which is small in comparison to the mammalian genome of $3X10^9$ bp (Stevens, 1986; Crooijmans, 2000).

Birds differ from mammals in certain characteristics associated with inheritance. One of the major differences is the genetics mechanism by which sex of the offspring is determined. In mammals, sex of offspring is determined by the male gametes, but in birds it is determined by the female gametes. Basically this procedure depends on the number of complete sex chromosomes (**Z**) in each tissue cell. In birds there are two complete sex chromosomes in the male but the female possesses only one. Since all male cells contain a pair of complete sex

chromosomes, after meiosis in the testes cells, only sperm cells with a single complete sex chromosome can be produced. On the other hand all female cells contain only a single complete sex chromosome, after meiosis in the ovary cells, one-half of her ova will contain a complete sex chromosome and the other half will contain the incomplete sex chromosome. Ova from 50% of her ovulation containing the complete **Z** sex chromosome, if united with any male sperm cells, will produce male offspring containing both complete **Z** sex chromosomes, one from each parent. Ova from the other 50% of her ovulations not containing the complete sex chromosome, but containing the **W** chromosome, if united with any male sperm cells, will produce female offspring containing a single complete **Z** sex chromosome from the male parent and the incomplete **W** chromosome from the female parent. Thus, in birds, the female determines the sex of the offspring (Crowford, 1990; Nichlas, 1996). The opposite is true in mammals, including humans.

Since females have only one complete chromosome, genes carried on that chromosome (sex-linked genes) will occur only on that chromosome while males will carry such genes on both of the chromosomes. Due to this a male chicken can transmit a sex-linked characteristic to his sons and daughters. The female, having only one complete sex chromosome cannot contribute one to her daughters. Therefore, any characteristics carried on the sex chromosome by the female cannot be transmitted to her female offspring. The very fact that only one complete sex chromosome from the male parent is transmitted makes these particular progeny female. Knowledge of these facts has been very important in poultry breeding for the transmission of desired characteristics.

4. Poultry breeding compared to other livestock

Poultry breeding have achieved a level of practical application that is not even approached in large animal breeding. Selection and crossbreeding techniques have enabled the production of a laying fowl, which will provide up to 300 eggs a year, as against less than 100 from unimproved poultry. Similar improvement in growth rate is observed in a relatively short time. There are several reasons for this fast progress, however generation interval and high

reproductive rate played the major role in using the two important breeding techniques namely, inbreeding and crossbreeding.

Generation interval : Generation interval is defined as the average age of parents when their chicks which are going to be used as replacements are hatched. It is shorter in chicken than any other livestock. Age at sexual maturity in chickens is about 21 weeks of age and generation interval is as short as one year. This has accelerated developments in poultry breeding.

High reproductive rate: The major reason for fast progress in poultry production through breeding is the high reproductive rate. The female chicken can potentially produce one fertile egg per day with relatively few non-production days per year. Embryonic development commences outside of and unattached to the dam's body, allowing continuing ovulation during the incubation period. The incubation period for the fertile chicken egg is only three weeks before hatching. Thus, many more offspring are available from which to select breeding stock than are possible with mammals.

These unique biological advantages (high reproductive rate, their relatively low cost and short generation interval) of chicken have made it possible to develop inbred lines. Intense inbreeding increases the chance of expression of deleterious recessive genes and perhaps death of chicks. In addition, affected animals will be culled, and this will reduce the frequency of detrimental genes in the offspring generation. The cost of removing even large numbers of animals with undesirable genes is relatively small in poultry and the remaining stock could easily multiply to produce adequate numbers of replacements.

5. Genetic diversity in domestic fowl

Unlike the developed countries, developing countries still have indigenous chicken with diverse uses and benefits to the households. Birds are non-descriptive, known in their ability to survive on irregular supplies of feed and water, and with no health care, and parts of a "balanced" farming systems. Retrospective research studies on some of the indigenous birds from the tropics have shown that their potential for egg and meat production is low. These results are very low when compared with the improved egg and meat type breeds, which can produce + 250 eggs/hen/year and +2 kg body weight in 6 weeks with an average egg weight

of 60 g. Although the local chicks are slow growing and poor layers of small sized eggs, they are, however, ideal mothers, good sitters (Tadelle and Ogle, 2001), excellent foragers, and hardy (Teketel, 1986; Dorgham, 1989) and Darwish et al., 1990) and posses natural immunity against common diseases (Mtambo 2000).

In spite of the expected variations among the different strains, they are characterised by having small body size with not more than 1.5kg mature body weight (Horst, 1989). The small body size is a desirable character in tropical and sub-tropical environments. In line with this, Youssef (1993) reported that most of the native strains are characterised with having relatively longer legs and lighter body weights. One of the most important positive characters of village chicken is their hardiness, which is the aptitude to tolerate the harsh environmental conditions and poor husbandry practices (climate, handling, watering, and feeding) without an excessive drop in production. According to Dorgham (1989) and Darwish et al (1990), local Egyptian chickens are more tolerant to feed restrictions compared to Leghorn and New Hampshire. Teketel (1986), after testing five indigenous ecotypes on-station conclude that indigenous birds had the capacity of sustained egg production at times of increased environmental temperatures and also in the second year of laying compared to the reference breed, White Leghorn. One of the most important fitness traits in chicken is fertility. Teketel (1986) and Saleh *et al*. (1994), from Ethiopia and Egypt reported higher fertility rates of eggs from local stocks as compered to eggs from White Leghorns. Moreover, Mtambo (2000) reported that rural chicken showed resistance to *Salmonella gallinaruem* and typhid infections. However, unlike specialised high performing chicken breeds, indigenous birds in developing countries are non-uniform regarding plumage colour, comb type, down colour, feather cover and morphometrics.

According to Horst (1989), despite the important role-played by tropical fowl as a supplier of meat and eggs in developing countries, there is very little information on its genetic makeup. The most important genes already proved for their special utility in the tropics (Table 2) are namely Na (naked neck), F (frizzle), dw (dwarf), h (silky), k (slow feathering), id (non-inhibitor), Fm (fibro-melanosis, p (peacomb) and O (blue shell) which are dominant or recessive or sex-linked traits of local chickens of the tropics (Haaren-Kiso *et al.* 1988; Horst, 1989). Even though the information collected in the FAO Domestic Animal Diversity

Information System (DAD-IS) and other sources show that these genes are prevalent in the local populations across the African countries (Table 3), but little information exists on the genetic make-up of the indigenous chicken of Africa.

Few attempts have been made on the incorporation of the above genes mentioned in genetic improvement. Mathur *et al.* (1989) reported an increase in egg production through incorporating naked neck (Na) genes in a crossbreeding programme of local Fayoumi. Similarly, Horst and Mathur (1992) reported favourable effects of naked neck (Na) and frizzle (F) genes on egg production and egg weight and of the dwarf (dw) gene on feed efficiency of chickens under heat stress.

Although, indigenous birds have a number of adaptive traits and genes with special utility in the tropics, the real value of indigenous breeds is often under-estimated mostly due to their poor appearance, relatively low productivity and alleged low "commercial" value. As stated by Hodges (1990), developing countries in most cases opt for high performing commercial breeds from developed countries to increase animal productivity through crossbreeding or if conditions allow by breed substitution without properly investigating the production potential of the indigenous birds. According to Peters (1988), there is an apparent lack of information regarding the existing production problems, possible intervention and performance of animals within the prevailing production systems to properly utilise the available genetic diversity to enhance production. This is particularly true in developing countries where breeds or types have not yet been fully identified and characterised, despite the fact that the indigenous breeds survive and produce under unfavourable environments and limited availability of feed, above all they are also parts of the prevailing production system.

Currently there is an understanding (Seré and Steinfeld, 1996) that introducing high-yielding breeds of animals and specialised modes of production can lead to loss in genetic diversity among indigenous animals. However, in developing countries, the less intensive production systems are the mainstay of the existing species and breeds. It is, therefore, absolutely necessary to evaluate existing genetic resources from a standpoint of bio-diversity and from the standpoint of matching available genotypes with the environment and feed resource under which they are maintained.

Table 2 Major genes in local fowl populations with important effects on tropical oriented breeding

Gene	Mood of Inheritance	Direct effects	Indirect effects
Dw: dwarf	-recessive, -sex-linked, -multiple allele	Reduction of body size between 30 and 10 % from the normal size	-Reduced metabolism -improved fitness -disease tolerance
Na: naked neck	Incomplete dominant	-Loss of neck feathers, -Reduction of pterylat width, -Reduction of secondary feathers	-Improved ability for convection -Reduced embryonic liveability (hatchability) -improved adult fitness
F: frizzle	Incomplete dominant	-curling of feathers, -reduced feathering	-Decreased fitness under temperate conditions -Improved ability for convection
K: slow feathering	-dominant, -sex linked -multiple allelic	Delay of feathering	-reduced protein requirement -reduced fat deposition during juvenile life -increased heat loss during early growth, -reduced adult viability**(?)**
Id: non-inhibitor	-recessive, -sex linked, -multiple allelic	Dermal melanin deposition -skin -shanks	Improved ability for radiation from shanks and skin
Fm: fibro-melanosis	Dominant with Muli-factorial modifiers	Melanin deposition -all over the body -sheats of muscles and nerves -blood vessel walls	-protection of skin against UV-radiation -improved radiation from the skin, -increased pack cell volume and plasma protein
P: peacomb	Dominant	Change of skin structure -compact camb size -reduction of pterylae width -development of breast ridges	-Decreased frequency of breastbllisters -sex limited (Γ) -improvement of late juvenile growth
O: blue shell	Dominate, Sexlimited (E)	-deposition of blue pigment into egg shell	Improved eggshell stability

Source: Horst, 1989

Table 3 Identified characteristics of some indigenous chickens in Africa

Country	Local name	Identifiable characteristics	Mature male weight	Mature Female weight	Source
Burkina Faso	Cou nu, Joub-kole	Na: naked neck F: frizzle	1.5	1.2	DAD-IS
Chad	Chicken of Moulkou	P: peacomb	1.5	1.	DAD-IS
Chad	Dijded	P: peacomb	1.5-2	1-1.5	DAD-IS
Ghana	Local Ghanaian	Na: naked neck F: frizzle P: peacomb	1.2	1.1	DAD-IS
Lesotho	Basotho	P: peacomb	1.8	1.6	DAD-IS
South Africa	Kaalnekke	Na: naked neck	-	-	DAD-IS
Swaziland	Inkhukhu	Na: naked neck	2.1	1.6	DAD-IS
Sudan	Large balady	Na: naked neck	-	-	Youssef (1993)
Ethiopia	*Melata*	Na: naked neck	-	-	Teketel (1986)

Understanding the roles of local chicken in the socio-economic life of the farming community, through economic appraisal of traits, breeding objectives and selection criteria of poultry producers need to be dealt with, to quantify the performance values attributable to animals and quantifying these values in order to develop implementing mechanisms and policies that permit the 'capture' and improvement of these performance values.

6. Methods to assess the genetic diversity

Marker genes, which are assumed to be neutral to selection forces and which are hidden to man, are appropriate tools in the study of relationship between breeds and within breeds. Genetic variability has been measured directly with different genetic markers in chicken, for example with Restriction Fragment Length Polymorphism (RFLP) (Bumstead *et al.* 1987),

with protein polymorphism (Mina *et al.* 1991) or with microsatellite markers (Vanhala *et al.* 1998; Zhou and Lamont 1999). The comparison of cytogenetic, protein electrophoretic and molecular genetic techniques revealed that the typing of highly polymorphic DNA-Markers (microsatellites) is the most appropriate method for descriptive genetic studies (Avise *et al.,* 1995). Wimmers et al. (1999) used 20 microsatellites to group Nigerian chicken ecotypes according their genetic similarity as a contribution to the identification of genetic resources.

The techniques of gel electrophoresis allows detailed analysis of molecular or protein variation without dissecting the molecules down to their ultimate residues. This method detects only a fraction of amino acid changes in proteins. However, the method has shown that most neutral populations have a high degree of variation at a protein level. Electrophoresis has been successfully applied to study the relationship between cattle breeds and by estimation of genetic distances between breeds (Baker and Manwell, 1980; 1987; Kotze and Muller, 1994). Due to the advent of Polymerase Chain Reaction techniques and genetic markers, the use of DNA has become an alternative for the research of various genetic, breeding and physiological questions in animal sciences.

6.1 Polymerase Chain Reaction (PCR)

The PCR technique is a primer extension reaction for amplifying specific nucleic acids in *vitro* (Strachen and Read, 1996). The sources of DNA used in PCR reaction can be genomic DNA from whole blood or tissue, or forensic specimens and ancient biological samples (Turner *et al,* 1998). The use of a thermostable polymerase allows the dissociation of newly formed complimentary DNA and subsequent annealing or hybridization of primers to the target sequence with minimal loss of enzymatic activity. PCR will allow a short stretch of DNA (usually fewer than 3000 bp) to be amplified to about a million fold so that one can determine its size, nucleotide sequence, with the aim of providing a fragment large enough for cloning, sequencing or detection on a polyacrylamide gel. The particular stretch of DNA to be amplified, called the target sequence, is identified by a specific pair of DNA primers and oligonucleotides which are usually about 20 nucleotides in length (Takezaki and Nei, 1996).

PCR is a powerful technique that allows to amplify DNA sequence millions of times in just a few hours. The technique was invented by Mullis in 1983, for which he received the Nobel prize in chemistry ten years later. PCR is revolutionising many areas of genetic research including genetic disease, forensic medicine and molecular evolution. Two important innovations were responsible for automating PCR. First, a heat-stable DNA polymerase was isolated from the bacterium *Thermus aquaticus,* which inhabits hot springs. This enzyme, called the *"Taq"* DNA polymerase (which is often used), remains active despite repeated heating during many cycles of amplification. Second, DNA thermal cyclers have been invented in which a computer controls the repetitive temperature changes required for PCR (Strachen and Read, 1996).

Within a dividing cell, DNA replication involves a series of enzyme-mediated reactions, resulting in a faithful copy of the entire genome. Enzymes first unwind (denature) the DNA double helix into single strands. Then, an RNA polymerise synthesises a short stretch of RNA complementary to one of the DNA strands at the start site of replication. This DNA/RNA hetroduplex acts as a "priming site" for the attachment of the polymerise, which then produces the complementary DNA strand. During PCR, high temperature is used to separate the DNA molecules into single strands, and synthetic sequences of single-strand DNA (20-30 nucleotides) serve as primers. Two different primer sequences (forward and reverse) are used to bracket the target region to be amplified. One primer is complementary to one DNA strand at the beginning of the target region; a second primer is complementary to the other strand at the end of the target region (Miesfeld, 1999). To perform a PCR reaction, a small quantity of the target DNA is added to a test tube with a buffered solution containing polymerase, short oligonucleotide primers, the four deoxynucleotide building blocks of DNA, and a cofactor $MgCl_2$.

The purpose of a PCR is to make a huge number of copies of a gene. The product synthesized in one cycle serves as a template in the next, so that the original DNA is doubled in every cycle. This is necessary to have enough starting template for sequencing. The PCR mixture is taken through replication cycles. There are three major steps in a PCR reaction, which are repeated for about 30 cycles (the number of cycles depends on the type of further analysis

and amplification level required). This is done on an automated thermocycler, which can heat and cool the tubes with the reaction mixture in a very short time.

1. **Denaturation**-one to several minutes at 94 to 96°C : During which, the double strand melts open to single stranded DNA, all enzymatic reactions stop (for example : the extension from a previous cycle).
2. **Annealing**-one to several minutes at 50 to 65°C : The primers are jiggling around, caused by the Brownian motion. Hydrogen bonds are constantly formed and broken between the single stranded primer and the single stranded template. The more stable bonds last a little longer (primers that fit exactly) and on that little piece of double stranded DNA (template and primer), the polymerase can attach and start copying the template. Once there are a few bases built in, the hydrogen bond is so strong between the template and the primer, that it does not break anymore.
3. **Extension** at 72°C : This is the ideal working temperature for the polymerase. The primers, where there are a few bases built in, have a stronger attraction to the template, created by hydrogen bonds, than the forces breaking these attractions. Primers that are on positions with no exact match, get loose again (because of the higher temperature) and don't give an extension of the fragment. The bases (complementary to the template) are coupled to the primer on the 3' side (the polymerase adds deoxynucleoside triphosphate's (dNTP's) from 5' to 3', reading the template from 3' to 5' side, bases are added complementary to the template)

Because both strands are copied during PCR, there is an exponential increase of the number of copies of the gene. Suppose there is only one copy of the wanted gene before the cycling starts, after one cycle, there will be 2 copies, after two cycles, there will be 4 copies, three cycles will result in 8 copies and so on. Following thirty such cycles, a theoretical amplification factor of one million is attained. The amplicon or the PCR product can then be visualized on an agrasoe or polyacrylamide gel (Erlich, 1991; Nicholas, 1996).

PCR technology is used to amplify known sequences of a sample of DNA or for arbitrary priming of variable regions of the genome. PCR has the advantage of being a relatively fast, sensitive and reliable method. In addition to the fact that PCR amplifies a very small amount of DNA, it also amplifies degraded or poor sources of DNA (Strachen and Read, 1996;

Erlich, 1991). It is therefore possible to use PCR for the following DNA-based markers: Randomly Amplified Polymorphic DNA (RAPD), Variable Number Tandem Repeats (VNTR's), Amplified Fragment Length Polymorphism (AFLP) and Restricted Fragment Length Polymorphism (RFLP) (Erlich, 1991). All these genetic markers can be used for estimation of genetic variability and are commonly grouped into two as Fingerprints (FP) and Clone Sequence Based (CSB) markers.

6.2 DNA-based markers

Genetic markers are the basic tool of the geneticist and according to Botstein *et al.* (1980), three properties define a genetic marker: locus-specific, polymorphic in the studied population and easily genotyped. Table 4 provides a summary of the properties of DNA-based markers, which are often used in the studies of genetic variability in farm animals.

6.2.1 Restriction Fragment Length Polymorphism (RFLP)

Restriction Fragment Length Polymorphism (RFLP) is a technique in which organisms may be differentiated by analysis of patterns derived from cleavage of total genomic DNA into fragments by restriction enzymes and separation of the fragments on the basis size by gel electrophoresis and transfer to nylon membranes (Southern, 1975). If two organisms differ in the distance between sites of cleavage of a particular restriction endonuclease, the length of the fragments produced will differ when the DNA is digested with a restriction enzyme. The similarity of the patterns generated can be used to differentiate species (strains) from one another. Restriction endonucleases are enzymes that cleave DNA molecules at specific nucleotide sequences depending on the particular enzyme used. Enzyme recognition sites are usually 4 to 6 base pairs in length. Generally, the shorter the recognition sequence, the greater the number of fragments generated. If molecules differ in nucleotide sequence, fragments of different sizes may be generated. The fragments can be separated by gel electrophoresis. The DNA fragments of different lengths are then subjected to electrophoresis and fragments will migrate according to their weights, smaller fragments are faster and larger fragments are slower (Nicholas, 1996). Restriction enzymes are isolated from a variety of bacterial genera and are thought to be part of the cell's defences against foreign DNA by cutting it into fragments. According to Dodgson *et al.* (1997) in order to use RFLP it is often required, that many enzymes need to be tested in the initial phase to be able to identify the polymorphism,

but even then it is still an easy and relatively cheap marker to use. However, the potential disadvantages of the RFLP technique are its dimorphic nature, since RFLP only indicates the presence or absence of a cleavage site, and therefore does not give a great deal of genotypic information. In addition, it requires large amount of DNA, it is time consuming and labour intensive. However, PCR can be used to amplify very small amounts of DNA, to the levels required for RFLP analysis. Therefore, more samples can be analyzed in a shorter time. RFLP as a technique is mostly applied in detection of diseases. RFLPs in farm animals have been reported in cattle, sheep and dog, however, few reports have been published in poultry (Bulfield, 1990).

Table 4 Summaries of the properties of DNA-based markers

Variables	Clone Sequence Based (CSB)		Fingerprints (FP)		Single Nucleotide Polymorphism (SNP)
	RFLP	Microsatellites	RAPD	Mini-stellite	
Genome surveyed	sc & mr	Sc	Sc & mr	Sc	sc
Genome distribution	Ubiquitous	Ubiquitous	Ubiquitous	Hetrochromatien	Ubiquitous
Typical PIC	Low	High	Moderate	High	Low
Typical allele number	2	2-10	2	2	2
Inheritance mode	Co-dominant	Co-dominant	Dominant	Dominant	Co-dominant
Type of loci	I and II	II>I	II	II	I and II
Reliability	High	High	Low	High	High
Speed of assay	Low	High	High	Low	High
Initial investment	Moderate	High	High	Low-moderate	High

sc = single copy; mr = moderately repetitive and PIC= Polymorphic Information Content

(Source = Dodgson *et al.,* 1997)

6.2.2 Amplified Fragment Length Polymorphism (AFLP)

Amplified Fragment Length Polymorphism (AFLP) or its fluorescent version (fAFLP) is a PCR-based fingerprinting technology. Estimations of genetic divergence or genetic distance between populations by DNA fingerprinting is based on band sharing and band frequency

(Lynch, 1991). In its most basic form, AFLP involves the restriction of genomic DNA, followed by ligation of adaptors complimentary to the restriction sites and selective PCR amplification of a subset of the adapted restriction fragments. These fragments are visualised using gel electrophoresis (Vos *et al.,* 1995) either through autoradiographic or fluorescence methodologies. The availability of many different restriction enzymes and corresponding primer combinations provides a great deal of flexibility, enabling the direct manipulation of AFLP fragment generation for defined applications (e.g. polymorphism screening, QTL analysis, genetic mapping).

Compared to other marker technologies, including Randomly Amplified Polymorphic DNA (RAPD), AFLP provides equal or greatly enhanced performance in terms of reproducibility, resolution, and time efficiency. Probably the single greatest advantage of the AFLP technology is its sensitivity to polymorphism detection at the total-genome level (Vos *et al.,* 1995). With all of these assets, AFLP markers are fast becoming a molecular standard for investigations ranging from systematic to population genetics. According to Vos *et al.* (1995), AFLP technique can be done at a reasonable cost and has been extensively used, particularly in the genome mapping of plants.

6.2.3 Microsatellites

Microsatellites are stretches of DNA that consist of variable number tandem repeats (VNTRs) of a simple sequence of nucleotides or loci (2 to 4 bases). Simple tandem repeats exhibit a considerable degree of polymorphism in the genome of many eukaryotic cell (Kammerbaner *et al.,* 1989) and are dispersed in the entire genome. The basic units of the simple tandem repeats consist of small numbers of base pairs (i.e CAC, GATA, GACA etc). Tautz *et al.* (1986) estimated that one microsatellite is located approximately every 10 kb along the genome. Microsatellites consist of tandem repeats between one and six bp unlike the minisatelites which, consist of up to 200 bp and are found to be longer repeats than microsatellites. According to Tautz and Renz (1984); Tautz (1989); Smeets *et al.* (1989), these domains were first demonstrated by Hamada and colleagues, during the early eighties. Repeat units consist of $(A)_n$, $(TG)_n$, $(CA)_n$ or $(AAT)_n$ repeats. For example in most vertebrates the $(CA)_n$ repeat is the most common motif (Beuzen *et al.,* 2000). Microsatellites are highly polymorphic due to the variation in the number of repeats. According to Goldstein and Polack (1997), it is not uncommon to find up to 10 alleles per locus and hetrozygosity

values of 60% in a relatively small number of samples. Using the PCR, these repeats can be easily amplified since they are well distributed in animal genomes and are multi-allelic in nature (Tautz, 1989). The number of repeat units that an individual has at a given locus can be easily resolved using polyacrlyamide gels. From the gels, we can see two genetic marks for most individuals; each individual inherits one length of nucleotide repeats from his or her mother and one from his or her father (individuals with one band received the same band from both their mother and their father). Their abundance, distribution and polymorphic nature offer a general source of genetic markers for linkage analysis, population and pedigree studies.

The development of microsatellite markers requires the construction of a genomic library of the species. Briefly, the construction of a genomic library involves cloning the DNA of a specific species (e.g. chickens DNA) as follows: firstly, the genomic DNA is digested using restriction enzymes, which yields small DNA fragments. The DNA fragments are then cloned into vectors such as phages or plasmids, which allow proliferation in bacterial cells. The next step involves hybridisation where thousands of clones are screened with synthetic polynucleotides such as $(TG)_{13}$, $(CAC)_5$ and $GAT)_4$, which are, labelled radio actively with $^{32}P\gamma$-ATP. Positive clones are then isolated and sequenced (Crooijmans *et al.* 1993). This sequence information is used to synthesise PCR primers, which are then also tested on a panel of unrelated animals. This step is essential to ensure that primers work optimal and that there is no cross reactions (Crooijmans *et al.*, 1993; Crooijmans *et al*., 1997). Primers are developed in pairs and usually labelled with a fluorescent dye for application on automated sequencing machines.

Microsatellite have been mapped for various species, including humans, mice, fruit flies, cattle, sheep, pigs and chickens (Goldstein and Polack, 1997). As a consequence these microsatellite have become most valuable markers in studies on genetic variability, parentage verifications and genome mapping projects.

6.3 Genetic markers and variablity in chickens

6.3.1 Genetic markers used

In estimation of genetic variablity of chicken, both types of markers (FP and CSB) were found to be useful, however genetic variablity in chicken (commercial and indignous) has

mostly been studied by using DNA-FP and microsatellite markers (Table 5). In addition both also has been applied in evaluation of potential QTL's in chickens (Dunnington *et al.,* 1993).

Table 5 Different markers used in estimation of genetic variablity in poultry

Objective of the study	Breeds/lines of chicken studied	Marker (s) used	Reference
-DNA-FP's for individual identification and linkage studies in poultry	-Broilers: Cornish X White Rock breed, Layers: Leghorn; Muscovy Duck, Turkey & Geese	DNA-FP's	Hillel et al., 1989
-Determnation of genetic distance	-French broiler breed, random bred and inbred lines of White Leghorn	DNA-FP's	Kuhnlein et al, 1989
-Genetic diversity between different breeds	-Cameroon (naked neck and normal feathered) and Dahlem Red breeds	DNA-FP's	Mafeni, 1995
-Estimation of genetic variation within and between different lines	-Two White Leghorn lines, 3 commercial broiler lines, Rhode Island Red and 8 other breeds	DNA-FP's	Ponsuksili et al, 1996
-Genetic characterization of differrent chicken lines	-Ten lines of White Leghorn, 2 Fayoumi and one Spanish breed	DNA-FP's and RAPD	Plotsky et al, 1995
-Genetic variablity among layers and their correlation with performance	-Nine different lines bred from commercial strains imported from Romania and USA	DNA-FP's	Meng et al, 1996
-Relatedness and diversity in chicken and turkys	-Rhode Island Red, White Plymouth Rock, single comb White Leghorn, Araucoona and Turkeys	RAPD	Smith et al, 1996
-Estimation of relatedness in White Leghorn lines	-White Leghorn	RAPD	Deepak et al., 1998
-Estimation genetic distance	-Different chicken breeds from Africa, Asia and Latin America	Micro satellites	Wimmers et al, 2000
-Genetic characterisation	-Different native fowl populations from South Africa, Mozambique, Botswana and Zimbabwe	Micro satellites	Köster, 2001

However, in recent years there is a tendency towards microsatelite markers as the preferred markers in genetic studies of poultry and other mammalian species. A study result reported by Ponsuksili *et al.* (1996), using both mictosatellite and DNA-fingerprinting techniques in analysing the genetic distance of native breeds from Egypt, India, Indonesia, Thailand and Taiwan, a higher hetrozygosity among the lines was found using microsatellite markers, compared to the DNA-fingerprinting results. Meanwhile, microsatellite markers have been successfully applied in characterisation of waterfowl (Fields and Scribner, 1997), chicken

(Wimmers *et al.,* 2000; Köster, 2001) and are frequently used in studying genetic variability in other mammalian species such as sheep, pigs and cattle (Buchanan *et al.,* 1994; Van Zeveren *et al.,* 1995; MacHugh *et al.,* 1997). Microsatellite markers were also found to be accurate and reliable for characterisation of highly inbred lines (Zhou and Lamont, 1999). Different study results were reported using different numbers of microsatellite markers that ranges from 8 to 27. According to Takahashi *et al*. (1998), the study results on genetic relationships among Japanese native chicken breeds based on eight microsatellite markers were reliable and accurate.

6.3.2 Gene diversity (Hetrozygosity)

Estimation of genetic variation included gene diversity or heterozygosity and genetic distance using genetic markers such as microsatellites. Phylogenetic trees can be constructed from sequence data or microsatellite data to illustrate relationships among the populations studied (Nei, 1987; Weir, 1996). As it is described by Nei (1987), the average heterozgosity (H) over all loci in the genome takes into account the number of loci and number of individuals per locus. It is assumed that sampling was done from the loci and of the genes at each locus. For a single locus **h** can be estimated as follows:

$$\mathbf{h=2n(1-\Sigma x^2 i)/(2n-1)}$$

and for more than one locus:

$$\mathbf{H= -\Sigma\, h_k/r}$$

Where: h_k = the value of h for k_{th} locus

n = the number of individuals sampled

x^2 = the population frequency of the genotype at the locus

r = the number of loci studied

Intra-locus variance will be influenced by the number of individuals sampled at each locus and can be reduced by increasing the number of individuals, while the inter-locus variance can be reduced by increasing the number of loci studied (Nei, 1987). Nei (1987); Goldstein

and Pollock (1997) recommended for the estimation of genetic variance an increase in number of loci rather than the number of individuals.

6.3.3 Genetic distance

The concept of Genetic distance was first used by Sanghvi (1953) for evolutionary study. Genetic distance is a measure of the magnitude of genomic difference between populations or species. If two populations are isolated from each other for geographic or reproductive reasons, the two populations tend to accumulate different genes. Genetic distance is a function of allele frequencies and is used to explain genomic differences or similarities between two populations (Nei, 1987). Genetic distance is often used to estimate time of divergence in evolutionary studies. The distance between two populations could be zero, if no differences were observed; or it could be a maximum of 1, if there were no common alleles found at a common locus (Weir, 1996). Many measures of genetic distance have been proposed, but most of them are related to the fixation index (Wright, 1951) which is based on the allelic correlations in a population structures of diploid organisms but depending on the objectives of the study, different distance measures can be used. However, the distance measures proposed by Nei and Roychoudhury (1974) and Nei (1978) are the most common and widely used ones (Table 6).

Table 6 Some of the distance measures that can be applied in analysing molecular data

Distance measure	Equation*	Reference
Nei standard genetic distance D_s	$I=J_{XY}/\sqrt{J_X J_Y}$ $D_s = -1n\ [J_{XY}/\sqrt{J_X J_Y}]$	Nei (1987)
Nei minimum genetic distance D_m	$D_m = (J_X + J_Y)/2 - J_{XY}$	Takezaki and Nei (1996)
Roger's distance D_R	$D_R = \frac{1}{\gamma} \Sigma\sqrt{\frac{\Sigma^{mj} I(X_{ij}-y_y)^2}{2}}$	Takezaki and Nei (1996)

* I refers to the genetic identity and D to the genetic distance

7. Methods to study village chicken: on-farm, on-station and at DNA level

The utilisation of genetic variation through selection has led to improved crops and animals that have fed an ever-increasing human population. Maintaining this variation is crucial if we want to continue to improve our animals and respond to changes in climate, disease, and

consumer preferences. All species on earth represent a pool of genetic diversity that is of potential value in improvement programs. Consequently, the focus of characterisation, evaluation and conservation efforts in animal breeding should be expanded to encompass all biodiversity. Genetic diversity is lost through the extinction of populations, and through loss of variation within finite populations. Human induced extinction represents the greatest threat to genetic diversity. Genetic diversity needs to be preserved:

1. To allow response to improvement through selection and /or crossbreeding for desirable economic traits
2. To cope with changes in consumer preference
3. To cope with changes in production environment
4. To use as a sources of novel functions now and the future

A systematic identification and description of the chicken ecotypes in relation to their production environment and management systems should be considered as prerequisite for planning the rational use of the national chicken genetic resources followed by breed characterisation, sustainable utilisation and conservation (FAO, 1992). Bruns (1992) suggests a three level approaches in characterisation of animal genetic resources.

Macro level studies: on-farm surveys to describe the population structure and make a detailed physical description of the breed. *Meta levels studies:* for phenotypic characterisation of breeds, a more detailed on-farm performance monitoring is needed. This should be designed to allow performance (productive and adaptive traits) comparisons between breeds. *Micro level studies:* compressive on-station characterisation studies for the estimation of genetic parameters. However, the further development of molecular techniques has opened additional and new doors for phenotypic, genetic, genomic and gene level studies and it has become the additional and alternative answer for various genetic, breeding and physiological questions in farm animals. According to Peters (1988) and Bruns (1999), the assessment of indigenous genetic resources should have the following components in order to establish the required information for understanding the genetic resource and its sustainable use.

- the production system (current conditions and prospects)
- morphological and other phenotypic traits, performance evaluation, economic appraisal of traits and breeding objectives
- assessment of population parameter
- analysis of the genetic distance on the basis of molecular markers

7.1 On-farm characterisation

7.1.1 The importance of farmers participation

The development of innovative ideas for improving rural poultry production requires a complete understanding of the system and its operators. Furthermore, research directions and strategies should be geared to address farmers' real problems and constraints. This in turn requires careful and detailed analysis and understanding of farmers' circumstances and practices through participatory research and/or development activity. For example, the purpose for which a farmer keeps poultry determines his/her management practices. On the other hand, as summarised by Röling (1988), the development and transfer of appropriate technologies should be a function of the farmers' socio-economic and management practices at the field level. Hence, an important element in the sustainable development of a community is the active involvement of the community members in any development activity, which should start with their participation in identifying their problems and constraints, and in deciding on the best alternatives and most appropriate strategy to meet such needs.

Indigenous chicken ecotypes kept under smallholder conditions require a set of behaviour and reproductive traits to secure sustainable production. Under station conditions with different husbandry circumstances, these traits are difficult to assess or even suppressed, causing incomplete or even misleading information about the sustainable production ability under less intensive systems (Teketel, 1986). The continued importance of traditional or family poultry production with indigenous poultry stock is determining the need to consider the value of indigenous poultry ecotypes (Traoré, 1997). A stratified On-Farm analysis is required for appraising the needs and opportunities of the production system, for a realistic assessment of the economic value of traits, and thus for the definition of breeding objectives as part of the establishment of a breeding policy for small holder farmers (Langholz, 1994; Valle Zarate, 1995; Peters, 1998).

7.1.2 Participatory methodologies

The fact that rural poultry has a socio-cultural context (Kitalyi, 1998; Sonaiya, 1999) demands the examination of its characteristics in the context (no matter how preliminary) of socio-cultural circumstances rather than a solely biological study (Sonaiya et al, 1993) and with interactive data gathering and analysis tools. The soci-economic assessment of village chicken production systems are usually achieved through base line surveys using questionnaires, focus group discussions, participant observation, formal and informal interviews and other participatory methods that are usually used in social science research (Sonaiya, 2002). Participatory methodologies and their associated tools and techniques are proofed to be quite effective in communicating with the right section of the population (Sharland, 1989). Participatory methods lead to more relevant and realistic results in an attempt to understand the system. Different household members are affected by enterprise development in different ways. Participatory methods enable better identification of who is affected in which ways and the involvement of the very poor, women, children and vulnerable groups to be heard (Rietbergen-McCracken and Narayan, 1998), who often have a close link to poultry keeping. However, as Tadelle (1996), found from investigation studies of village chicken production systems in the highlands of Ethiopia, even though women manage birds and have considerably more knowledge about keeping poultry, their participation in village meetings and other data collection activities were rather restricted. The same author using participatory techniques suggested five key questions to answer before starting to work with a household. The suggested questions are: 1) Does the household keep birds at present and is there an interest in expanding production? 2) Who is responsible for the birds? 3) Do the innovations demand additional work? and if yes, who is to carry out this work? 4) Can technical information be delivered directly to the family member who looks after the birds? 5) Will the people who look after the birds benefit directly from an increase in production?

According to Rietbergen-McCracken and Narayan (1998), participatory methods have been used to learn about local-level conditions and local people's perspectives and their priorities during project appraisal. Nevertheless, one can go further, and use participatory methods not only at project formulation stage, but also throughout the duration of the project. The wide array of participatory methods also provide the researcher with the opportunity to take actual

measurements of production parameters (live weight, clutch sizes, egg numbers, egg weight, fertility, hatchability, survivability, etc) and non-production parameters (ownership, ethnoveterinary, uses and benefits of poultry and poultry products, traditional and religious roles, opportunities, constraints and problems associated to the production system) in the villages.

A once-off-diagnostic survey followed by a repeated survey could give more contact and understanding of the system and its operators. Subsequently, the information obtained during the repeated survey provides the basis for a quantitative characterisation of the poultry production system and the actual performance of chicken ecotypes included in the survey. In addition the obtained data will allow: a comparison between similar data from the once-of-diagnostic survey in order to estimate the accuracy and information reliability and subsequently a comparison of on-farm and on-station information on laying and growth performance within ecotypes. In the mean time in order to increase the number of birds in a study and the population dynamics of the flocks, Sonaiya (2002) proposed considering the whole village flock in a study as an important means to the validity of the tests instead of considering household flocks.

None of the participatory methods are substitutes for good quality survey work and a continuous data recording whenever required for quantifying performance traits. Indeed, they are often used in conjunction with other methods. Findings from a study using PRA technique will give useful directions and focus to subsequent appropriate methods. In turn, the subsequent method can verify and quantify the qualitative findings from participatory evaluations and be applied on a larger scale. The basis of sampling study population and number of households and/or birds included in the study remains speculative. Population to be sampled for characterisation should be selected based on a hypothesis built on the available knowledge from previous studies, evolution of production systems, agro-ecologies, significance of the existence of chicken production in the area and of market sheds that supply chicken and chicken products to a sub-regional market. The assumption is that markets allow to measure diverse functions of village poultry for assessing opportunities and perspectives of village poultry and to understand production and breeding practices in different market sheds which are believed to be the centres of genetic add-mixture. So far,

there is no appropriate experimental and statistical designs developed for on-farm study of local chicken production systems in the tropics. Viable mathematics and statistical models are required for flock performance estimation during cross-sectional and longitudinal studies (Sonaiya, 2002).

7.2 On-Station characterisation

Phenotypic traits, like coat color are not well correlated with productive traits and their genetic base (Smith, 1988), since they are based on a small number of loci and can be rather modified rapidly by artificial selection. Thus, they are not ideal measures of genetic similarities, differences or performance. The economically important quantitative traits require considerable recording efforts and are more important to be integrated in genetically based performance evaluation schemes.

Testing the production and productivity of indigenous chicken ecotypes/breeds under improved management with the objective of understanding their phenotypic potential is essential. Limited reports from On-station studies with local strains showed a remarkable increase in growth and egg production compered to production under farmers management conditions; e.g. Valle Zarate *et al.* (1988) reported an increase of 54%, 10% and 70% in egg production, egg weight and egg mass per bird per year in the *Dandarawi* breed from Egypt. Table 7 shows the performance levels of different local chicken ecotypes/strains from the tropics as reported or summarised by different authors in different management systems. The main objectives of those studies were ecotype typology, identification, and characterisation through measuring growth and laying performances.

Wherever evaluation schemes were implemented, it has been found that there are highly productive indigenous birds (Nwosu, 1979; Mathur *et al*., 1989). The task is to identify such breeds, determine genetic performance abilities, assess genetic variation within and between ecotypes and determine sustainable breeding strategies for the improvement of indigenous chicken populations. This was also supported by a growing concern for securing biodiversity and the potential value of indigenous poultry resources not only for current purposes but for future novel uses, too.

Table 7 Some of the indigenous chicken strains/ecotypes in the tropics and their production level on farm (F) and on station (S)

Country	Name of the breed /ecotype	Phenotypic Characteristics	Management type	Egg number/year	Matured Body wt. (kg)	Reference
Sudan	Large Balady	Different colour	F	40-50	1.5	Youssef (1993)
	Rakabany	Naked neck	F	50-60	1.5	
	Batol	Small in size	F	70-80	0.75	
Morocco	Balady	Different colour	F	60	1.5	Shawky (1993)
Tunisia	Balady	Different colour	F	80	----	
Tanzania	Local	Different colour	S	140	1-2	Mtamlo (1999)
Egypt	Fayoumi	Pincelled (W&B)	S	140	1.1	Saleh (1994)
	Dandrawi	Black & white	S	140	1	
	Fayoumi (PP line)	Pincelled (W&B)	S	260	----	Hossari et al (1992)
Indonesia	Kampung	------	S	104	1.15	Horst (1989)
Malaysia	Kampung	------	F	55	1.1	Horst (1989)
Nigeria	Local	------	F	50	---	Nwosu (1979)
	Local	------	S	128	---	Nwosu (1979)
	Local	-------	S (cage)	146		Omeje and Nwosu (1984)
Mali	Local	------	F	32	---	Wilson et al (1987)
Cameron	Local	------	S	150	1.2	Mafeni (1995)

Only limited research has been directed towards a performance comparison in conjunction with a structured breeding scheme which will allow the estimation of population parameters, the identification of performance levels and useable variability, and subsequently the assessment of selective breeding schemes as well as of combining ability and utilisation of heterosis. In India, Iyer (1950) conducted selection in local chicken strain called *Desi,* and reported an increase in annual egg production from 116 to 140 eggs per bird per year and egg weight from 43 to 49 grams after six generations. The other attempt was by Oluyemi (1979) in Nigeria reported considerable improvement in the 12 weeks body weight of local chicks by 297 grams after seven years of selection.

On-station tests of strains and ecotypes need also to focus on behavioural and reproductive traits (e.g. broodines) and auxillary traits which can easily be used to estimate production and productivity on-farm (e.g. shank length) and develop prediction equations. Including a well-

established and possible unrelated breed as a reference breed, which will give a very good chance to compere the on-station performance data and consecutive genetic analysis data.

7.3 Genetic characterization

Besides the evaluation of the performance traits, genetic charactrization using genetic markers has been recognised as a valuable tool to (1) characterise the genetic variability within and the genetic distance between local chicken populations, (2) to identify genetic resources (3) to give information for the use of heterosis in crossbreeding programs and (4) to preserve genetic diversity.

Animal populations differ in size and may change as they are continuously subjected to the forces of natural selection, migration, and mutation and directed selection. In livestock populations, kept for specific functions, selection plays a major role in population changes. Selection, migration and mutation may lead to non-random or directional changes in the allele frequencies of the population (Hartl, 1988). In the past, some efforts have been made to identify and characterise animal breeds using different measures of variation or relationships and evolution. Among which, to determine evolutionary trends, evolutionists have used fossil records, but there have not been enough records (Nei, 1987). Previously attempts were also made to characterise local chicken using morphological traits. Morphological traits have limited usefulness to study the genetic variation or the divergence between population since appearance is not necessarily a good guide to genetic variation. Members of a breed of animal may look outwardly similar but be quite different genetically. Conversely, breeds may look very different but be genetically closely related. Kidd and Sgaramella-Zonta (1972) suggested that, morphological classifications are difficult to relate quantitatively to average between genetic differences. Which is mainly because of the fact that morphological traits (such as plumage colour, comb type, etc.) are linked to a small number of loci and can be rather modified rapidly by artificial selection. Thus, they are not ideal measures of genetic similarities or differences. Blood groups, blood protein and proteins found in blood plasma, serum and milk have been largely used in detection of genetic differences in farm animals (Hines, 1999). The economically important traits are strongly influenced by environment so they are poorly situated for classification. Traits used for

classification purposes should be largely independent of the environment. Genetic distance is a more reliable measure of difference between breeds through examining the number and frequency of alleles. Classification based on genetic markers does provide a stable unbiased measurement of average similarities and differences.

Characterisation studies' were improved in the mid 1960's when molecular techniques were introduced in the study of evolution. More recently, biochemical polymorphisms were also applied in genetic characterization of most farm animals (Baker and Manwell, 1980; Arranz *et al.*, 1996). Further, the development of molecular biology techniques during the eighties has opened up new horizons for the study of genetics, breeding and physiological questions in farm animals.

8. Chicken production in Ethiopia

According to Alemu (1995), poultry production systems in Ethiopia show a clear distinction between traditional, low input systems and modern production systems using relatively advanced technology. There is also a third up coming "small scale" intensive system with small number of birds (from 50 to 500) as an urban and peri-urban household income source using exotic birds and relatively improved feeding, housing and health care (Alemu and Tadelle, 1997). More than ninety five percent of the poultry population consists of local breed types under individual farm household management (Alamargot, 1987).

Rural poultry production in Ethiopia represents a significant part of the national economy in general and the rural economy in particular and contributes about 90% and 92% of the national egg and poultry meat production, respectively. This is equivalent to an annual output of 72,300 metric tonnes of meat and 78,000 metric tonnes of eggs (ILCA, 1993). The low productivity of local birds coupled with the infancy of the commercial sector (only contribute less than 10% of the total poultry and poultry products) has resulted in a low supply of poultry meat and eggs to the nation. As a result, the per capita egg and chicken meat consumption is about 57 eggs and 2.5 chicken per annum, only. These figures are very low by international standards (Alemu, 1985). Although there is no current data on the present per capita consumption of eggs and poultry meat, similar or an even worse trend is anticipated

because the Ethiopian population has increased by 3% per annum over the last 20 years without marked increase in production of poultry meat and eggs. According to Tadelle *et al.* (2000), the major reasons for the low poultry productivity are a low standard of management and a low performance of the indigenous chicken.

8.1 Research and development efforts

Poultry development and research in Ethiopia started in the early 1950's with the establishment of higher learning agricultural institutes in Ethiopia. The activities of these institutions mainly focused on the introduction of exotic breeds into the country and the distribution of these genotypes to farmers with recommendation on appropriate feeding, housing, health care and other husbandry practices. This was expected to have a considerable positive influence for the expansion of large scale commercial farms in the country. However, after 40 years the contribution of exotic birds in terms of egg and meat production is less than 10%. A number of factors can be cited as causes for this low rate of adoption. First, one should recognise that poultry, particularly exotic birds, are food converters not food producers. The foodstuffs used to feed chicken are often of a quality that could be fed directly to humans. Thus, in grain deficient countries such as Ethiopia, adopting intensive poultry industry will be frustrated by the severe shortage of appropriate feed. Unless the grain production in the country is improved considerably, such a system cannot be economically sustainable and socially acceptable.

8.2 The rural poultry production systems

8.2.1 Description of the system

According to Alemu (1995) and Tadelle (1996) the village poultry production systems in Ethiopia is based on low input-output levels which represents a part of a balanced farming system, has a unique position in the rural household economy as supplier of high quality protein to the family food supply system, provides small cash income and plays a significant role in the religious and cultural life of the society A study reported by Tadelle (1996), showed that in Ethiopia the demand for poultry and poultry products is high, since other proteins of animal origin are beyond the reaches of the poor and consumption of pork is not allowed for religious reasons for most Ethiopians (Orthodox Christians (about 40 %) and

Muslims (about 40 %)). Moreover, poultry rearing is one of the most appropriate activity for rural women, for land less and marginalized farmers and it provides cash income, generates employment opportunities for the poor and at the same time increases the supply of high quality animal protein. Family poultry management is usually the responsibility of women in the household. Guèye (1998) has estimated that in rural areas of sub-Saharan Africa, probably more than 70% of chicken owners are women.

This system of production, although appearing primitive, can be economically efficient because even if the output from the individual birds is low the inputs are even lower or virtually non-existent. This low output of local birds is expressed as low egg production, small sized eggs, slow growth and low survivability of chicks (Smith, 1990; Tadelle, 1996). The feed resource base for rural poultry production is obtained by the birds scavenging in and around the house, and consists of household waste, anything edible found in the immediate environment and small amounts of grain supplements provided by the household women. As indicated by Cumming (1992), Tegene (1992), Tadelle (1996), and Tadelle and Ogle (2000), the scavenging feed resource base (SFRB) for village chickens is very variable and depends on the season and rainfall. The portion that comes as a grain supplement and from the environment varies with activities such as land preparation, sowing, harvesting, grain availability in the household, season of the year and the life cycles of insects and other invertebrates. The extremely high chick mortality (more than 60%) (Tadelle, 1996), unsuccessful brooding (because most of the broods died) and high rates of mortality caused by disease reduces the efficiency of the system. Past approaches of improving the genetic potential of local birds through distribution of cockerel, pullet and fertile eggs from birds of exotic origin have had negative effects because of: reduction of the brooding ability of hens, reduced adaptation of crossbred to the low input feeding system, and the long term adverse modification of the genetic base of indigenous chicken population. However, since most of these approaches were implemented over a short time span the lasting effect of these polices have been negligible.

8.2.2 Evaluation of local chicken

The local chicken in Ethiopia are entirely nondescript birds closely related to the jungle fowl *(Gallus gallus*) (AACMC, 1984) which show a great variation in their body size, plumage

colour and conformation. Their use is largely limited to home consumption and the generation of small cash income to the household. However, they have a great value in the cultural and religious life of rural communities. Very little scientific work has been done to characterise the local stock under either traditional or improved management conditions. The studies carried out to date have generally attempted to establish the performance potential of the indigenous birds under conditions of confinement, an environment to which the birds are not adapted. Furthermore, the studies lacked co-ordination, depth and continuity (Alemu and Tadelle, 1997).

Studies on the traditional poultry production system have indicated that farmers prefer to raise birds with different plumage colours for different purposes such as for egg production, meat production, healing ceremony and cultural purposes. For example traditional birds with light plumage colour are sought for egg production while birds with black and red plumage are selected for meat production (Tadelle, 1996). However, these preferences are not confirmed by results of performance testing. Furthermore, considerable morphological variation is observed between populations in the lowland (1500 m.a.s.l.) and highland (2800 m.a.s.l.) areas (Tadelle, 1996). The few attempts made to evaluate the egg and meat production potentials of different local strains of chickens will be discussed below:

Egg production: Research studies on some of the indigenous birds have shown that their potential for egg production is very low. A study at the College of Agriculture, *Alemaya*, has indicated that the average annual egg production of a native chicken was 40 eggs under farmers management, but under experimental conditions with an improved feeding, housing and health care conditions the level of production was elevated to 99 eggs per hen per year (Bigbee, 1965). In a study at *Soddo*, by the *Wolaita* Agricultural Development Unit (WADU) (Kidane, 1980), it was reported that the egg production of indigenous birds was reported to be 84 eggs /bird/year. According to the study by the Ministry of Agriculture (1980), average annual egg production of the native chicken is 30 to 40 eggs under village conditions and that this could be increased to 80 eggs when birds are provided with an improved feeding, housing and health care. A more recent study at the *Assela* Livestock Farm revealed that the average production of local birds in Arsi was 34 eggs/hen/year, with an average egg weight of 38 g under scavenging conditions (Brännäng and Pearson, 1990). These results are

extremely low when compared with production levels of egg type exotic birds which were observed to produce over 200 eggs/hen/year with an average egg weight of 60 grams. In an on station experiment in *Debre Zeit* Agricultural Research Centre White Leghorns were observed to produce over 236 eggs per hen per year at Debre Zeit, Ethiopia (DZARC, 1991).

In depth studies to determine variation in egg and meat production and productivity between different poultry ecotypes has not been undertaken in Ethiopia. A study in Southern Ethiopia, where birds were identified and characterised into different ecotypes based on their plumage colours and feather cover as Tikur (for black), Kei (for red), Gebsima (for greyish mixture), Netch (for white) and Melata (for naked neck) showed a considerable variation in egg production (Table, 8). Of the five ecotypes, the *Melata* ecotype was found to be superior. Although the average performance of the different ecotypes was about 69% of the hen-housed egg production of what was achieved by White Leghorn stock but the indigenous birds had the capacity of sustained egg production at times of increased environmental temperatures and also in the second year of laying (Teketel, 1986).

Table 8 Egg production (% hen day) and age at first egg (Days) by different local ecotypes and White Leghorn in two studies in Ethiopia

Ecotypes	% hen day	Age at first egg
Kei (red)	13.63	141
Tikur (black)	15.23	140
Kokima (Red brownish)	15.30	149
Wossera (Black and white)	14.89	149
Gebsima (greyish mixture)	4.99	147
Netch (white)	12.9	Na
Melata (nacked neck)	19.2	Na
White Leghorn	46.43	148

Source: Teketel (1986) and Abebe (1992)

A similar study at Alemaya University of Agriculture, showed that local chicken from eastern Ethiopia were able to produce 70 % of the hen-day and hen-housed egg production of what was achieved by White Leghorn stock (Abebe, 1992). This study also revealed a considerable variation in egg laying performance between different ecotypes (Table 8). In addition the different study results for different traits suggest that there is a considerable variation between local types (Table 9). However, generally the fertility rate of eggs from local stocks was found to be higher than that from White Leghorns (Teketel, 1986).

The average weight of eggs produced by local birds was found to be about 40g (AACMC, 1984; Abebe, 1992 and Tadelle, 1996), but 46 g was reported by Teketel (1986). Predictably, in view of their lower rate of production, local stocks produce eggs with thicker shells than White Leghorns (Abebe, 1992).

Meat production: Only few research results are available on the meat production abilities of local stocks. The AACMC (1984) reported that local males may reach 1.5 kg of live weight at 6 months of age and females about 30% less. Teketel (1986) also found that under station conditions local birds reach 61% and 85% of White Leghorn body weights at 6 months of age and at maturity, respectively. Abebe (1992) reported that local birds in Eastern Ethiopia attain 71.5% of weights of White Leghorn at 6 months of age. The mean carcass weight of local birds at 6 months of age was 559g and significantly lower than that of the 875g of White Leghorn (Teketel, 1986). However, the local stock had a higher dressing percentage than the White Leghorn. As it is indicated in Table 9 and 10, there were wide variations in meat production and other traits among the different ecotypes (Teketel, 1986 and Abebe, 1992).

Mortality and survival rate: Teketel (1986) and Abebe (1992) found higher moralities and morbidities among local stocks compared with White Leghorn birds when raised under intensive management in Awassa and Alemaya, respectively (Table 11). Similarly, Brännäng and Pearson (1990) observed a high mortality, among local birds when kept in confinement in the livestock farm at Assela.

The major reason for the high mortality rate of local birds could be due to the fact that they are not used to confinement. Diseases which are important under confinement, such as coccidiosis, may have a more serious effect in local stock than in exotic stock.

Table 9 On-station egg production and other performance potentials of five Ethiopian chicken ecotypes

Performance traits	*Tikur*	*Melata*	*Kei*	*Gebsima*	*Netch*
Age at 1st egg, days	173	204	166	230	217
Mature body weight, kg					
- Male	1.3	1.7	1.6	1.5	1.4
- Female	1.0	1.2	1.2	1.1	1.1
Feed intake, kg/ bird/ year	50.9	53.2	37.0	36.4	39.1
Egg/ bird/ Year	64	82	54	58	64
Egg weight, g	44	49	45	44	47
Egg mass, kg/ bird/ year	2.8	4.0	2.4	2.6	3.0
Egg shape index	75.4	69.3	70.7	Na	69.0
Shell thickness, mm	0.374	0.311	0.383	Na	0.317
Albumen, % egg	50	49	51	49	49
Yolk , % egg	36	38	38	36	36
Fertility, %	56	60	57	53	56
Hatchability, %	42.0	41.8	44.3	39.3	39.0

Na = Not available
Source : Mebratu (1997) as compiled from different sources

Table 10 Body weight development of different local ecotypes and White Leghorn in two study sites (Awassa and Alemaya) in Ethiopia.

Ecotype	Body weight (g)					
	Day old		8 Weeks of age		24 Weeks of age	
	Study sites					
	Alemaya	Awassa	Alemaya	Awassa	Alemaya	Awassa
Kei	27	32	237	209	1003	1360
Tikur	27	32	240	199	775	1350
Kokima	27	Na	256	Na	850	Na
Wossera	26	Na	225	Na	1013	Na
Gebsima	26	31	228	200	968	1300
Netch	Na	32	Na	223	Na	1420
Melata	Na	35	Na	242	Na	1480
White leghorn	32	43	333	294	1291	1620

Na = Not available
Source: Teketel (1986) and Abebe (1992)

Table 11 Mortality (%) at starter and grower age by different local ecotypes and White Leghorn in two studies in Ethiopia

Ecotypes	Starter		Grower	
	Alemaya	Awassa	Alemaya	Awassa
Kei	23	30	36	Na
Tikur	8	13	28	33
Kokima	27	Na	54	Na
Wossera	30	Na	31	Na
Gebsima	22	39	33	25
Netch	Na	18	na	Na
Melata	Na	13	na	40
White leghorn	16	17	33	7

Na = Not available
Source: Teketel (1986) and Abebe (1992)

8.2.3 Past attempts for genetic improvement

Distribution of exotic birds: The general conclusion that one can make from the above studies and observations is that the local birds grow slowly and lay few eggs and their survival ability under intensive type of management is low. "Upgrading" the blood level of local birds using exotic birds through distribution of cockerels to farmers was considered as the most important strategy to effect improvement by policy makers. The extension system of the Ministry of Agriculture has promoted schemes in which cockerels from selected strains (mainly White and brown Leghorns) are reared up to 15 to 20 weeks of age and then exchanged for local cockerels owned by rural subsistence farmers in order to "upgrade" the genetic potential of local birds (Tadelle *et al* 2000). In addition, exotic pullets and fertile eggs were distributed to individual farm households in rural Ethiopia. Even through the impact of this strategy has not been assessed carefully, the imperical evidence suggests that these approaches were met with a limited success due to high mortality rate of the exotic breeds.

The study result reported by Tadelle (1996), shows that there has been an introduction of exotic breeds to the three study villages of the central highlands of Ethiopia at various times and in different forms (cockerels, pullets, or fertile eggs) but their impact in upgrading the village chicken has been minimal. This is because the programs were usually planned without the participation of the farmer and parallel improvement in feeding, housing and health care. Usually the farmers were given advice on improved feeding and housing and were asked to remove all remaining local cockerels, but success has not been achieved.

From the population genetics point of view one may picture the village poultry population as a pool of genes under pressure from many directions. Disease, predators, lack of feed, poor housing and poor drinking water are the main pressures. Throw a few "high egg number" genes into the pool and what happens? The negative correlation with low broodiness in crossbreeds will reject them when they try to multiply and establish themselves. We should not assume village farmers not to understand that commercial poultry lay many eggs but make poor mothers. Farmers quickly realise: that these "foreign laying machines" can not look after themselves very well, but will produce many eggs if fed and cared for properly. Farmers are usually well aware of the risks involved in losing mothering and survival ability to gain more egg numbers. Thus, the concern about loss of local genetic material is fully justified.

Cross breeding: Evaluation of egg production performance of crossbreeds between local and exotic birds was conducted by different research and development organisations. A study at Debre Zeit Agricultural Research Centre compared birds with different level of inheritance (50 and 62.5% White Leghorn blood). The result showed that the overall performance including egg production of the crosses was better than either the native or exotic parents under the prevailing condition of production. The 50% and 62.5% Leghorn crosses produced 146 and 193 eggs per bird per year, respectively. The other crossbreeding study involving Yarkon as an exotic breed which was carried out at Assela (Brännäng and Pearson, 1990), in terms of egg production, F_1 crosses produced 129 eggs and were found to be better than 75% crosses which produced 114 eggs (Table, 12). In the same study it was observed that crossbred hens (50 and 75% exotic) had almost entirely lost their broodiness. Some started to brood but left the eggs a few days later which, lead to a loss in hatching ability in the flock and therefore it could result in the breakdown of the self-sustaining system of production at village level.

Local chicken have an irreplaceable characteristic that cannot be found in any "exotic" breed of chicken and they are appropriate for the traditional low input-output system because they make the best use of locally available resources, hatch their own eggs, brood chicks and posses some degree of tolerance for common poultry diseases, which are important features

since farmers have no means to buy and use incubators, electric brooders and expensive concentrate feeds. Past approaches of improving the genetic potential of local birds through distribution of cockerel, pullet and fertile egg from birds of exotic origin has changed the composition of traits and reduced vital behavioural traits of the reproduction complex.

Table 12 Productivity of two exotic breeds and their crosses with local hens at Assela; Ethiopia

Parameter	WL	Y	L	Crosses	
				Y*L (50%)	Y*L (75%)
Wt.(kg) at 5 months.	1.05	1.20	.71	Na	Na
Mature wt.(kg)-hens	1.4	1.5	1.2	1.4	1.5
Mature wt.(kg)-Cocks	1.7	2.5	1.5	Na	Na
Egg prod./hen/year	167	160	32	129	114
Average egg wt.(g)	58	61	39	48	53
Egg prod.(kg/hen/year)	9.6	9.8	1.2	6.1	6.0
Mortality, Chicks (%)	12	53	93	Na	Na
Mortality, mature (%)	11	14	34	Na	Na

Y= Yarkon; WL= White Leghorn ; L= local; Na = Not available
Source: Brännänng and Pearson (1990)

8.2.3 Scavenging Feed Resource Base (SFRB)

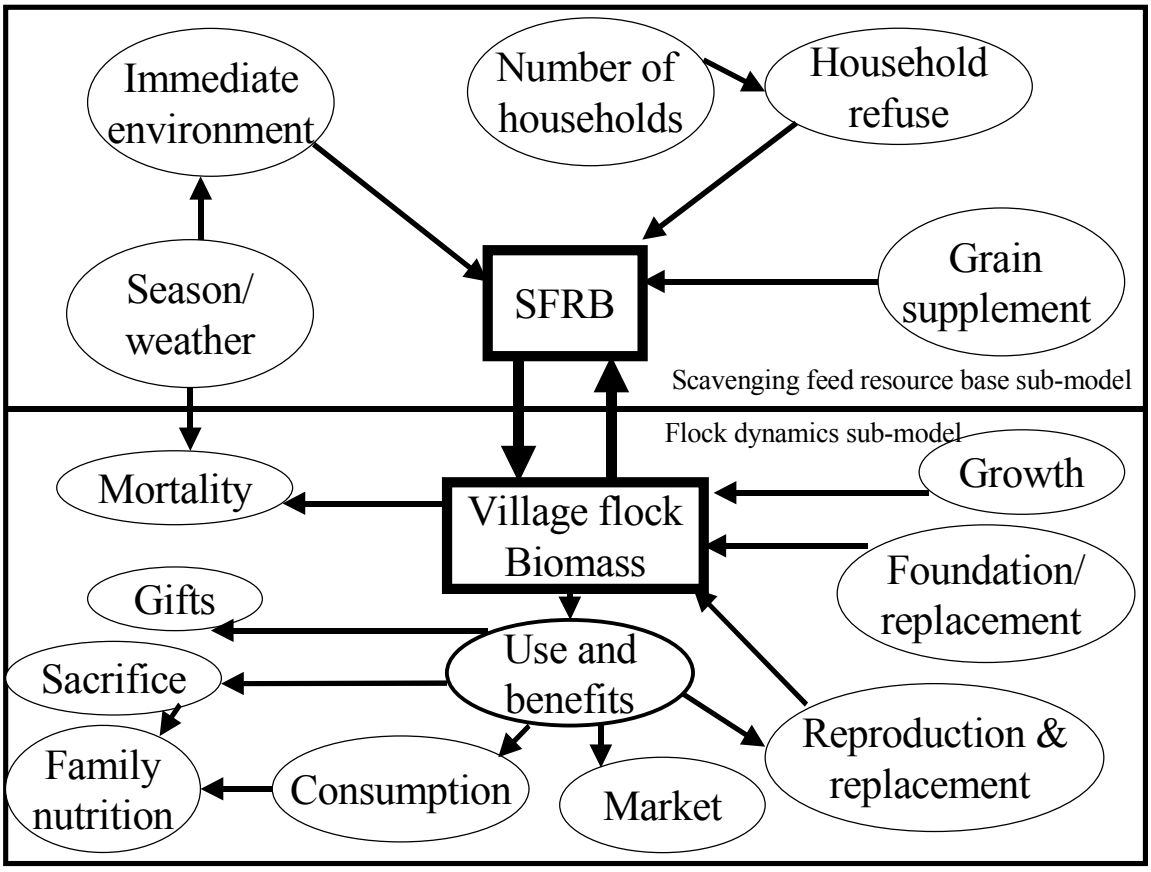
8.2.3.1 Quantification of SFRB

As in most other Sub-Saharan African countries (Sonaiya, 1998), the largest proportion of the feed of village chickens in Ethiopia is based on free range Scavenging Feed Resources (SFR) constituting of materials from the surrounding environment, by-products from harvesting and processing of grains and cultivated and wild vegetation, which are frequently supplemented by household wastes (Fig.1) (Tadelle and Ogle, 2001). The food leftover portion of the SFRB is more or less constant throughout the year but the portion from the environment and the grain supplement are varied with seasonal conditions and with activities such as cultivation and harvesting.

As described by Roberts (1992), who suggested determining the capacity of the SFRB in relation to the village flock bio-mass. A village flock bio-mass is above the carrying capacity of the SFRB will increase mortality and morbidity of chicks. Above all the quality and quantity of the feed resource is seasonal in nature and according to Savory (1989) and

Cumming (1992) the diet of scavenging poultry is usually adequate in protein but deficient in energy. This is especially true in Ethiopia in the rainy season due to the abundance of large numbers of invertebrates, but protein supply may be critical during the dry season. However, after the end of the short rainy season in April-May the amount of available grain decreases, so the birds then have to rely on scavenging only, even though farmers agree that scavenging alone does not provide enough food. The absence of this supplement in the diet of the birds in the rainy season results in a dramatic decline in the production of eggs, due primarily to a lack of energy (Tadelle and Ogle, 2001).

Fig. 1 A pictorial model of the scavenging village chicken production system in the central highlands of Ethiopia



Source: Tadelle and Ogle (2001)

The amount of feed available for scavenging in relation to the carrying capacity of the land areas and flock dynamics across the different seasons and agro-ecologies is still not adequately quantified. However, studies on the physical quantities of nutrient supply conducted in three villages of the highlands with different altitudes and in three seasons revealed that the materials present in the crop, as visually observed, were, seeds, plant materials, worms, insects and unidentified materials (Tables 13 and 14) (Tadelle and Ogle, 2000). According to the same report, during the short rainy season (March to May) the percentage of seeds in the crop contents is higher at all the three study sites, probably because of the increased availability of cereal grains which had just been harvested and are given to the birds in larger amounts than during the other two seasons of the year. Another factor is the relative amount of available plant material is lower during the short rainy season.

The mean percentage of plant materials in the crop contents is highest during the rainy season (June to September) as a result of the increased availability of plant materials generally in this season, and in particular the abundance of green shoots which are palatable to the birds and the relative scarcity of seeds during this season might have increased intake of plant materials. The largest proportions of worms in the crop content were found during the rainy season in all three-study villages, and during the dry season (October to February) in higher altitude village, which might be attributed to the relatively high and extended rainfall in the area.

Table 13 Effect of season on crop contents of scavenging local hens (physical observations)

		Physical components (% fresh basis)				
Season	N	Seeds	Plants	Worms	Insects	Other
Short rainy	90	37.5	22.5	2.6	14.6	22.7
Rainy	90	25.8	31.8	11.2	7.7	23.4
Dry	90	29.5	27.7	6.2	11.1	25.6
Means	270	30.9	23.3	6.7	11.1	23.9
± SE		±7.9	±6.0	±4.5	±4.5	±4.6

N = Numbers of birds slaughtered for crop analysis
Source: Tadelle and Ogle (2000)

A larger proportion of insects was also found during the short rainy season in the three study villages and also relatively higher numbers of insects was found during the rainy season in the high and middle altitude villages, which is expected, as the populations of many insect species decrease in the dry season.

Table 14 Effect of altitude on crop contents of scavenging local hens (physical observations)

		Physical components (% fresh basis)				
Altitude	N	Seeds	Plants	Worms	Insects	Other
High (90) (2780 m.a.s.l)	90	33.2	28.2	9.0	8.8	20.8
Medium (1850 m.a.s.l)	90	32.0	27.9	5.9	11.5	22.7
Low (1550 m.a.s.l)	90	27.7	25.8	5.1	13.1	28.3
Means (270)	270	31.0	27.4	6.8	11.2	23.6
±SE		±3.6	±0.8	±2.2	±2.3	±3.4

N = Numbers of birds slaughtered for crop analysis
Source: Tadelle and Ogle (2000)

According to Tadelle and Ogle (2000) the protein and energy content of the SFRB as determined from chemical analyses of crop contents of scavenging local hens, were on average 8.8% and 2864 kcal/kg, respectively (Table, 15). The protein contents fall even lower during the short rainy and dry seasons, while energy supply is more critical in the drier months (Tegene, 1995; Tadelle and Ogle, 2000).

These values were below the protein requirement of free ranging local hens of the tropics, estimated at about 11g/ bird /day, and ME supply could meet the requirement of a non-laying hen only (Scott *et al*., 1982), indicating limitations of the SFR in terms of nutrient supply to increased productivity. The results of the above study is in agreement with the conclusions of Cumming (1992) and Gunaratne *et al.* (1992), who describes the feed resources for village chickens as being very variable, and depending on the season, agricultural activities and

rainfall; Tegene (1992) reported that SFRB available to local chickens is critically deficient in CP, Ca and P.

Table 15 Chemical composition of the crop contents of scavenging hens, overall means, SD and range from three of the seasons and study sites (N=270).

	Chemical composition (%)	
	Mean ±SD	Range
Dry matter (DM)	50.7 ±12.5	26.4-85.8
As % of dry matter		
Crude protein (CP)	8.8 ± 2.3	4.3-15.4
Crude fibre (CF)	10.2 ± 1.6	6.5-14.
Ether extract (EE)	1.9 ± 0.9	0.3-4.7
Ash	7.8 ± 2.7	1.6-15.7
Calcium (Ca)	0.9± 0.4	0.2-1.9
Phosphorus (P)	0.6± 0.3	0.1-2.4
Energy (ME)		
(Kcal/kg calculated)	2864.3 ±247	2245.1-3528.1

N = Numbers of birds slaughtered for crop analysis
Source: Tadelle and Ogle (2000)

8.2.3.2 Improvement of feed and feeding

Assuming that chemical analysis of crop contents accurately reflects the feeds consumed, the nutritional status of laying village hens in the highlands of Ethiopia would satisfy maintenance needs only and production of about 40 eggs/hen per year (Tadelle and Ogle, 2000). According to Tadelle (1996) it was possible to attain a hen-day production of about 30% from local chickens by supplementing a combination of 15g maize and 15g Noug (*Guizotia abyssinica*) cake/bird/day in the short rainy and dry seasons. Supplementing 30g maize alone resulted in 28% production while about 20% production was attained with supplementation of 30g Noug Seed Cake/ bird/day during this period. On the other hand, non-supplemented local birds under a similar environment produced about 14% from scavenging only. Under these conditions, supplementation of 30g/head/day of a mixture of equal proportions of maize and Noug cake increased annual egg production of local hens by about 100%. Even more remarkable success was attained with higher levels of supplementation using improved breeds. In villages around the south-western part of the

country, scavenging White Leghorn layers offered 90g/hen/day of a commercial layer ration produced 200 eggs/hen/year (Solomon, 1997) indicating a tremendous potential for improvement in the village systems. However, supplementary feeding of Local and Rhode Island Red chicken was uneconomical during the main rainy season implying that the scavenging feed resource available during this season would be sufficient to support economical egg production (Negussie, 1999). The above significant improvements were achieved, mainly because of the fact that in addition to provision of extra supplemental feeds to scavenging flocks, vaccination against Newcastle disease, regular provision of water and small night enclosure were part of the package.

Although the traditional system is still believed to make effective use of locally available resources, research results indicate considerable opportunities for improvement (Solomon, 1992, Tadelle, 1996, Negussie, 1999 and Tadelle and Ogle, 2000). The country has diverse agro-climatic conditions favoring production of many different kinds of crops, providing a wide range of ingredients and alternative feed stuffs suitable for poultry feeding. Making use of these resources to complement the scavenging resource base promises a considerable potential for success.

In general, what has been accomplished so far in Ethiopia, is not tangible enough to show the relative effects of genetic and non-genetic factors on the performance of the local stocks and to design appropriate breeding and performance improvement strategies. The improvement of domestic animals to meet human needs is dependent on genetic variation: both variation within breeds and the variation between breeds. Studies demonstrated the existence of such variation which, could be exploited by planning appropriate breeding strategies

Furthermore, the diversity in agro-climatic conditions and criteria imposed by man in different regions and production environments in Ethiopia and the type of poultry found may be one reason to assume genetic diversity. Testing this diversity through measuring the genetic distance and evaluating the production and productivity of the different ecotypes is justifiable. Studies conducted so far are exploratory and dealt with the appraisal of the poultry population only in the study area without considering the different agro-ecological zones and corresponding market sheds.

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CHAPTER III

On-farm investigation of poultry systems and poultry ecotypes in Ethiopia

This chapter is based on papers:

1. Tadelle D, Million T, Alemu Y and Peters, K.J. 2003. Village chicken production systems in Ethiopia: 1. Flock characteristics and performance. *Livestock Research for Rural Development Vol. 15 (1)* . pp 65-74
2. Tadelle D, Million T, Alemu Y and Peters, K.J. 2003. Village chicken production systems in Ethiopia: 2. Use patterns and performance valuation and chicken products and socio-economic functions of chicken. *Livestock Research for Rural Development 15 (1) 2003*. pp 75-83

1. Introduction

Population growth, urbanisation and rising income in many parts of the developing world caused a growing demand for food of animal origin. The per capita consumption of meat was more than doubled in the developing world from 1967 to 1997, with even more spectacular increased in the consumption of poultry (Delgado *et al.,* 1999). Nevertheless, a typical person in developing world still consumes on average only a third as much meat as a typical person in the developed world. Poultry meat and egg production accounts for more than 28% of the total animal protein produced worldwide in 1997. The proportional contribution of poultry by the year 2020 is believed to increase to 40%, the major increase being in the developing world (Delgado *et al.*, 1999), and quantity for animal feed will increase to 26% of the cereal demanded by developing countries in 2020. Reflecting the demand for an increased cereal production, particularly maize for animal feed rather than for direct human consumption. Trends in poultry production and demand are highest in Asian countries and lowest in Sub-Saharan Africa, due to the lowest overall economic development in the region (Delgardo *et al.,* 1999). Sub-Saharan Africa is the only region in which both number and proportion of malnourished children have been constantly rising in the past years and expected to rise, rather than fall, over the next 20 years. According to Rosegrant *et al*. (2001) one-third of all children in sub-Saharan Africa continue to have their mental and physical development compromised by the ravages of malnutrition.

Poultry production in tropical countries is based on the traditional scavenging system and characterised by low-output per bird. However, according to Kiytali (1998), over 70 percent of the poultry products and 20 percent of animal protein intake in most African countries come from this sector. There are various advantages, which make poultry attractive in the context of poverty alleviation and quality protein supply in Sub-Saharan Africa (Sonaiya, 1990; Kiytali, 1998). Therefore improvement of the village poultry production would result in a positive impact on poverty alleviation, household food security and in income generation. However, a new research and development thrust, which combine technical improvements and socio-economic aspects, is required to achieve this endeavour-poverty alleviation, food security and income generation. In order to address those challenges it is necessary to understand farmers' circumstances, production practices, constraints to and opportunities for improvement of village chicken production systems. Thus, the objectives of this study were

1 To asses functions and importance of chicken production systems in different agro-ecological regions in Ethiopia
2 To valuate performance and other traits under village production conditions of low input-output levels
3 To understand production objectives and selection criteria of farm households
4 To identify and analyse constraints of and opportunities for sustainable improvement of chicken production under smallholder systems in the divers agro-ecological regions of the country

2. Materials and methods

2.1. Descriptions of the study eco-regions

This study was conducted in five different agro-ecological regions of Ethiopia (Fig. 1) namely, *Tilili, Horro, Chefe, Jarso* and *Tepi* regions, with the principal agro-meteorological characteristics as shown in Table 1. The description of each region based on the description of Agro-ecological Zones of Ethiopia is as follows:

Tilili is located in the northwestern part of the country and is part of a moist and sub-humid agro-ecological zone, receiving about 1460-mm rainfall per year. The agricultural system is characterized as a high potential cereal based crop-livestock mixed farming system with *Tef*, millet, maize and *Noug* being the major crops, and cattle, sheep, goat, chicken, donkey, horse and mule being the major animals.

Horro is located in the Western part of the country near the blue Nile gorge, in a sub-humid agro-ecological zone, receiving about 1141 mm rainfall per year. The agricultural practice in the area is crop-livestock mixed agriculture, maize, *tef* and pulses as the main crops, and cattle, sheep, goat, chicken, donkey, horse and mule being the major animals in the area.

Chefe is located in the central highlands of Ethiopia and is sub-moist agro-ecological zone with an average rainfall per year of 878 mm. The agricultural system is characterized as a high

potential cereal based crop-livestock mixed farming system with *tef,* wheat and pulses as the main crops, and cattle, sheep, chicken, donkey and horse being the major animals.

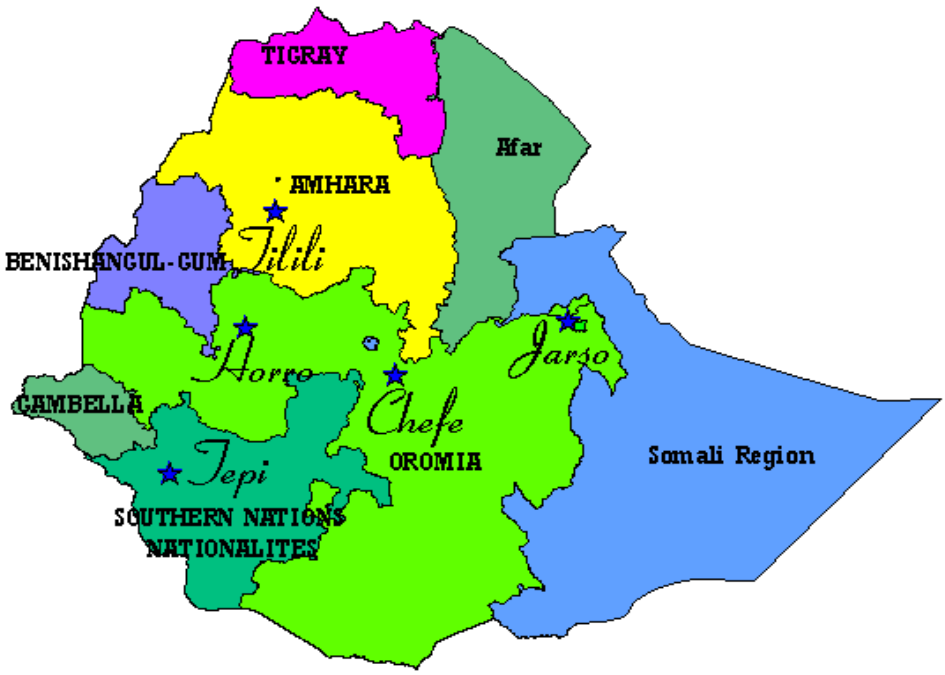
Jarso is located in the Eastern parts of the country receiving the lowest annual average rainfall (696 mm) and has the smallest average land holding per household (0.8 ha) relative to the other four study regions. Agricultural production in the area comprises highly integrated crop-livestock production with coffee, vegetables and *chat* being the major cash crops. Sorghum, maize, groundnut, tubers are the main crops cultivated, and cattle, goat camel and donkey are animals kept in the area.

Tepi is located in the southwestern part of the country as part of a Sub-humid and humid agro-ecological zone. The agricultural production is characterized as horticulture-livestock mixed system. This region is less populated and has high potential for large-scale coffee, tee, fruit and livestock farms and characterized as the high-potential horticulture/livestock zone. Sorghum, maize *enset* and tubers being the major crops, and cattle, sheep, goat, chicken and donkey being the major animals.

2.2. Selection of study sites

In this study two market sheds per region and one village per market shed with a total of 250 households were involved. The selection of market sheds was made on the basis of information from previous studies (AACMC, 1984; Teketel, 1986 and Tadelle and Ogle, 1996) regarding the importance of sub-regional poultry markets and in consultation with experts from Regional Agricultural bureauxs. A total of 10 market sheds each of which supply chicken and chicken products to a sub-regional market and urban centre, were selected. The assumption is that markets allow to measure diverse functions of village poultry for assessing opportunities and perspectives of village poultry and to understand production and breeding practices. Villages were selected and considered for the present study on the bass of the relevance of chicken production in the village economy, of no prior improvement programs (distribution of exotic birds) undertaken, and of villagers being willing to participate in the study. Villages from each market shed were also selected in consultation with agricultural experts in sub regional bureauxs.

Fig. 1 Map of Ethiopia showing five of the agro-ecological regions and corresponding market sheds where this study was conducted



2.3 Data collection

The essential of any agro-sociological survey is to gather basic first hand information with regard to farmers' circumstances and production practices. To this end, topical Participatory Rural Appraisal (PRA) methods relevant to rural poultry production and structured questionnaire were used. Three weeks before the actual exercise was started the necessary contacts were made with village officials, elders and community leaders through village development agent. In this contact the outsiders explained the objectives and the scope of the study, and the methods to be used in the data collection process. Based on the understanding and agreements made with village leaders in the first meeting, a village meeting was called to start the workshop with the villagers. After a brief introduction about the aims and structure of workshop, the community agreed to work with the group with full involvement.

Table 1 Location, agro-meteorological characteristics, constraints and potentials of the five study sites based on the description of Agro-ecological Zones of Ethiopia (1998)

Characteristics	Study areas				
	Tilili	Horro	Chefe	Jarso	Tepi
Altitude(m.a.s.l.)	2180	2320	2400	1856	1200
Latitude	11.17	9.32	8.44	9.19	7.05
Longitude	36.55	37.23	39.02	42.07	35.15
Rainfall (mm)	1460	1141	878	696	1555
Average land holdings (ha)	1.15	1.4	1.8	0.82	2.6
Major Agro-Ecological Zone	M/SH	SH	SM	A/M	SH/H
Farming system/ Livestock spp	Mixed, Cattle, sheep, goat, donkey, mule and horse	Mixed, cattle, sheep, goat, donkey, mule and horse	Mixed, Cattle, sheep, goat and donkey	Mixed, cattle, goat, sheep, donkey, camel	Mixed, Cattle, sheep, goat, and donkey
Major crops	Tef, millet, maize, Noug	Maize, sorghum, tef, pulses,	Tef, wheat, pulses	Maize, sorghum, tubers, coffee, vegetables and chat	Maize, sorghum, tubers, coffee, chat, enset and fruits
Major constraints	Degradation of soil, deforestation	Termite shallow soil depth, vertsol	Erosion and deforestation	Population density, moisture stress	Tography and landslide
Potentials	Highly potential for annual crops and livestock	High potential for cop and livestock	Rain-fed agriculture	Crop, livestock	High potential for small and large scale farming of coffee, fruits and livestock

The first activity was to choose five key informants from different age and social groups. The outsiders and key informants with the help of other villagers adopted a checklist developed by the ANRPD (1995) (appendix 1) to follow in the data collection process. In the following three days, information was gathered from individual farmers, extension officers, key informants and village

groups. The exercises were aimed at assessing the perspectives of the poultry production system, its function and importance in the socio-economic lives of the community. In addition information on the organisation, ownership, flock characteristics, flock performance, use pattern of poultry products, and production management and other related issues of poultry production (e.g. relationship between poultry keeping and wealth status of each household) were gathered. Problems prevailing in chicken production in each of the study villages, and opportunities for improving poultry production were assessed and attempts were made to closely examine other socio-economic aspects such as cultural roles of poultry production in the respective study areas.

Based on the proposition made and agreed by group members, a transect walk was made involving 10 households in each of the 10 study villages. In-depth visits in and around the residential quarters of the villages were then made in order to obtain first hand observation on all aspects of poultry production in individual households. The other objective was to involve women in the households in the data accusation process since their participation in the village meetings and other data collection activities were rather restricted. Based on the assumption that each women farmer has an idea on the performance of her animals, a recall survey was conducted to establish specific hen performance history in relation to production and productivity. In addition, the sources of present breeding females (as replacement) and foundation stock in the household and use patterns of poultry products were assessed.

At the end of the exercise in each village, the group presented the summary of the findings to the community in a second village meeting and after lengthy discussions and many corrections the community finally agreed with the conclusions. Finally, the PRA exercise was followed by a structured questionnaire survey (appendix 2).

2.4 Statistical analysis

The qualitative data sets were analysed employing the Statistical Package for Social Sciences (SPSS 10.0, 1996). Quantitative data from the study were subjected to the analysis of variances (ANOVA) procedure using the general liner model (GLM) procedure in SAS version 6.12 (SAS, 1996). Analysis of variance was used to identify sources of variance for flock composition by age and sex, number of breeding females, egg laying performance of pullets in their first, second,

third and further clutches, use patterns of chicken and chicken products per household between study regions and corresponding market sheds. The Duncan Multiple Range Test (Duncan, 1955) was used to locate sub factor means that were significantly different. Pearson's correlation analysis (Steel and Torrie, 1980) was made to depict the influence of wealth status on flock characteristics, performance indicators, use patterns of chicken and chicken products, and income from chicken farming.

Main model used was:

$Y_{ijkl} = \mu + r_i + m_j + rm_k + e_{ijkl}$

Where:

Y_{ijkl} : Individual observation

μ : The population mean

r_i :The discrete agro-ecology effect (1….5)

m_j : The discrete market shed effect (1…10)

rm_k : Interaction of the effects of agro-ecology and market shed

e_{ijkl} : Residual random error

3. Results

3.1 Socio-economic characteristics

Socio-economic characteristics of the average household in the study areas are shown in Table 2. The typical family has 6.7 members. On average, about 4.2 members per household were found to be illiterate while the others had different levels of schooling. Few households have family members engaged in off-farm activities such as weaving, civil service and trading activities. The average age of household heads was 40.5 years. Females head about 20% of the households, with the highest (64%) in *Jarso* and lowest proportion in *Tilili* (2%) market sheds. Farm households reported an overall mean of thirteen years of experience in chicken keeping.

3.2 Description of birds

Indigenous chickens are the predominant poultry species in the study villages. Rural farm households do not keep other domesticated birds (such as turkey, guinea fowl, ducks or geese).

Table 2 Some socio-economic characteristics in 250 households of the five Agro-ecological regions in Ethiopia (mean /household ± SD and %) (2000/2001).

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Parameters	Study locations					
	Tilili	Horro	Chefe	Jarso	Tepi	Grand mean
Age of the head	42.2±12.4	39.1±12.4	41.5±11.9	35.8±9.2	44.5±14	40.5±12.4
Family size	6.6±2.2	7.2±3.1	5.9±2.34	6.4±2.2	7.4±3.7	6.7±2.7
Sex of the HH head (%)						
-Male	98	82	90	36	94	80
-Female	2	18	10	64	6	20
Experience in keeping chicken (yrs)	16.7±9.6	11.2±9.9	16.0±9.9	8.6±6.9	14.0±8.9	13.4±9.5

Birds are non-descriptive, surviving on irregular supplies of feed and water, and with no health care, and are part of a "balanced" farming system. Indigenous birds in all study areas differed widely in plumage colour, comb type, down colour, feather cover and morphometrical variables. In two of the market sheds from the *Tepi* region, more than 50% of all chicken were found to be of the Naked Neck type, while the normal feathered chicken were dominant in all other study areas. Farmers, in *Tepi* region preferred to keep naked neck chicken for egg production. However, they are considered not to be good mothers and fetch a lower price in the market as a meat bird and thus their number is decreasing in the past years. Birds in *Tilili* and *Chefe* market sheds were taller and heavier compared to birds from the other three regions. Birds from *Tepi* region were predominantly vertical in their body positions while birds in *Tilili, Horro* and C*hefe* areas had a predominantly horizontal body position, and chicken from *Jarso* exhibited an intermediate body position. These distinctive differences in body positions were particularly manifested in male chickens. The plumage colour of birds in *Tilili* and *Tepi* market sheds were predominately red with black down colour or black, respectively, but the other ecotypes showed considerable heterogeneity.

3.3 Flock characteristics

3.3.1 Flock composition

The least squares means and overall mean flock composition by age and sex are presented in Table 3. There was a significant difference ($p<0.001$) on the number of chicken owned per household between the study regions. 9.8, 7.7, 6.9, 6.6 and 5.8 matured chicken were, respectively, recorded in households from *Tilili*, *Jarso, Horro, Chefe* and *Tepi* agro-ecological regions. There was a highly significant ($p<0.001$) difference in the number of birds owned per household between *Kubito* and *Berhan* market sheds in the *Tepi* region. This variation may be attributable to the fact that households in *Berhan* market shed, who are new settlers coming from the northern parts of the country, have experience in chicken farming. Conversely, those from *Kubito* market sheds are local people and only have a recent history of sedentary farming.

The mean numbers of breeding females per households were 5.4±0.2. The number of breeding females varied significantly ($p<0.001$) among the different regions and market sheds within each region. The highest (8.2±0.5) and lowest (3.0±0.5) numbers of breeding females were recorded in *Tilili* (*Absela market shed)* and *Tepi* (*Kubeto* market shed) regions, respectively.

Table 3 Least Squares Means (LSM±SE) of flock composition by age and sex in ten market sheds of the five Agro-ecological regions in Ethiopia (2000/2001)

Regions		Age and sex category				
	Market sheds	Mature chicken (n)	Hen/pullets (n)	Cocks (n)	Male: female (n)	Chicks (n)
Tilili	Absela	10.3±0.67^{a} (25)	8.2±0.5^{a} (25)	2.0±0.28^{ab} (25)	1:4.1 (25)	9.1±1.1^{a} (25)
	Ageza	9.3±0.67^{ab} (25)	7.2±0.5^{a} (25)	1.9±0.28^{b} (25)	1:3.8 (25)	9.5±1.1^{a} (25)
Horro	Achame	7.4±0.67^{bc} (25)	5.6±0.5^{b} (25)	2.5±0.30^{ab} (23)	1:2.2 (23)	8.5±1.2^{ab} (23)
	Aleku	6.4±0.67^{cd} (25)	4.9±0.6^{b} (24)	2.2±0.35^{ab} (25)	1:2.2 (25)	8.1±1.3^{ac} (17)
Chefe	Kersa	7.0±0.67^{c} (25)	4.6±0.6^{b} (25)	1.7±0.32^{b} (24)	1:2.7 (24)	9.4±1.2^{a} (21)
	Koka	6.2±0.67^{cd} (25)	5.3±0.6^{b} (25)	2.0±0.33^{ab} (22)	1:2.7 (22)	10.1±1.3^{a} (22)
Jarso	Diro	7.5±0.67^{bc} (25)	5.4±0.5^{b} (25)	2.2±0.29^{ab} (25)	1:2.5 (25)	10.1±1.1^{a} (25)
	Fedise	7.9±0.67^{bc} (25)	5.1±0.5^{b} (25)	2.8±0.29^{a} (25)	1:1.82 (25)	9.6±1.1^{a} (25)
Tepi	Kubito	4.8±0.67^{d} (25)	3.0±0.5^{c} (25)	1.8±0.29^{b} (25)	1:1.8 (25)	5.0±1.1^{c} (25)
	Berhan	7.0±0.67^{c} (25)	4.3±0.5^{bc} (25)	2.6±0.29^{a} (25)	1:1.65 (25)	5.8±1.1^{bc} (25)
Significance		***	***	NS		*
Over all mean		7.4±0.22 (250)	5.4±0.17 (249)	2.2±0.09 (244)	1:2.5 (244)	8.5±0.37 (235)

Figures in bracket represent number of households from which the means were derived.
^{abcd} Means within a column followed by different superscripts show the presence of significant differences,
Significance *= P<0.05; **= P<0.001, NS= non-significant;

The overall male to female ratio of village flocks was 1:2.5. The number of male birds in each household was more than required for breeding purposes. During group discussions and transect

walks, it was disclosed and observed that families tend to keep additional male birds. Having more male birds than required for breeding is a result of a preference for special colours and other features for cultural purposes and for sale in the forthcoming religious and traditional holidays to take advantage of the highest premium market price during such occasions. In all the studied regions, households also kept birds (both sex) for purposes other than for reproduction, sale, and consumption, in particular for their socio-religious functions. According to farm households, the flock number and composition varies with season and agricultural activities. Families tend to reduce the flock number during peak seasons of agricultural activities.

3.3.2 Sources of breeding animals

Sources of foundation and present breeding females in households of the five study regions in Ethiopia are presented in Table 4. Purchase only, and hatching and purchase were the main sources of birds for foundation and replacement stocks, respectively. The villagers bought breeding animals mostly from their acquaintances, or from markets with no recent history of disease outbreaks in the area. Gifts of chicken from relatives may at times serve as getting a foundation stock. The latter is particularly true for newly married couples or new settlers.

Table 4 Proportions (%) of households by sources of foundation and replacement stock (based on present breeding females) in five study regions in Ethiopia (2000/2001)

Study regions	Sources of foundation stock			Source of present breeding females		
	Purchase	Gift	Custody	Hatching only	Purchase only	Hatching and purchase
Tilili (20)*	60	30	10	15	---	85
Horro (20)	75	25	---	40	15	45
Chefe (20)	60	30	10	30	---	70
Jarso (20)	95	5	---	30	---	70
Tepi (20)	65	35	---	30	15	55

*= Figures in bracket represents number of households from which means were derived

Very few households obtained foundation stock in custody arrangements on sharing of outputs. There was a significant ($p<0.001$) difference in the source of breeding females as replacement stock among the study regions and sources. About 70% of breeding females in the studied households originated from hatching at home and the remaining 30% were purchased (Table 5).

3.4 Production and productivity

3.4.1 Flock performance

Least squares means (LSM) of hen performance history in the two market sheds from each of the five study regions are given in Table 5 and 6. There was no difference between regions and corresponding market sheds on sexual maturity of breeding females and the mean age at start of laying was 6.8 months. A highly significant difference ($p<0.001$) in egg laying performance of hens in their first, second, third and further clutches was observed between study regions and corresponding market sheds. The overall mean egg-laying performances of pullets for the 1st, 2nd and ≥3rd clutches were 17.0, 20.9 and 24.8 eggs, respectively (Table 6). Hen performance history revealed that the overall mean egg number/clutch/bird, mean clutch number/bird/year and mean egg number/bird/year were 17.7±0.25, 2.6±0.06 and 46.4±0.86, respectively. It was noted that productivity of birds was related to the agricultural calendar and age of pullets.

Group discussions held with farmers showed that higher egg production are always expected at the time of land preparation, sowing, and during and after harvesting. In addition, it was understood that pullets produce more number of eggs in their first year of production than in the subsequent year(s).

Table 5. Flock performance in five Agro-ecological regions of Ethiopia (2000/2001) (Least Squares Means ± standard error of means (LSM±SE))

Performance parameters	Study regions					SE	Sig.	Overall Mean
	Tilili	Horro	Chefe	Jarso	Tepi			
Age at start of laying (months)	6.9	6.7	6.8	6.8	6.9	0.13	NS	6.8±0.0
Mean egg no./bird/year-with hatching	47.1	44.4	45.8	47.3	46.3	1.9	NS	46.4±0.84
Mean egg no./bird/year-with out hatching (n)	72±1.7 (19)	75.6±1.8 (16)	73.1±1.8 (16)	76±2.4 (9)	75±1.8 (16)	---	NS	74.6±0.86 (76)
Clutch number to set eggs	2.2	2.0	2.3	2.1	2.0	1.9	NS	2.1±0.0
No. of eggs set for hatching	14.7[a]	13.2[b]	14.5[a]	12.8[b]	12.3[b]	0.44	***	13.5±0.19
No. of chicks hatched /set eggs	9.5	9.0	9.8	9.1	8.9	0.48	NS	9.3±0.21
Hatcheblity (%)	64.6	68.2	67.6	71.1	72.4		NS	68.8±10.6
No. of chicks survived at 8 wks	5.0	4.3	5.2	5.2	4.4	0.36	NS	4.8±0.16
Survival rate (%)	52.6	47.8	53.1	57.1	49.4		NS	51.4
Number of breeding females in the house hold (100)- Hatched at home	5.6 [a]	2.9 [b]	4.1 [ab]	4.0 [bc]	2.5 [c]	0.56	***	3.8±0.25
Number of breeding females in the household (100)- Purchased	2.5 [a]	1.4 [b]	1.2 [b]	1.6 [ab]	1.5 [b]	0.34	*	1.6±0.15

*Means were derived from 50 households per region unless it is indicated in bracket., [abc] Means within a row followed by different superscripts show the presence of significant differences, Significance level *=P<0.05; ***= P<0.001; NS= non-significant;

3.4.2 Egg storage, incubation and Chick survival

Storage time of eggs varies according to the intended uses (hatching and sale). The scenario in the five study regions in Ethiopia is presented in Table 7. 46% of the women in the households reported that eggs for hatching were stored until the time when the hen gets broody and ready to incubate. 35% of households reported setting three weeks old eggs for incubation. On the other hand, 49% and 46% of the farm households reported the storage duration of eggs for sale to be two weeks or until cash is needed at home, respectively.

Eggs were stored inside grains and other containers. Storage inside Tef *(Eragrostis tef)* grain was accepted and is believed to increase the shelf life of eggs and make it suitable for hatching, sale or consumption.

The least squares means for the preferred clutch number to set eggs, number of eggs set for incubation, number hatched and number of chicks survived reported in the different study regions are given in Table 5. The results revealed that there is no significantly ($p>0.05$) appreciable effect of the study region and corresponding market shed on preferred clutch number of pullets to set eggs, number of eggs per set for hatching, number of chicks hatched per set eggs and number of chicks survived at eight weeks of age. The overall preferred mean clutch number of pullets to set eggs were >2.1±0.05 (Table 5). The mean number of eggs set per bird was 13.5±0.19. The hatching rate was 68.8±10.6% ranging from 30-90% (n=250). There exists a positive and highly significant ($p<0.01$) correlation ($r = 0.75$), between hatching rate and the number of eggs set. Clay pots, bamboo baskets, cartons or even simply a shallow depression in the ground were common materials and practices used for egg setting. Crop residues, usually *tef,* wheat and barley straws were used as bedding materials. According to farm households, the number of eggs set per bird depends, in their orders of importance, on season, experience and size of the bird.

3.4.3 Measures to improve laying performance of hens

According to farm households in all the studied market sheds, all birds get broody between clutches. Normally, once a bird becomes broody and is not used for hatching eggs, she will remain broody for 3-4 weeks. Traditionally, households in all the study areas attempts to increase egg production by stimulating broody birds to resume egg laying. One or more of the three different "ways" were used to stimulate the bird to resume egg laying. 1/ pierce the nostrils with a feather to prevent sitting, 2/ physically move the bird to a nearby house for a couple of days, 3/ hang the bird upside down for a

limited period of time each day for about 3-4 days. The basis for these practices is to disturb the broody bird and to cause a hormonal shift and then it will start to lay eggs again within 8-10 days. Because of this human interference, the number of clutches and eggs produced /year /bird were increased. However, if the hen hatches eggs it will stay with its broods for up to eight weeks. Some farmers, however, set eggs under two birds at the same time, and after hatching give all the chicks to one of the hens. The one without chicks was then subjected to a special (either of the above indicated three treatments) treatment to stimulate the onset of egg production. The mean number of eggs produced /bird /year with and without hatching in different market sheds is presented in Table 5 and Fig. 2. Regular stimulation of birds to resume egg laying is reported to increase egg production by 62%.

Fig. 2 Hen performance history and results due to measures taken by households to improve laying performance of hens

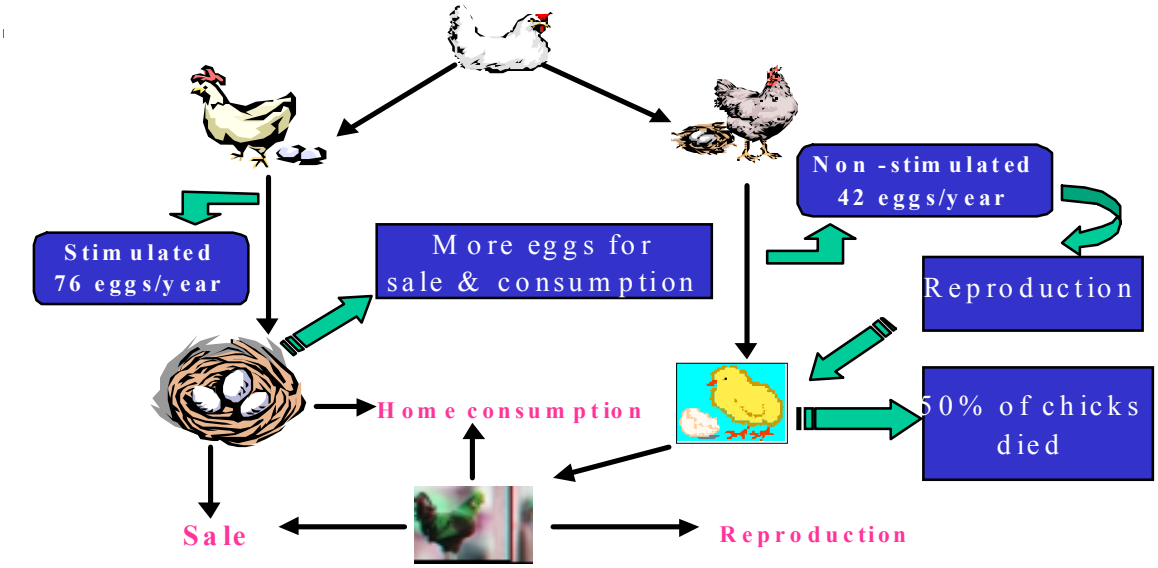


Table 6 Hen performance history established from recall survey with women in the household in ten market sheds of the five Agro-ecological regions in Ethiopia (2000/2001) (Least Squares Means (LSM±SE)).

Parameters	Study regions/ market sheds										±SE	Sig.	Overall mean
	Tilili		Horro		Chefe		Jarso		Tepi				
	Absela	Ageza	Achame	Aleku	Kersa	Koka	Diro	Fedise	Kubeto	Berhan			
Laying performance of pullets in different clutches													
1st	19.6[a]	20.0[a]	16.8[b]	16.5[b]	17.2[b]	17.4[b]	15.8[b]	15.4[b]	15.5[b]	16.6[b]	0.81	***	17.0±0.26
2nd	23.3[ab]	24.1[a]	20.7[c]	19.4[c]	21.2[bc]	21.1[bc]	19.9[c]	19.4[c]	19.5[c]	20.5[c]	0.83	***	20.9±0.27
≥3rd	27.1[ab]	28.0[a]	24.7[c]	23.4[c]	25.3[bc]	25.1[bc]	23.8[c]	23.5[c]	23.6[c]	24.5[c]	0.82	***	24.8±0.26
Mean egg no. per clutch/bird #	18.5[ab]	19.7[a]	17.4[bc]	16.4[bc]	17.9[ac]	17.8[ac]	17.5[ac]	17.1[bc]	16.2[c]	18.2[ac]	0.80	*	17.7±0.25
Mean clutch number/year	2.9[a]	3.0[a]	2.8[a]	2.8[a]	2.8[a]	3.1[a]	2.0[b]	2.1[b]	2.9[a]	1.7[b]	0.18	**	2.6±0.06

*Means were derived from 10 households per market shed, # = Flock mean egg number,
[abcd] Means within a row followed by different superscripts show the presence of significant differences, Significance level *=P<0.05;
** =P<01; ***= P<0.001; NS= non-significant;

Table 7 Storage ages of eggs used for hatching and sale in ten market sheds of the five study regions in Ethiopia as percent of respondents (2000/2001)

Parameters	Study regions/ market sheds										Overall mean
	Tilili		Horro		Chefe		Jarso		Tepi		
	Absela	Ageza	Achame	Aleku	Kersa	Koka	Diro	Fedise	Kubeto	Berhan	
Age of an egg for hatching (10)*											
-Two weeks	30	40	10	50	30	20	---	---	---	10	19
-Three weeks	50	40	20	---	30	20	40	60	50	40	35
-When the hen is ready	20	20	70	50	40	60	60	40	50	50	46
Age of an egg foe sale (10)											
-One weeks	10	10	---	---	10	---	10	---	---	10	5
-Two weeks	30	20	60	50	60	60	40	70	60	40	49
-When cash is needed	60	70	40	50	30	40	50	30	40	50	46

*= Figures in bracket represents number of households from which means were derived

From group discussions held with farmers, it is understood that setting eggs immediately before the onset of the rainy season is not recommended because of the high risk of spoilage of eggs, expected disease outbreaks and destructive effects that the chicks may bring about on seasonal crops cultivated in the backyard. Hens were often identified to incubate eggs based on past performances of their mothering ability and age. Normally, farmers set eggs six months before an important holiday to take advantage of the high prices for meat birds during such occasions.

Chick mortality rate was found to be generally high. The overall mean mortality rate before the chicks reached two months of age after hatching was 49%. Positive and highly significant ($p<0.01$) correlation ($r = 0.64$) was evident showing an increase in survival rate with larger number of chicks hatched per incubation (Table 8).

3. 5 Use pattern of chicken and chicken products

The least square means of use patterns of chicken and chicken products in the five study regions are given in Table 9. The analysis of variance showed the presence of a statistically significant ($p<0.001$) difference in use patterns of chicken and chicken products between the different study regions in Ethiopia. However, no significant effect of market sheds within each region was depicted. In order of importance, eggs were used for hatching, sale and home consumption while chicks produced were used for replacement, sale and home consumption. Unlike the other four regions which followed the above trend, in *Tepi* region eggs produced were used for hatching, home consumption and sale while chicks produced were used for consumption, sale and replacement in decreasing orders of importance, respectively. About 50, 27 and 23% of the eggs produced were reported to be used for hatching, sale and home consumption, and 44, 31 and 25% of birds were used for sale, replacement, and home consumption, respectively. Farmers from *Tepi* region reported the lowest sale and the highest home consumption of chicken and chicken products. Highest proportions of eggs were sold in *Jarso* and *Chefe* regions, whereas the highest number of chicken sold were reported in the *Tilili region*. A significant ($p<0.05$) and negative correlation ($r = -0.22$) was evident between proportion of consumption and sale of eggs, showing a decrease in proportion of eggs consumed at home with an increase in proportion of eggs sold by households, respectively (Table 8).

Table 8 Correlation coefficients between flock characteristics, performance indicators and use patterns of village chicken production in Ethiopia (2000/2001)

HH	Proportion of eggs consumed	Proportion of eggs sold	Proportion of eggs set	Number of eggs incubated	Number of chicks hatched	Number of chicks survived	Number of chicken cons.	Number of chicken sold	Wealth status of
Proportion of eggs sold	-0.22 [b]								
Proportion of eggs hatched	-0.58 [b]	-0.67 [a]							
Number of eggs/set	-0.05 [NS]	-0.03 [NS]	0.06 [NS]						
Number of chicks hatched	-0.15 [NS]	-0.13 [NS]	0.24 [a]	0.75 [a]					
Number of chicks survive	-0.27 [a]	-0.05 [NS]	0.25 [a]	0.51 [a]	0.64a				
Number of chicken consumed	0.26 [b]	-0.07 [NS]	-0.16 [NS]	0.14 [NS]	0.04 [NS]	-0.13 [NS]			
Number of chicken sold	-0.29 [a]	0.22 [b]	0.03 [NS]	0.12 [NS]	0.17 [NS]	0.35 [a]	-0.17 [NS]		
Wealth status of the HH	0.37 [a]	-020 [b]	-0.12 [NS]	0.01 [NS]	-0.08 [NS]	-0.25 [b]	0.34 [a]	-0.14 [NS]	
Income from chicken farming	-0.25 [b]	0.07 [NS]	0.13 [NS]	0.04 [Ns]	0.03 [NS]	0.22 [b]	-0.45 [a]	0.27 [a]	-0.48 [a]

Significance level a = P<0.01; b = P<0.05; NS = P>0.05; HH= household

Table 9 Use pattern of eggs and chicken produced in the households of the five study regions of Ethiopia (2000/2001) (Least Squares Means (LSM±SE))

Study regions	Use patterns					
	Eggs (%)			Chicken (number)		
	Sales	Consumption	Hatching	Sales	Consumption	Replacement
Tilili	26.5[ab]	17.1[c]	56.7[a]	7.3[a]	2.5[b]	5.6[a]
Horro	24.7[ab]	21.4[bc]	54.2[a]	4.8[c]	3.0[b]	2.9[bc]
Chefe	30.1[a]	17.5[c]	52.7[a]	6.1[b]	2.5[b]	4.1[ab]
Jarso	30.7[a]	24.2[b]	44.9[b]	5.9[bc]	2.9[b]	4.0[ab]
Tepi	21.5[b]	37.7[a]	39.9[b]	3.5[d]	4.5[a]	2.5[c]
SE	2.5	2.2	2.9	0.41	0.21	0.57
Sig.	*	**	**	**	***	**
Overall mean	26.6±1.3	23.3±0.9	50.1±1.3	5.5±0.18	3.1±.09	3.8±0.25

Means were derived from 50 households per region,
[abcd] Means within a column followed by different superscripts show the presence of significant differences; Significance level *=P<0.05; ** =P<01; ***= P<0.001

The plumage colour, sex, comb type, feather cover and age of the bird used were very important for socio-religious functions of birds, as was the commitment of an individual or the household to a particular spiritual being or a cosmic force, season and traditional and/or religious festival. Farm households from the study areas mentioned the socio-cultural role of birds and corresponding financial benefits as an important source of cash income from sales of birds. During group discussions, farmers mentioned colour, comb type and feather cover of birds as important selection criteria since very high market values are attached to these characters during socio-religious festivals. Specific colours, comb types and down feather colours with corresponding sex and age are high in demand for particular traditional and religious festivals and fetch higher prices as compared to birds with the same colour, comb type and down feather colour during normal market days. The means and ranges of market prices of live chicken and eggs in ordinary market days and eves of four festival markets in *Debre Zeit* town (located in central Ethiopia) are presented in Table 10. The mean relative increase of prices during festival markets were 89, 75, 74 and 47% for mature male, mature female, growers and eggs, respectively. In some cases, live birds were also kept at home for spiritual uses and never intended for consumption.

Table 10 Mean and ranges of market prices of live chicken and eggs in ordinary market days and market days on eves of four festivals in *Debre Zeit*, Ethiopia (2000/2001)

	Price of birds (by age and sex) and eggs (Birr*/unit)			
Market time	Mature male	Mature female	Growers	Eggs
Ordinary weekly market days	11.9±2.7 (7-20)** (125)***	8.0±1.9 (5-18) (125)	5.4±1.2 (3.5-10) (108)	0.31±0.04 (0.25-0.40) (129)****
Market days of eves of festivals				
-Eth. New year (Sep., 12)	21.5±4.3 (12.5-30) (105)	13.4±3.2 (9-25) (102)	9.0±1.9 (5-15) (73)	0.45±0.06 (0.29-0.50) (102)
-*Meskel* (Sep. 30)	22.3±4.0 (15-30) (32)	13.7±3.0 (10-20) (32)	9.3±2.0 (7-16) (20)	0.46±0.05 (0.33-0.50) (31)
-X-mass	21.4±3.9 (13-30) (58)	13.7±3.6 (6-25) (58)	9.1±2.4 (5-15) (42)	0.45±0.06 (0.29-0.50) (57)
-Easter	24.7±3.8 (12.5-33) (125)	15.3±4.3 (8-32.5) (123)	10.2±3.0 (5-18) (87)	0.46±0.07 (0.29-0.66) (122)
Mean percentage increase of prices in festival markets (%)	88.9	75.3	74.1	46.8

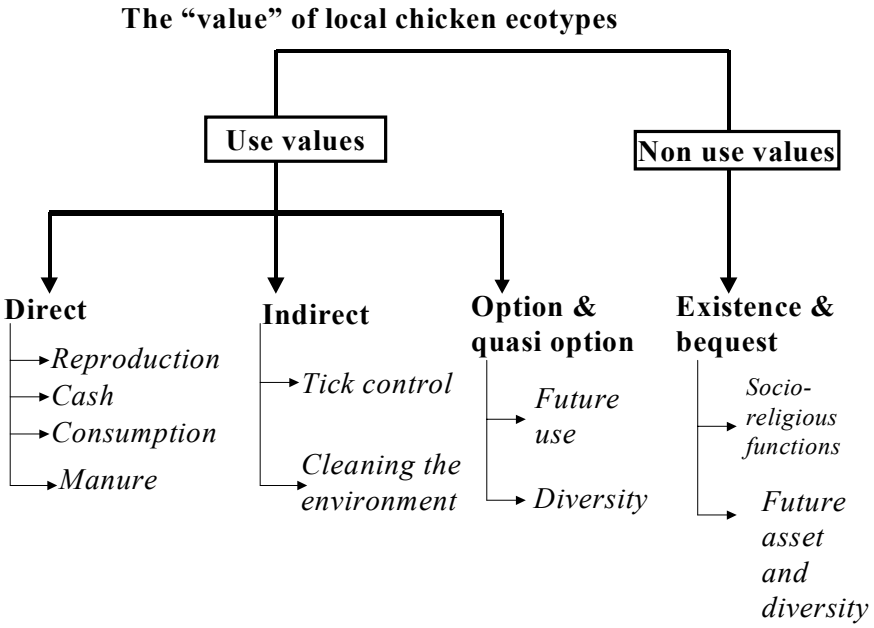
* 8.50 Birr is equivalent to 1 USD; ** Ranges; ***= Figures in bracket represents number of birds from which means were derived
****= Figures in bracket represents number of sellers from which means were derived

In case of hens, they are allowed to lay eggs, which were not consumed, but sold in the market and the money used to buy non consumable items. Apart from these beliefs, traditional *"healers"* prescribed a sacrifice or keeping a live bird at home for example, to ensure a safe journey, to cure a

sick person in the family, etc. Sacrificed animals are usually consumed, but some members of the family, often women, refuse to eat the meat. Birds of exotic origin and naked necks were not accepted for sacrifice. Households (except from *Jarso* market sheds) reported to invite special guests to partake of the popular dish *" doro wat"*, which contains both chicken meat and eggs and is considered to be one of the most exclusive national dishes in the country.

The additional use and benefits of local chicken comprises the role played by the flock in cleaning the environment and livestock tick and other external parasite controls. In-group discussions with farmers from three of the study regions (*Tepi, Tilili* and *Horro*), rearing of chicken was recognised to substantially reduce tick population both on the host and the ground. This in effect means that the role of chicken in the control of ticks contributes to combat against the direct (e.g. damage to skin and hides) and indirect (eg. disease transmission) deleterious effects; and economic losses due to ticks in rural farming conditions are unequivocally considerable. The option and quasi option use values are the diversity and their future use. For a better understanding of the role of chicken in the life of the society it is necessary to know exactly the purposes for which the households keep chicken. The main values of keeping chicken from farmers and researchers perspective are summarised in Fig 3.

Fig. 3 Use and non use values of indigenous chicken ecotypes in Ethiopia



***Direct**: Directly consumed, traded or used as input to commercial activity*
***Indirect:** Values, which has social or public dimension*

***Option and quasi-option**: Serves as an option to uncertainty in the future*
***Existence and bequest**: Diversity for their pure existence and possibility of maintaining for future generation and linked to socio-cultural functions of animals*

3. 6 Marketing of chicken and chicken products

Live birds and eggs were usually sold in local markets, to civil servants in the village, in large towns and occasionally to middlemen or traders (Fig. 4). Traders usually come to buy chickens and eggs in village markets and/or from village producers and/or from intermediaries and resell them in markets of big towns and cities of the market shed or outside the market shed. In *Tilili, Horro* and *Chefe* regions, most of the middlemen were students from the same and/or the surrounding villages. According to households, more males than females were sold from household flocks.

The estimated distance of the marketplace from the villages varies from 1-7 km with an average of 2.8km. According to farm households, the largest off-take rates from the flock occurred particularly during holidays and festivals, and during the onset of disease outbreaks. The latter is a measure to prevent or minimise expected financial losses from high morbidity and mortality. In such circumstances prices fall dramatically since supply is higher than demand and all the birds brought to a market should be sold at any price. This is mainly exercised as part of a precautionary measure to prevent introduction of disease(s) from markets to flocks at farm site.

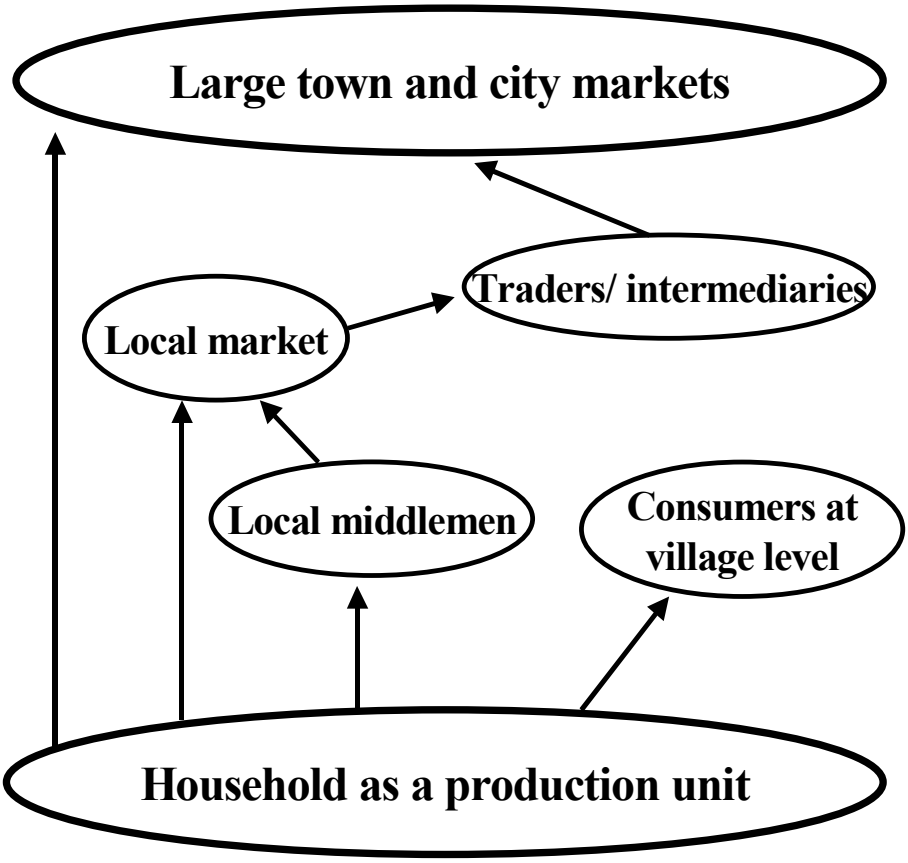
Farmers also sell birds and eggs in order to meet their cash requirement for small household expenditures. Despite the importance of this sector in the country, the marketing system is quite informal and poorly developed. The price of chicken largely depends on body weight and sex in addition to colour and comb types. However, there is generally no weighing machine or scale available in poultry markets and in villages.

3.7 Socio-economic aspects of keeping chicken

The present study revealed that women have considerable more knowledge about poultry and poultry production than their men counterparts. In all the 10 study villages poultry flocks are mainly managed by women (Table 11) and the money generated from sales used within the household. There was no statistically discernible ($p>0.05$) variation between wealth status and number of birds owned by households. However, it was learned that households with different wealth status have different

motives for keeping poultry. On the one hand, wealthier families keep birds as a sideline activity and much of the products were used for home consumption with only smaller proportions used for sale or hatching.

Fig. 4 Marketing channels of chicken and egg in Ethiopia



On the other hand, poorer households keep birds for income generation through sales, and devote more time and effort to their management. These assertions were further confirmed by the significant ($p<0.01$) and negative correlation ($r = -0.48$) between wealth status and cash income from chicken farming. About 30.8, 23.2, 29.6 and 16.4% of the households were, respectively, earning a cash income of >300, 200-300, 100-200 and less than 100 Ethiopian Birr (1 USD=8.3 Ethiopian Birr) per year from sales of live chicken and eggs (Table 12).

Table 11 Responsibilities of household members in managing birds and product sale in five of the study regions in Ethiopia as percent of respondents

Parameters	Study regions					
	Tilili	Horro	Chefe	Jarso	Tepi	Overall mean
Management responsiblites						
-Mother	65	70	60	70	75	68
-Childeren	25	25	15	30	5	20
-All members of family	10	5	25	0	20	12
Responsiblities for maketing						
-Mother	5	5	25	100	20	31
-Childeren	0	0	5	0	20	5
-Any member of family	95	85	70	0	60	64

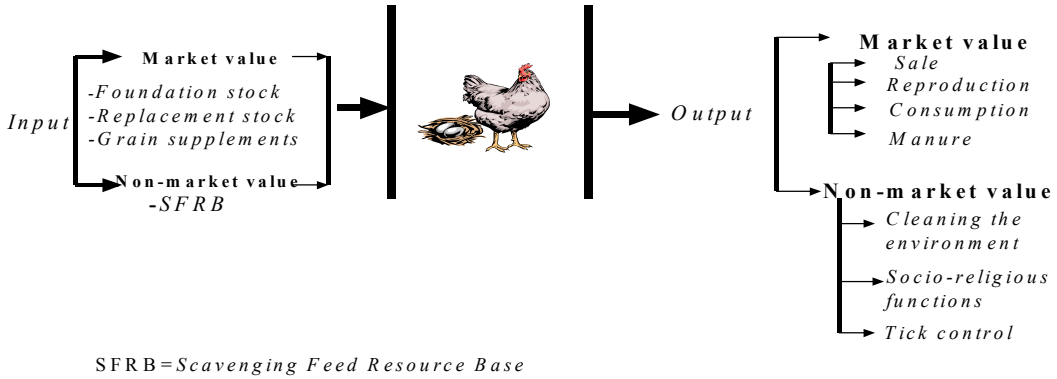
Table 12 Mean percentage of households by wealth status and annual cash income from chicken farming in 250 households from five Agro-ecological regions in Ethiopia

Income from sales (Birr)	**Wealth status of the household**		
	Rich	**Medium**	**Poor**
Tilili			
<100	30	43	12
100-200	10	17	24
200-300	20	17	29
>300	40	61	35
Horro			
<100	67	31	33
100-200	22	39	40
200-300	11	19	13
>300	-	12	13
Chefe			
<100	20	-	19
100-200	-	21	25
200-300	60	24	63
>300	20	55	50
Jarso			
<100	25	23	7
100-200	50	48	47
200-300	25	26	33
>300	-	3	13
Tepi			
<100	25	3	-
100-200	50	28	8
200-300	25	35	17
>300	-	35	77
Overall mean			
<100	16		
100-200	30		
200-300	23		
>300	31		
The criteria used in determining the wealth status of households as rich, medium and poor was considering the heads of cattle,land, number of coffee trees, the quality and number of Chat (Catha edulis) trees, income from off-farm activities etc owned by the household and based on the information from the key informants about the household. A household in the rich category in one location might be medium in the other location.			

3.8 Input-output relationships

Birds are owned by individual households and maintained under a scavenging system, with little or no inputs for housing, feeding or health care. The only expenditure is related to the costs of foundation and/or replacement stocks and a hand full of grain supplements (Fig. 5), which can be considered as market value inputs of the production system. The major non-market value input in all the study areas was the Scavenging Feed Resource (SFR), as the main sources of feed constituting of materials from the surrounding environment, by products from harvesting and processing of grains and cultivated, wild vegetation and invertebrates which are frequently supplemented by household wastes.

Fig. 5 Input-output relationship in village chicken production systems in Ethiopia



SFRB=*Scavenging Feed Resource Base*

Market value inputs are inputs which are either bought or sold or which have a value in terms of opportunity costs, labour, land and means of production
Market vale outputs are goods and by products sold and/or consumed in the farm households.
Non-market value inputs and outputs are free goods from the farmers' point of view

The outputs with market values from the prevailing production system in the study areas were chicken and chicken products to farm households. The major non-market value outputs are socio-religious functions of birds, the role-played as cleaner of the pre-domesticated environment and livestock tick control.

3.9 Selection criteria and production goal and objectives of households

The production objectives for keeping chicken were for income generation and consumption in their orders of importance and reproduction, sale and consumption were the main uses of poultry and poultry products by the households from all the study regions in their orders of importance. Productivity, size of the eggs, conformation of the mother bird, broodiness (ability to sit and remain sitting over long periods) and alertness were reported to be used as selection criteria by farm households n addition to the colour, comb type and feather cover for social and religious functions. Criteria used for culling birds (for consumption or sale) were low productivity of birds, old age and sickness if not required for any other socio-cultural purpose at home (Table 13). About 83% of the farm household, culled birds in order to avoid an expected disease.

Table 13 Purposes and factors considered by the households in using birds in the five study agro-ecologies in Ethiopia.

	Study locations					
Purposes/factors	Tilili	Horro	Chefe	Jarso	Tepi	Grand mean
Purpose of culling (%)						
Sale	63.9	48.4	63.2	68.6	45.4	57.1
Consumption	36.1	51.6	36.8	31.4	54.6	42.9
Factor determine culling (%)						
Productivity	34.5	42.2	31.1	33.8	26.8	33.4
Old age	33.6	24.4	32.6	37.8	30.9	31.9
After sickness	31.9	33.3	36.2	28.4	42.3	34.8
Culling to avoid expected disease (%)	94.9	63.3	96.0	60.7	85.1	83.0
Productive ages of breeding females (years)	2.9±0.8	3.8±1.8	3.5±0.9	4.1±1.7	5.0±1.6	3.9±0.8

3.10 Financial valuation of performance traits

Mean values of reproductive performance of breeding females of local chicken ecotypes under farmers management in Ethiopia over a period of one year is presented in Table 14. The economic analysis was based on the performance of breeding females from all the study areas. The overall Gross Return (GR) as percent of initial values (IV) and GR per breeding female per year were 67.5% and 12.48 Birr, respectively. GR was highly affected by survival rate of chicken. The mean age of

breeding females in reproduction were reported to be 3.9 years ranging from 2.5 to 5 years. The lowest was reported in the *Tilili* market shed and the highest in the *Tepi* market shed, respectively.

Table 14.Mean values of reproductive performance of breeding females of local chicken ecotypes under farmers management in Ethiopia over a period of one year (2000/2001)

Study regions		Reproductive performance of breeding females			Financial value (Birr)*			
	Mean N Of Breeding females/HH	Mean No of hatchs per hen per year	Mean No. of chicks per hatch	Mean No of Chicks survived (8 wks)	Initial value (IV)	Gross return (GR)	GR as % of IV	GR per Breeding female
Tilili (50) **	8	2.9	9.5	5.0	137.60	116.00	84.30	14.50
Horro (50)	5	2.8	8.9	4.2	88.00	58.80	66.80	11.7
Chefe (50)	4	3.0	9.8	4.9	72.40	58.80	81.20	14.70
Jarso (50)	5	2.1	9.3	5.1	95.00	53.55	56.40	10.71
Tepi (50)	4	2.3	8.9	4.6	82.00	42.32	51.60	10.58
Overall mean (250)	5	2.6	9.3	4.8	92.50	62.40	67.50	12.48

* 8.50 Birr is equivalent to 1 USD, ** N = Number, ***= Figures in bracket represents number of households from which means were derived; HH = household

3.11 Production problems and health management practices

The list and relative importance of constraints, as perceived by households, prevailing in village chicken production in the study regions is presented in Table 15. These, in their order of importance, include diseases, predators, lack of feed and lack of information.

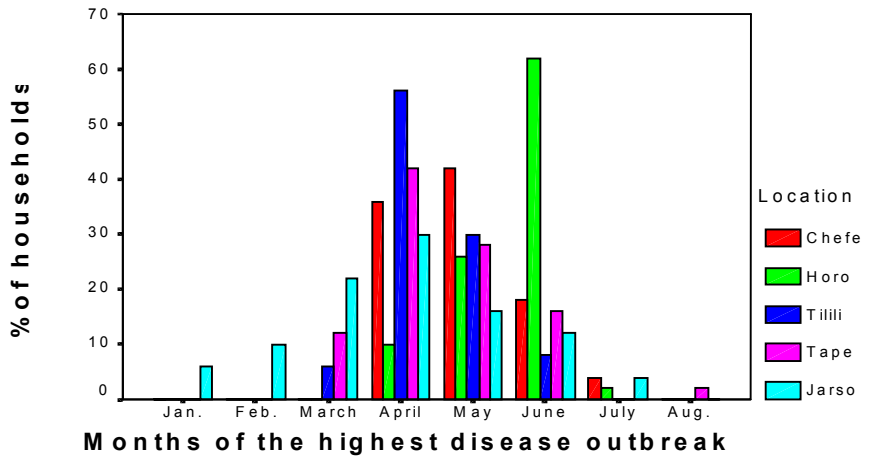
Table 15 Constraints to village chicken production causing mortality and morbidity in five of the study regions in Ethiopia as perceived by households (N=250, % of respondents).

	Regions					
Constraints / problems	Tilili	Horro	Chefe	Jarso	Tepi	overall mean
Disease	75.5	54.0	66.0	64.4	42.8	63.8
Predation	18.4	36.0	18.0	22.2	26.5	21.8
Feed	4.1	8.0	6.0	8.9	8.2	9.5
Information	2.0	2.0	10.0	4.4	22.4	4.9

3.11.1 *Infectious diseases*

The results from this study indicate that infectious diseases, referred with divers local names, were the important constraints that affect village poultry production in the study regions. One of the diseases commonly reported as *"Fengle"* and is believed to be Newcastle Disease (NCD). The local name implies sudden death featured with dorsal prostration, which in fact signifies the acute nature and extreme severity of the disease. The disease was characterised by the households by its high incidence and recurrent outbreaks causing heavy mortality. The prevailing free ranging management system, exposure to wild birds, selling or giving away of live birds, absence of regular vaccination programs and unrestricted contact between different household flocks were believed to be predisposing factors, considerably contributing to the rapid spread and persistence of infectious diseases among village birds, as it was reported from the households. The outbreaks usually occurred from April to June (Fig. 6) coinciding with the beginning of the main rainy and end of short rainy seasons.

Fig. 6 Months of higher poultry disease outbreaks as perceived by the respondents in the five study areas in Ethiopia



3.11.2 *Health management of NCD*

Traditional remedies used for health management are listed in Table 16, giving the common names, botanical names, preparation methods, modes of administration, and purpose of usage. Due to lack of easy access to NCD vaccines, farmers often treat their birds, during clinical outbreaks, using locally accepted traditional medicines. Of which: a/ the use of medicinal plants such as '*feto'* (Brasica spp.), administered per os (orally) often mixed with feed or in drinking water and b/ magico-religious therapies, which are usually based on religious beliefs of owners are the common ones. At times of disease outbreak, some

farmers use 'Holy soil/*Emenet'* as remedy and c/ pharmaceuticals meant for humans. Most farmers, however, realised that despite the traditional control methods the losses due to NCD are still considerable. The effectiveness of these treatments is not scientifically proved and should be subjected to future research.

Table 16 Summery of traditional medicines (ethnoveterinary) and other remedies used for health management in the five study regions of Ethiopia.

Local/common name	**Scientific/botanical name**	**Preparation and route of administration**	**Regions in use**	**Usage**
'Feto'	*Brasica spp*	Mixing with feed or in drinking water	All	Newcastle disease
Ginger *'Gingibile'*	*Zingger officinale*	Crushed and soaked in water to make juice. Topical or oral	*Tilili, Horro* and *Chefe*	All diseases
Lemon	*Citrus limon*	Crushed to make juice in water. Topical or oral	All	All diseases
Eucalyptus leaves	*Eucalyptus spp*	Squeezed to obtain sap juice extract and given with water	*Tilili and Horro,*	All diseases
'Emenet'* (holy soil)		In drinking water and dipping	*Tilili and Tepi*	All diseases
Hot pepper *'Karya'*	*Capsicum frutenscens*	In drinking water and feed	All	All diseases
'Kencheb'	*Euofoaya spp*	Squeezed the *'milk'* and in drinking water	*Chefe and Tepi*	All diseases
Edible oil		Mixed with feed or alone drenching with spoon	All	Respiratory diseases
Garlic *'Nech shenkurt'*	Allium sativum	Crushed and ground into pieces given mixed with feed	*Chefe, Tepi, and Jarso*	All diseases
Human antibiotics	e.g. Tetracycline	In drinking water	All	All diseases
Wood ash		Rubbed into the feathers	*Tilili, Chefe and Tepi*	External parasite
Bleeding of wing veins			All	All diseases
Bleeding of one of the limbs			All	Ale diseases

*Ash of burned incense obtained from Orthodox Churches

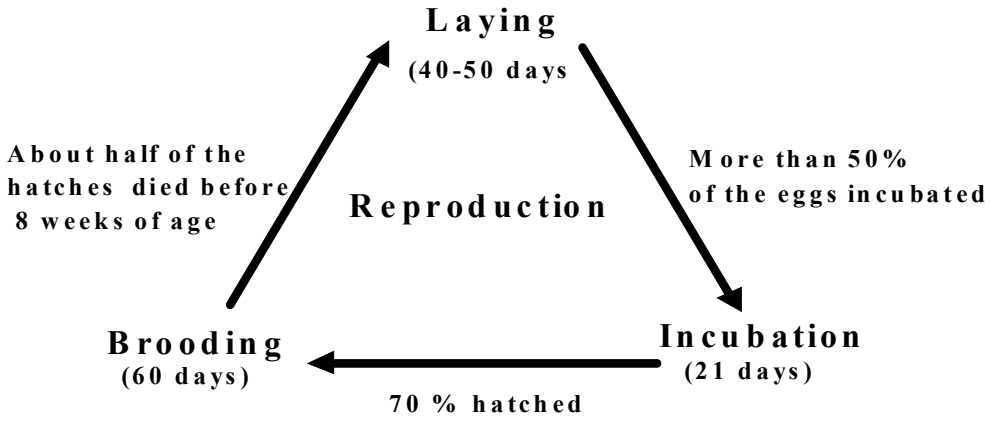
4. Discussions

The present study showed that a village hen annually produces on average between 40 to 50 eggs and about 12 eight week old chicks. This result is in agreement with earlier reports for scavenging village chicken under village conditions in tropical Africa and sub-tropical Latin America (AACMC, 1984;

Tadelle, 1996; Rushton and Ngoni, 1998 and Paterson et al., 2001). The village chicken production system based on low input-output levels represents a part of a "balanced" farming system in which every egg or chicken meat produced is an addition to the family livelihood system. However, Cumming (1992) and Tadelle (1996) reported that the present system has a high reproductive wastage and unexplored performance potentials. The high mortality rate necessitates a rigorous replacement strategy, which in turn affects the potential egg production and off-take rate. Periodically flocks are decimated by endemic diseases and consequently more than 50% of the eggs produced are required for incubation to replace birds that have died. A laying hen needs about 130 to 140 days to accomplish one production cycle, that comprises 50 to 60 days of laying, 21 days to incubate eggs and 60 days of brooding the small chicks (Fig. 7). In addition, the time taken by the laying hen to incubate her eggs and to brood small chicks and the subsequent high chick mortality represent a considerable loss of eggs that could have been consumed or sold which, signifies the wastefulness and cyclic nature of the present system. The system is sustained through egg laying, incubating and brooding, which indicates reproduction for replacement as the major purpose of keeping village chicken (Fig. 7). Huchzermeyer (1973), and Kingston and Cresswell (1982) suggested that more protein would be available for human consumption if the eggs were harvested instead of being incubated, which eventually ends to unsuccessful brooding. The results of this study showed that farmers took remedial measures to increase egg production by way of stimulating broody birds to resume egg laying and increase egg production by 62%. Broodiness is a vital characteristic of traditionally managed local birds and a prerequisite to sustain the present system.

Poultry occupies a unique position in contributing a high quality protein food to rural smallholder farming families in Africa (Tadelle, 1996; Sonaiya *et al,* 1999). There are only few alternative animal protein sources available and there are only a few cultural or religious taboos that stand against the consumption of eggs and poultry meat. However, from the results of this study it is known that the amount of egg and chicken consumed by farm households in the study areas is generally below the needs for animal protein. According to Smith (1990), an average adult human needs about 65g of protein a day of which only 10% needs to be protein of animal origin.

Fig 7 Pictorial presentation of the wasteful and cyclic nature of the present system: the main purpose -Reproduction



Evidence from developing country shows that human productivity and educational attainment of adult people depends to a considerable extent, on the health and nutrition condition during early childhood. An IFPRI report by Rosegrant *et al* (2001) showed that healthy adults with a nutritionally adequate diet has a higher level of economic productivity in both own-farm production and labour-market than those one who eats and keep less well. Village poultry could be particularly important in improving the diet of young children in Sub-Saharan Africa in which currently inhabits about 33 million malnourished children, which are below five years old and responsible for deaths of millions. Even though this discussion is being made with out a household nutrition survey and assuming that the farm households could get their 50% animal protein requirements from other foods of animal origin e.g. milk and milk products; one egg or 40g of poultry meat could provide animal protein needed to supply the remaining 50% of essential amino acids to one person for two days. Provision of one egg per person per two days would necessitate a supply of 182 eggs per individual per year. If a similar amount of protein could be provided from chicken meat one 1.5kg bird per person would be needed every two months. The results of the present study showed that a typical family in the study villages consists of one nourishing mother, a man and four children aged 1, 5, 9 and 11. The total animal protein requirements/day/family would, therefore, be 28.9g, 50% of which could be obtained

from three 50g eggs (6.1g protein/egg) a day or one 1.5 kg chicken (25g protein/100g chicken meat) consumed by the family each week. Based on the current number of hens and their productivity status, and assuming that all eggs produced per year will be used for home consumption plus the number of chicken consumed by farm households, it can be projected that a scavenging poultry flock could provide as much as 50% of the animal protein requirements, which is sufficient to satisfy requirements for only 120 days. From this depiction based on the prevailing production system, it is only possible to satisfy about 32% of the annual animal protein requirements for rural families. If it is assumed that a 1.5 kg chicken is needed/week to meet the 50% animal protein needs of a family of six, which would demand a total requirement of 52 birds. This could be supplied under the prevailing management system with a flock size of at least three times more breeding females. This is clearly a much larger flock than is kept by most families in village chicken production systems.

Smith (1990) and Sonaiya *et al.* (1999) stated that productivity increases is directly related to the level of confinement and management. In view of the experiences from past poultry improvement programmes which have centred on introducing commercial stocks, a new approach aiming at increasing flock productivity instead of individual animal productivity should be adopted to break the vicious cycle of poverty, malnutrition and disease.

An on-farm study report from Ethiopia revealed a 100% increase in egg production /bird/year through employing a scavenging flocks package that consisted of a provision of supplemental feed (30g maize or a mixture of 15g maize and 15g *Noug* seed cake/day /bird), vaccination against Newcastle disease, regular provision of water and small night enclosure as compared to birds managed as scavenging only (Tadelle, 1996; Tadelle *et al,* 2002). Therefore, it would be possible to obtain the necessary poultry meat and eggs from a much smaller flock size, as small as 15 to 20 indigenous breeding females, through a combined package approach and focused extension services and farmers training. According to the statement made by Branckaert (1996), village chicken is the backbone for sustainable well-adapted semi-commercial subsector since those households that appreciate the economic importance of the village chicken and are willing to invest more will easily adopt more intensive poultry keeping when resources allow. However, it is important to make poultry producers aware that there are options and that is possible to increase the benefits from local birds with small additional inputs and improvements in management. Otherwise the villagers perceive these scavenging birds as natural low-grade animals that are not considered to represent wealth and high losses are considered as normal.

The Scavenging Feed Resource Base (SFRB) for the village flock consists of materials in their peri-domestic areas, food leftovers and small amounts of grain provided by the housewife. Roberts (1992) suggested that determining the capacity of the scavenging feed resource base (SFRB) in relation to the village flock bio-mass is of practical significance. If the village flock bio-mass is more than the capacity of the SFRB, it will result in increased mortality and morbidity and poor performance of the flock. Quality and quantity of the feed resource are seasonally variable in nature. Egg production and bird growth rate are both associated with grain harvest, sowing and land preparation seasons. According to Savory (1989), Cumming (1992), and Tadelle and Ogle (2000), the diet of scavenging poultry is often rich in protein but deficient in energy. Village chicken kept under scavenging should be strategically and routinely supplemented and encouraged to frequent the vicinity of the household. According to Mallia (1999) this practice will improve the diet, encourage hens to lay eggs close to the house, be convenient for collection of eggs or segregating an incubating hen. If chicken are encouraged to roost close to the house, problems of theft, predation and losses from inclement weather are lessened and this would probably result in lower chick mortality (Kitalyi, 1998), redaction of disease incidences and predation (Tadelle, 1996).

Poultry, in one form or another, do make a considerable contribution to improve income and to satisfy the animal protein needs of rural families. Most specifically, there is considerable scope for increasing this contribution. Scavenging chicken are particularly appropriate because they do not compete for those foodstuffs with humans. The SFR does cover at least to their maintenance need plus the first 40 to 50 eggs, and is a system that makes the best use of SFR, which otherwise is wasted. Although the traditional system is still believed to be making effective use of locally available resources, research results indicated the presence of considerable opportunities for improvement with out changing the genetic make-up of the animals (Tadelle, 1996; Solomon, 1997; Negussie, 1999; Tadelle *et al.,* 2002). Ethiopia has diverse agro-climatic zones/regions favoring production of many different kinds of crops, providing a wide range of ingredients and alternative feed stuffs suitable for poultry feeding. Making use of these resources to complement the scavenging resource base will provide a considerable potential for success.

Newcastle disease is rated as the most devastating disease of village chickens in the study regions in Ethiopia, which is similar to other areas of Africa (Sonaiya, 1990), Asia (Aini, 1999) and Central America (Mallia, 1999). Sonaiya (1990), after summarising reports from six African countries, concluded that the mortality caused by Newcastle disease ranges from 50-100 % and that season has

an effect, because the severity is higher in the dry season, whereas the condition was found to be more severe in the rainy season in the central highlands of Ethiopia (Tadelle and Ogle, 2001) which, is in agreement with the results of this study. Epidemiological surveys and the keeping of records are important for collecting long-term information regarding disease and productivity (Traoré, 1999). As it is outlined by Pandey *et al.* (1993), the relative importance of NCD in relation to other diseases of chicken and the various biological, physical and socio-economic factors in village chicken production systems are poorly understood. In addition to NCD, the presence of fowl cholera, fowl pox, marek's disease, among others, are known to affect family poultry (Aini, 1999; Sonaiya et al., 1999; Traoré, 1999), actual incidence rates are often not available. For example, as many as 750 million poultry in Africa are estimated to die each year as a result of various diseases (Sonaiya, 1990). Furthermore, environmental and management risk factors are rarely identified and ranked, nor is their interaction assessed. This partly explains why field trials and studies with NCD vaccines in Africa were disappointing (Traoré, 1999). The cause and magnitude of the loss, which occurs among chicks, growers and adult, has not been precisely determined in Ethiopia, calling for an extensive study of the causes, risk factors, control and preventive measures and the associated magnitude of losses. In addition, indigenous knowledge on poultry production and health management needs to be closely assessed.

In order to improve flock productivity a concerted effort is needed which includes: identification of the right clients, motivation, attitude change and training of target farmers and/or groups, followed by input and credit supply and follow up. From traditional chicken farming, what appeared as minor changes in management practices (e.g. preferential provision of feed to newly hatched chicks), home remedies (e.g. in door management of chicks) and control of predators) may to bring about considerable effects in a form of minimising losses and improving off-take rates. It is inferred that improving the offtake rate from traditional chicken production as through changing the genetic potential; cockerel exchange programme as a means or by using improved breeds not make sense, before showing the producers the possibility improving offtake rate through vaccination against NCD and improving the husbandry aspect. Above all it is important to make poultry producers aware that there are options and that it is possible to increase the benefits from local birds with small additional inputs and improvements in management as the first step for improvement, then thinking about breeding strategy to improve the genetic potential of the local birds.

5. Conclusions

The Village chicken production systems are characterised by their low input-low output levels. A range of factors such as sub-optimal management, lack of supplementary feed, low genetic potential and high mortality rate causes the apparent low output level. However, village chicken production is part of a balanced farming system, plays an important role in supply of high quality protein to the family food balance, and provides small disposable cash income in addition to the socio-religious functions important in the rural peoples lives.

Village chicken production forms the basis for transforming the rural sector from subsistence to a more economically productive base. Given that the potentials, major constraints and possible solutions for improved production have been identified, it is imperative to conclude that a holistic interdisciplinary approach to rural poultry production, including the lacking institutional and organisational capacity are important to tackle the major constraints and to bring the anticipated improvement. In view of the experiences from past poultry improvement programmes which have centred on introducing commercial stocks, a new approach aiming at increasing flock productivity instead of individual animal productivity using locally available resources should be adopted to break the vicious cycle of poverty, malnutrition and disease. Developing schemes that aim to promote and improve the village poultry sub-sector need to incorporate local knowledge in productivity and health management in addition to the roles and contributions of women.

Considering the different regions and market sheds for village chicken systems, characterisation as a measure and the diverse functions of the animals in their production environment, a detailed characterisation of opportunities and perspective of the system is appropriate. Participatory methodologies for collection of information using questionnaires supported by focus group discussions, participant observation, formal and informal interviews help to improve the reliability of on-farm investigation and achieve both empirical breadth and depth in the results and above all helps to reach the different household members which are affected differently.

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CHAPTER IV

Phenotypic diversity of indigenous chicken ecotypes in Ethiopia: growth, feed utilization and carcass characteristics

This chapter is based on papers:

1 Tadelle D., C. Kijora and Peters K. J. 2003. Indigenous Chicken Ecotypes in Ethiopia: Growth and Feed utilization potentials. *International Journal of Poultry Science Vol. 12 (2):* pp 144-152.

2 Tadelle D., Feldkamp C.R. and Peters K.J. *(In press)* Phenotypic diversity of indigenous chicken ecotypes of Ethiopia: inferred from growth characteristics (*Accepted in British poultry science journal)*

1. Introduction

Village chicken production system is characterised by its low input-output levels. Poor nutrition, housing, health care and lack of structured breeding are also mentioned as major constraints for low levels of output (Ajuyah, 1999) and birds are characterised as low producers of small sized eggs and slaw growers (Smith, 1990). However, they have special features such as ability to better utilise the limited and poor quality feed resources, hatch their own eggs and special meat and egg qualities (Kitalyi, 1998; Chapter III). Indigenous chickens are not always the best option under optimal conditions. However, under less-intensive production situations, the unique characteristics and added advantages of local chicken breeds that will guarantee its production sustainability. long-term stability and survival. According to Ramsay, *et al.* (2000) the long-term future of any breed of farm animal depends largely on its value-and/or its ability to meet specific needs through unique traits. Indigenous birds are non-uniform with different plumage colour, comb type, down colour, feather cover and body positions are variable from region to region in Ethiopia (chapter III). However, the existence of those morphological variation are not well correlated with productive traits and their genetic base (Smith and Burt 1998)**,** since they are based on a small number of loci and can be rather modified rapidly by artificial selection. Thus, they are not ideal measures of genetic similarities, differences or performance. The economically important quantitative traits require considerable recording efforts based performance evaluation schemes since very little is known of their production potentials. This need is also supported by a growing concern for securing bio-diversity and the potential value of indigenous poultry resources not only for current purposes but for future uses, too. Therefore, the main objective of this study was to investigate the growth, feed utilisation and carcass production potentials of the different ecotypes from different ecological regions of the country under on-station management conditions.

2. Materials and Methods

2.1 Description of the study site

An on-station evaluation of growth and meat production performance of different chicken ecotypes was conducted at the Debre Zeit Agricultural Research Centre, Ethiopia. Debre Zeit is located at $8^0$44’ latitude and $39^0$02’ longitude with an elevation of 1900 m.a.s.l. The

topography is generally flat with many small crater hills and mountains. The climate is characterised as bimodal with two rainy seasons in a year. The short rainy season called *belg* occurs between March and May and the main rainy season is during July to September. The average annual rainfall during the last 35 years is 825.4mm, the average monthly temperature was 17.98^0 and the average monthly relative humidity is 52.4%.

2.2 Study animals and management

This study involved chicken ecotypes from five ecological regions, *Tilili, Horro, Chefe, Jarso* and *Tepi* and corresponding market sheds (chapter III-Fig 1). The Fayoumi chicken breed was included as a reference breed. Fayoumi chicken are a small, white-egg laying, tropical bred that orginated from Egypt.

Eggs were collected from one representative village per market shed from each of the five agro-ecologies. The assumption is that market contact is the main cause of genetic admixture of chicken populations and that chicken from each of the regions and market shades are genetically more homogenous than that of the overall population. Eggs were purchased directly from households to avoid possible inclusion of eggs with exotic blood. Eggs were transported to the respective nearest hatchery for hatching.

Hatched chicks (one day old) were transported to the Debre Zeit Agricultural Research Centre (DZARC). Even though the number of eggs purchased from each region were similar, the hatchablity was highly variable and the number of chicks hatched and used in the trial were 484, 89, 227, 343, 132 and 315 chicks from *Tilili, Horro, Chefe, Jarso*, *Tepi* and Fayoumi ecotypes, respectively. Chicks from each ecotype were further randomly sub-divided into replicates based on the number of chicks available and placed in deep litter pens heated by electric bulbs (250W) until 6 weeks of age where group body weight was taken. At the age of 6 weeks, chicks were sexed, wing banded and transferred to a rearing house till they were 18 weeks of age. Tef *(Eragrostis tef)* straw was used as litter material.

Chicks were fed standard starter and grower rations (Table 1). Representative samples of the starter and grower rations were analysed following standard procedures of the Association of Official Analytical Chemists (1980).

Table 1 Ingredients and proportion used in the starter and grower diets (% bases)

Ingredients	Starter	Grower
Corn	53.00	46.00
Wh.Short	17.00	24.00
Noug Cake	17.50	21.00
M&Bone meal	10.00	05.00
Salt	00.50	00.50
Pre-Mix	02.00	02.00
Lime Stone	-	01.50
Total	100.00	100.00

Chicks were fed a diet containing 21.7% CP and 2784.1 Kcal ME/Kg from day one, while the growers' ration containing 16.2% CP and 2920.2 Kcal ME/Kg was fed from six to twelve weeks of age (Table 2).

Table 2 Nutrient composition of starter and grower diets (%, air-dry basis)

Diets	DM	CP	EE	CF	TA	Ca	P	ME Kcal/kg DM
Starter feed	91.6	21.7	5.9	7.5	9.5	2.3	0.3	2784.1
Grower feed	92.0	16.2	6.9	6.9	14.9	0.9	0.2	2920.2

All birds were vaccinated against Newcastle Disease (at day old and 21 days of age) which is the common infectious diseases in the country and treatment was given based on the recommendation of veterinarians. At around 14 weeks of age, there was a disease out break in the farm. After a long symptom and post mortal investigations it was confirmed that it was Mareks disease. Mareks disease was not considered as an economically important chicken disease at the start of this work by authorities in the veterinary department, thus, experimental birds were not vaccinated.

2.3 Data collected

Body weight was taken every two weeks until 12 weeks of age and then at 18 weeks of age. From day old to six weeks of age group body weight of the replications were taken but individual body weight was recorded until 18 weeks of age. Ten chickens (five male and female) were selected from each ecotype at two weeks of age and then weighed and shank

length was measured every two weeks. Birds were provided daily with a known amount of feed *ad libitum*. Feed refusals was measured and recorded daily.

At 12 weeks of age, a sample of 10 birds (5 male and 5 female) from each genotype were randomly selected and slaughtered. During slaughter, birds were allowed to bleed, and feather plucked before evisceration. Separate weight measurements were taken on carcass, crop, gizzard, feet, head with wattles liver and heart. The Gastro Intestinal Tract (GIT) length and Thigh Mussel Circumference (TMC) were measured using close measuring tape. The Breast angle was taken with calipers. The weights of these parts were calculated as percentages of live weight. The slaughter and dressing percentage determinations were done as recommended by Kubena *et.al*. (1974). Mortality was recorded as it occurred.

2.4 Statistical analysis

Variance between and within populations was analysed using the General Linear Model (GLM) procedure of the Statistical Analysis Systems (SAS, 1987). The Duncan Multiple range test (Duncan, 1955) was used to locate means that were significantly different. Mortality data were subjected to square root transformation before analysis because of deviations from assumptions of analysis of variance (*Gomez and Gomez, 1984)*.

The statistical models used were:
Day old to six weeks of age:

$Y_{ij} = \mu + g_i + e_{ij}$

Where:

Y_{ijm} : Individual phenotypic observation

μ : The population mean

gi : The discrete ecotype effect (1….6)

e_{ij}: Residual random error

Eight to eighteen weeks of age:

$Y_{ijkl} = \mu + g_i + s_j + gs_k + e_{ijkl}$

Where:

Y_{ijkl} : Individual phenotypic observation

μ : The population mean

g_i :The discrete ecotype effect (1….6)

s_j : The discrete sex effect

gs_k : Interaction of the discrete effects of ecotype and sex

e_{ijkl} : Residual random error

2.5 Modeling study

In order to summarize the live weight information in a single variable, the live weight data were fitted to growth models. Exponential growth models were used due to the fact that the inflection points of the live weight evolution plots were not found. Besides, the simplicity of this growth model with only one parameter to fit makes it easy to understand the potential differences between effects. Assuming that bird's growth can be modeled through an exponential model implies that birds gain each day a constant percentage of their current live body weight.

$$LW = LW_0 * e^{(K*t)}$$

Where,
LW : Estimated live weight at time t.
LW_0 : Hatching live weight.
t : Age in weeks.
K : Growth parameter.

The exponential model implies that the growth rate (dLW/dt) is proportional to the current LW. K is the constant relating growth rate and current LW. Therefore, growth parameter K can be interpreted as the efficiency of use of the "growth machinery" for live weight gain, understanding as growth machinery the whole body. Hence, for two birds with the same current LW, the most efficient (highest K) is the one with higher growth rate. The constant K, called also relative growth rate, is defined as:

$$K = \frac{dLW/dt}{LW}$$

Where,

K : Constant.

LW : Current live weight.

dLW/dt : change in live weight.

Since birds were not individually identified before eight weeks of age, individual hatching live weight was not known. The hatching weight for each bird was estimated selecting randomly ten values from an assumed normal distribution. These estimated values of hatching weight were generated with between groups standard deviation and group mean of day-old live weight for each ecotype. Thereby, for each individual animal ten different K values were calculated through ten day-old estimated live weights, and with the same eighth, tenth, twelfth and eighteenth week live weights.

The resulting K values were analysed through the following statistical model using Statistica 6.1 release 2002:

$$Y_{ijkl} = \mu + g_i + s_j + gs_k + e_{ijkl}$$

Where,

Y_{ijkl} : Individual replication of K value

μ : The population mean

g_i :The discrete ecotype effect (1..6)

s_j : The discrete sex effect

gs_k : Interaction of the discrete effects of ecotype and sex

e_{ijkl} : Residual random error

To locate groups that were significantly different, Tukey's Unequal N Honest Significant Difference (HSD) test using Statistica 6.1 release 2002 was used.

3. Results

3.1 Live body weight

3.1.1 Day one to six weeks of age

The analysis of variance showing the effects of ecotypes on live body weight development with coefficients of variation of 17.3, 25.9, 23.7 and 23.4% for day old and two, four and six weeks of age is presented in Table 3. The result from the analysis of variance showed a highly significant ($p<0.01$) difference in live body weight development among the different ecotypes. The least square means for live body weight development from day old to six weeks of age are presented in Table 4. Mean (±SE) live body weight development of six ecotypes of chicks in Ethiopia (day old to six weeks of age) is shown in appendix 4-chapter IV. Ecotype had a significant effect ($p<0.01$) on body weight development.

Table 3 Analysis of variance for live body weight of six ecotypes of chicks in Ethiopia (day old to six weeks of age)

Source of variation	d.f	Day old body weight MS	Two weeks body weight MS	Four weeks body weight MS	Six weeks body weight MS
Ecotypes	5	4233.4**	13027.4**	45174.7**	104681.5**
Error	21	0.42	23.1	29.8	67.9
r^2		0.99	0.98	0.97	0.97
CV %		17.3	25.9	23.7	23.4

d.f :Degrees of freedom; MS: Mean squares; Significant **: $P<0.001$; r^2 : adjusted value of coefficients of determination; CV: Coefficients of variation

The highest day old body weight was recorded for Fayoumi chicks followed by chicks from *Chefe, Tilili, Horro, Tepi* and *Jarso* market sheds having 41.04±0.37g, 32.4±0.29g, 30.7±0.38g, 28.7±0.37g, 26±0.4g and 25.8±0.3g, respectively. Chicks from *Tepi* and *Jarso* market sheds showed a significantly ($p<0.05$) lower day old body weight than local chicks from the other three ecological regions and corresponding market sheds.

The Fayoumi chicks were 31.3, 21.1 and 37.1% heavier than the mean day old body weight of local chicks, chicks from *Chefe* (heaviest locals) and Jarso (least day old body weight), respectively. *Chefe* Chicks showed a 20.4% positive deviation over chicks from *Jarso* market sheds in terms of day old body weight. Local chicks had a significantly ($p<0.01$) lower body weight at two, four and six weeks of age than chicks of Fayoumi breed. Fayoumi breed

chicks had the highest mean live body weight at two weeks of age followed by chicks from *Chefe* and *Tilili* having 71.2g, 68.1g and 57.2g, respectively.

Table 4. Least Squares Means (LSM±SE) for body weights of six ecotypes of chicks in Ethiopia (day old to six weeks of age)

Ecotypes	Live weight			
	Day old body weight (g)	Two weeks body weight(g)	Four weeks body weight (g)	Six weeks body weight (g)
Ecotype				
Tilili (7)*	30.7 ± 0.25 [c]	57.2 ± 1.9 [b]	111.2±2.1[c]	159.5 ± 3.1[c]
Horro (3)	28.7± 0.37 [d]	54.5± 2.9 [b]	83.7±3.2 [d]	131.6±4.8 [d]
Chefe (5)	32.4 ± 0.29 [b]	68.1± 2.1[b]	118.2 ±2.4[b]	179.7±3.7 [b]
Jarso (6)	25.8 ± 0.26[e]	36.7±2.0 [c]	64.7±2.2 [e]	108.2± 3.4 [e]
Tepi (3)	26.0 ±0.37 [e]	41.2 ±2.9 [c]	73.8±3.2 [e]	113.2±4.8 [e]
Mean local	28.7±0.15	49.9±1.5	90.3±1.24	138.4±1.7
Fayoumi (3)	41.04 ± 0.37 [a]	71.2± 2.8 [a]	131.9 ±3.2 [a]	206.7±4.8 [a]
Overall mean	30.8± 0.13	53.4±1.0	97.3±1.1	149.8±1.7

*Figures in bracket represent number replications from which the means were derived. [abcd] Means within a column followed by different superscripts show the presence significant differences (P<0.001).

3.1.2 Eight to 18 weeks of age

The analysis of variance showing the effects of ecotype, sex and ecotype-sex interactions on live body weight development with overall coefficients of variation of 35.6, 36.2, 36.5 and 35.8% for the six ecotypes of chicken at eight, 10, 12 and 18 weeks of age is presented in Table 5. The results from the analysis of variance showed a significant ($p<0.01$) effect of ecotype and a highly significant ($p<0.001$) effect of sex on live body weights of chicken at eight, 10, 12 and 18 weeks of age. The ecotype-sex interaction had a non-significant ($p>0.05$) effect on live body weight at all ages. Mean (± SE) live body weight development of six chicken ecotypes in Ethiopia (eight to 18 weeks of age) is shown in Appendix 5-chapter IV.

Least squares means for live body weight development at eight, 10, 12 and 18 weeks of age, as shown in Table 6, were 273.4±3.2g, 377.8±4.6g, 479.1±6.3g and 760.8±9.4, respectively. The mean live body weights at eight, 10, 12 and 18 weeks were highest for Fayoumi chicken followed by chicken from*, Tilili, Chefe, Horro*, *Tepi* and *Jarso* market sheds, respectively. The mean body weight of locals were 66, 63, 67 and 74% of the mean live body weight of Fayoumi chicken at eight, 10, 12 and 18 weeks of age, respectively.

Table 5 Analysis of variance on body weight for six groups of chicken by ecotype and sex in Ethiopia (eight to 18 weeks of age)

Source of variation	d.f	Eight weeks body weight MS	10 weeks body weight MS	12 weeks body weight MS	18 weeks body weight MS
Model	12	4335568.7**	8482055.4**	14045501.9**	44553055.7**
Ecotype	5	211878.2**	548629.1**	860724.9**	1926429.3**
Sex	1	698631.8***	1288269.8***	2564841.1***	6003618.3***
Ecotype*sex	5	7574.7NS	17525.1NS	29994.5NS	263131.2NS
Error	731	4095.6	8613.4	16055.9	39024.5
r^2		0.95	0.94	0.93	0.94
CV %		35.6	36.2	36.5	35.8

d.f: degrees of freedom; MS: Mean squares:; Significant ** p<01; *** p<0.001; NS: non significant; r^2 : adjusted value of coefficients of determination; CV: Coefficients of variation

Chicken ecotypes from *Tilili* and *Chefe* market sheds showed a significantly (p<0.01) higher live body weight than local chicken ecotypes from the other three ecological regions and corresponding market sheds. However, there was no statically detectable (p>0.05) live body weight difference among chicken from *Jarso* and *Tepi* regions at all age.

The *Tilili* chicken (heaviest locals) attained 78, 74, 78 and 81% of the mean live body weights of Fayoumi chicken at eight, 10, 12 and 18 weeks of age, respectively, while chicken from *Tepi* (lightest body weight among the locals) showed only 74, 61, 60 and 74% of the body weight of *Tilili* chicken.

As expected, it is also observed in this study that male chicks had significantly higher (P <0.001) live body weights compared to females from the same ecotype. Male chicken were 36, 35, 39 and 36% heavier in mean live body weight than female chicken at eight, 10, 12 and 18 weeks of age, respectively.

Table 6 Least Squares Means (LSM) for body weight of six groups of chicken by ecotype and sex in Ethiopia (eight to 18 weeks of age).

Groups	Live weight							
	8 wk (g)		10 wk (g)		12 wk (g)		18 wk (g)	
	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE
Ecotype								
Tilili (n)*	327	284.5±4.5 [b]	271	395.0±6.6 [b]	227	519.8 ±8.9 [b]	194	783.4± 15.2 [b]
Horo (n)	75	266.9±11 [c]	64	366.7 ± 16.5 [c]	47	421.4 ±22.6 [c]	42	689.2±35.8 [c]
Chefe (n)	217	281.4 ±4.7 [b]	203	391.1 ±6.9 [b]	200	509.3 ±9.3 [b]	185	772.3±15.2 [b]
Jarso (n)	257	215.9± 5.9 [d]	191	299.3 ±8.6 [d]	148	385.4 ±11.7 [c]	134	660.5±19.6 [c]
Tepi (n)	107	226.0±9.4 [d]	96	283.1 ±13.6 [cd]	54	372.3±18.6 [c]	50	659.9±29.9 [c]
Mean local	983	241±2.3	825	332.7±3.14	676	443 ±5.7	605	719±11.1
Fayoumi (n)	303	365.0 ± 8 [a]	281	531.8 ±11.6 [a]	264	666.3±15.9 [a]	236	969.3±12.9 [a]
Overall mean (n)	1286	273.4±3.2	1106	377.8±4.6	940	479.1±6.3	841	760.8±9.4
Sex								
Male (n)	409	314.7± 5.2 [a]	364	433.9±7.6 [a]	346	558.2±10.4 [a]	296	877.5±15.9 [a]
Female (n)	877	232.2±3.5 [b]	742	321.8±3.8 [b]	594	399.9±7.0 [b]	545	643.9 ±10.1 [b]
Sig. Level		***		***		***		***

N= number of chickens from which means were derived, [abcd] Means within a column followed by different superscripts are significantly different; ***P<0.001.

Coefficients of variations (%) based on individuals live body weight of the five local ecotypes and Fayoumi chicken under on station management conditions at eight, 10, 12 and 18 weeks of age are presented in Table 7. The lowest coefficients of variation were observed among chicken from Fayoumi breed, which is an established egg laying breed and exposed to selection for relative uniformity. In all the local ecotypes, females did show more variability than their male contemporaries. The highest coefficient of variation at eight, 10, 12 and 18 weeks of age were recorded for female chicks from *Horro* followed by chicks from *Tepi, Jarso, Tilili, Chefe* and Fayoumi, respectively.

3.2. Shank length (SL)

The analysis of variance showing the effects of ecotype, sex and ecotype-sex interaction on shank length for six of the chicken ecotypes from two to 18 weeks of age is presented in appendix 6-chapter IV. The result from the analysis of variance showed a significant ($p<0.01$) effects of ecotype and a highly significant ($p<0.001$) effect of sex on shank length at all age, however, the ecotype-sex interaction exhibited a non-significant ($p>0.05$) effect.

The least squares means for shank length and its correlation coefficient with live body weights of growers from two to 18 weeks of age for six ecotypes of chickens are presented in Table 8. Ecotype had a significant ($p<0.05$) effect on shank length of the different chicken

ecotypes. The over all mean shank length at two, four, six, eight, 10, 12 and 18 weeks of age were 2.3, 2.9, 3.4, 3.7, 4.2, 5.2 and 8.9 cm, respectively.

Table 7 Coefficients of variation (%) of live body weight of five local ecotypes and Fayoumi chicken under on station management conditions by genotype and sex at eight, 10, 12 and 18 weeks of age in Ethiopia.

Ecotypes	Coefficients of variation (%)							
	8 weeks		10 weeks		12 weeks		18 weeks	
	Male	Female	Male	Female	Male	Female	Male	Female
Tilili	20.1	26.9	26.6	27.7	25.6	28.6	23.1	30.3
Horo	18.2	40.1	26.1	42.5	24.7	43.9	18.2	36.7
Chefe	20.7	25.0	15.2	24.8	19.3	26.8	25.9	27.0
Jarso	20.4	30.8	22.1	29.0	20.1	30.2	33.2	35.1
Tepi	24.5	38.2	26.4	39.0	29.4	41.8	24.8	35.2
Fayoumi	20.6	19.7	21.4	23.6	16.2	21.1	19.6	20.6

The mean shank length at all ages were highest for Fayoumi and *Tilili* chicks followed by chicks from *Chefe and Tepi* regions as ecotypes with medium sized shank lengths, whereas chicks from *Horro* and *Jarso* regions had shorter shank lengths. The overall phenotypic correlation coefficients between shank length and live body weight of the different ecotypes at 2, 4, 6, 8, 10, 12 and 18 weeks of age were significant ($p<0.01$) and were positive and varied between $r_p = 0.64$ to 0.79.

Table 8 Least squares means (LSM) (cm) of shank length and its correlation coefficient with live body weight of five local ecotypes and Fayoumi chicken by ecotype under on station management conditions in Ethiopia (two to 18 weeks of age).

Age in weeks	N	Ecotypes									r_p
		Tilili LSM	Horo LSM	Chefe LSM	Jarso LSM	Tepi LSM	Fayo LSM	± SE	Overall Mean ± SE	Sig	
2	10	2.5^{a}	2.2^{b}	2.3^{a}	2.1^{b}	2.3^{a}	2.5^{a}	0.06	2.3±0.024	*	0.64
4	10	3.1^{ab}	2.6^{d}	2.8^{c}	2.5^{d}	2.9^{bc}	3.2^{a}	0.06	2.9±0.024	*	0.68
6	10	3.8^{a}	3.0^{e}	3.3^{d}	2.9^{e}	3.5^{c}	3.9^{a}	0.07	3.4±0.025	*	0.69
8	10	4.1^{a}	3.2^{c}	4.0^{ab}	3.1^{c}	3.8^{b}	4.1^{a}	0.07	3.7±0.026	*	0.71
10	10	4.8^{a}	3.6^{d}	4.5^{b}	3.5^{d}	4.0^{c}	4.9^{a}	0.08	4.2±0.026	*	0.79
12	10	5.7^{a}	4.6^{c}	5.6^{a}	4.3^{c}	5.1^{b}	5.9^{a}	0.13	5.2±0.051	*	0.75
18	10	9.3^{a}	8.4^{c}	8.7^{b}	8.4^{c}	8.7^{b}	9.5^{a}	0.13	8.8±0.05	*	0.76

N= number of chicken from which means were derived; ^{abcd} Means within a row followed by different superscripts are significantly different, r_p = Correlation coefficient (Shank length Vs live body weight)

The least squares means for shank length and correlation coefficients of shank length and live body weight of growers at two, four, six, eight, 10, 12 and 18 weeks of age for six ecotypes of chicken by ecotype and sex is presented in Table 9. Male chickens were found to have on average 11% longer ($p<0.01$) shanks as compared to their female contemporaries ranging

from 8 to 19%. The ecotype-sex interaction showed a non-significant ($p>0.05$) effect on shank length at all ages.

The Prediction equations for live body weight (BW, g) on the basis of shank length (SL, cm) for the five local ecotypes at 12 and 18 weeks of age is presented in Table 10. The comparison of R^2 values for different regression equations (linear and non linear) indicated that, when linear relationship of regression equation techniques based on shank length was used instead of a non linear regression equations of a polynomial, there were improvements in R^2 values from 0.55 and 0.59 to 0.63 and 0.64 for 12 and 18 weeks of age for both sexes and gives higher level of accuracy. Thus, the better models to estimate live body weight is the linear regression equations based on shank length at different ages. The slightly higher R^2 values for male chickens gave an indication that the equations estimated more accurate to males as compared to females.

Multiple liner regression models developed including the three measurements, Shank Length (SL, cm), Thigh Mussel Circumference (TMC, cm) and Breast Angle (BA) resulted in R^2 = 0.73 (BW at 12 weeks of age (g) = -59.6 +156.9 (SL, cm) -14.8 (TMC, cm) -58.2(BA)).

3.3 Growth model

The analysis of variance showing the effects of ecotype, sex and ecotype-sex interactions on K parameter of the six ecotypes of chicken is presented in Table 11. The results from the analysis of variance showed a highly significant ($p<0.01$) effect of ecotype, sex and their interaction on K parameter.

Table 9 Least squares means (LSM) (cm) of shank length by sex from five local ecotypes and Fayoumi chicken under on station management conditions in Ethiopia (two to 18 weeks of age)

Age*	Ecotypes							
	Tilili (LSM)	Horro (LSM)	Chefe (LSM)	Jarso (LSM)	Tepi (LSM)	Fayoumi (LSM)	± SE	Overall mean (LSM ± SE)
Sex:								
Male:								
2	2.7[a]	2.3[a]	2.5[a]	2.2[a]	2.5[a]	2.7[a]	0.085	2.5±0.035
4	3.4[a]	2.7[a]	3.0[a]	2.6[a]	3.1[a]	3.4[a]	0.084	3.0±0.034
6	4.0[a]	3.2[a]	3.5[a]	3.0[a]	3.7[a]	4.1[a]	0.085	3.6±0.035
8	4.4[a]	3.3[a]	4.2[a]	3.2[a]	4.0[a]	4.3[a]	0.090	3.9±0.037
10	5.1[a]	3.7[a]	4.7[a]	3.6[a]	4.1[a]	5.0[a]	0.090	4.4±0.037
12	6.2[a]	4.5[a]	5.7[a]	4.9[a]	5.4[a]	6.5[a]	0.180	5.5±0.073
18	9.4[a]	8.7[a]	9.1[a]	8.9[a]	9.0[a]	9.9[a]	0.190	9.2±0.075
Female:								
2	2.2[b]	2.0[b]	2.1[b]	2.0[b]	2.2[b]	2.3[b]	0.085	2.1±0.035
4	2.8[b]	2.4[b]	2.6[b]	2.4[b]	2.7[b]	3.0[b]	0.084	2.7±0.034
6	3.5[b]	2.8[b]	3.2[b]	2.8[b]	3.3[b]	3.7[b]	0.085	3.2±0.035
8	3.9[b]	3.0[b]	3.8[b]	3.0[b]	3.6[b]	4.0[b]	0.090	3.6±0.037
10	4.5[b]	3.4[b]	4.3[b]	3.4[b]	3.8[b]	4.7[b]	0.090	4.0±0.037
12	5.3[b]	4.1[b]	5.4[b]	4.4[b]	4.8[b]	5.3[b]	0.180	4.9±0.073
18	8.9[b]	8.2[b]	8.3[b]	8.1[b]	8.3[b]	9.1[a]	0.190	8.5±0.075

[ab] Means within a column followed by different superscripts are significantly different

Table 10 Prediction of body weight (BW, g) on the basis of shank length (SL, cm) for the five local ecotypes at 12 and 18 weeks of age.

BW by age and sex	Regression equation	R^2 (adj)	t-value	Sig.
Both sex				
-12 weeks(BW)	= -260.7 + 155.2 (Shank length at 12 wks)	63.2	9.08	0.01
-18 weeks(BW)	= -85.9 +112.6 (Shank Length at 18 wks)	64.4	9.31	0.001
Males				
-12 weeks(BW)	= -306.7+163.6 (Shank length at 12 wks)	65.8	6.4	0.01
-18 weeks(BW)	= 16.9 +101.2 (Shank length at 18 wks)	64.4	6.2	0.001
Females				
-12 weeks(BW)	= -84.8 + 117.2 (Shank length at 12 wks)	63.3	6.5	0.01
-18 weeks(BW)	= -111.9 + 113.8 (Shank length at 18 wks)	61.0	6.1	0.01

Table 11 Analysis of variance on K parameter of growth for six groups of chicken by ecotype and sex in Ethiopia.

Source of variation	Sum of squares	d.f.	MS	F	P
Intercept	136.8777	1	136.8777	878034.6	0.01
Ecotype	0.0100	5	0.0020	12.9	0.01
Sex	0.3108	1	0.3108	1993.5	0.01
Ecotype * Sex	0.0271	5	0.0054	34.8	0.01
Error	1.2343	7918	0.0002		

d.f: degrees of freedom; MS: Mean squares; p: level of significance.

Table 12 Least Squares Means (LSM) for K growth parameter of six groups of chicken by ecotype and sex in Ethiopia.

Ecotype	Sex	N	K growth parameter	Standard Error
Jarso	F	930	0.170863^{e}	0.000501
Fayoumi	F	1110	0.171534^{de}	0.000259
Horro	F	310	0.171906^{de}	0.000699
Tepi	F	310	0.174200^{cd}	0.000843
Tilili	F	1380	0.175420^{c}	0.000394
Chefe	F	1160	0.175781^{c}	0.000366
Chefe	M	590	0.185539^{b}	0.000477
Fayoumi	M	1000	0.190526^{a}	0.000290
Horro	M	90	0.190981^{ab}	0.000711
Tilili	M	550	0.191782^{a}	0.000469
Jarso	M	340	0.191845^{a}	0.000841
Tepi	M	160	0.193068^{a}	0.001069

^{abcde} Means within a column followed by different superscripts are significantly different (alpha = 0.05) following the Unequal N Honest Significant Difference (HSD) test.

Table 12 and Fig. 1 show that regardless of the ecotype, male chickens have significantly higher K parameter than females. Within the males there are two homogenous groups. The most efficient group (highest K) includes *Tepi*, *Jarso*, *Tilili*, *Horro*, and *Fayoumi*. The second least efficient group, contains the ecotypes *Horro* and *Chefe*. Within the females there are three homogenous groups. The most efficient ecotypes are *Chefe*, *Tilili*, and *Tepi*. *Tepi*, *Horro* and *Fayoumi* belong to the second group and *Horro*, *Fayoumi* and *Jarso* belong to the third and least efficient group.

Table 13 Least Squares Means (LSM) for K growth parameter and predicting equation for live weight of six groups of chicken by ecotype in Ethiopia (both sexes pooled).

Ecotype	N	K growth parameter	Standard Error	Predicting equation $LW = LW0 * e^{(K*Age)}$
Horro	400	0.176198[c]	0.000691	$LW_H = 28.7 * e^{(0.176198*Age)}$
Jarso	1270	0.176480[c]	0.000503	$LW_J = 25.8 * e^{(0.176480*Age)}$
Chefe	1750	0.179071[b]	0.000311	$LW_{Ch} = 32.4 * e^{(0.179071*Age)}$
Tilili	1930	0.180083[ab]	0.000354	$LW_{Ti} = 30.7 * e^{(0.180083*Age)}$
Fayoumi	2110	0.180535[a]	0.000283	$LW_F = 41.0 * e^{(0.180535*Age)}$
Tepi	470	0.180624[ab]	0.000782	$LW_{Te} = 26.0 * e^{(0.180624*Age)}$

[abc] Means within a column followed by different superscripts are significantly different (alpha = 0.05) following the Unequal N Honest Significant Difference (HSD) test.

Least Squares Means for K growth parameter and the predicting equations for live weight of six groups of chicken by ecotype in Ethiopia, both sexes pooled, are presented in Table 13 and differentiate three groups. The most efficient (highest K) group include *Tepi*, *Fayoumi* and *Tilili*, the second group involves *Tepi*, *Tilili* and *Chef,* and *Jarso* and *Horro* represent the least efficient (lowest K) group. It is important to notice that the ecotype with the highest least square mean K, *Tepi*, belongs to both first and second group, while *Fayoumi*, with the second highest K belongs only to the first group. This is because the standard error of *Tepi* is much higher than *Fayoumi's* and so the Honest Significant Difference of *Tepi* is much higher than *Fayoumi's*.

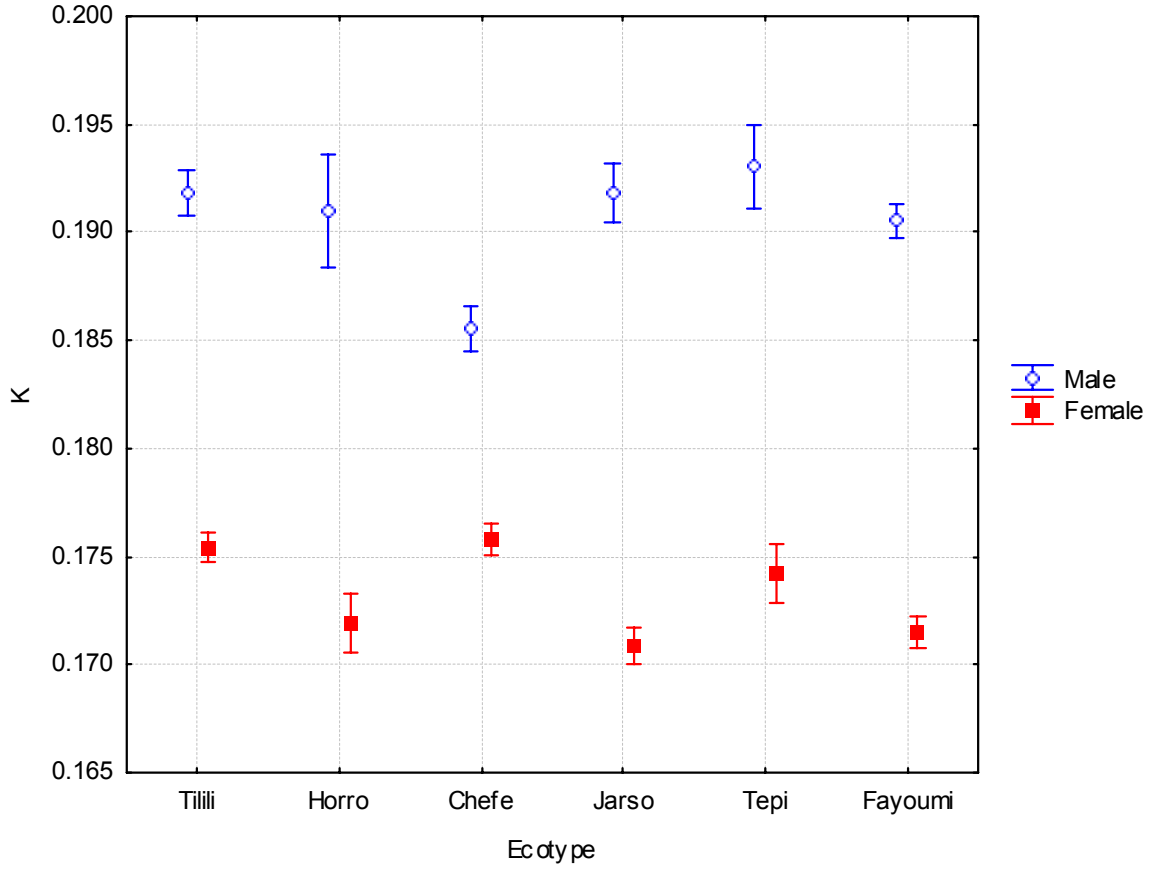
3.4 Body weight gain and feed efficincy

3.4.1 Day old to six weeks of age

Results of the analysis of variance (Table 14) shows the significant effects of ecotype on body weight gain per bird, feed intake, feed conversion ratio (feed: gain) and survival rate from day old to six weeks of age with coefficients of variation of 25.3, 35.4, 27.1 and 15.2%. The result from the analysis of variance showed a highly significant ($p<0.001$) difference in feed intake and significant ($p<0.01$) difference in body weight gain among the different ecotypes between day old to six weeks of age.

The least squares means for different performance parameters from day old to six weeks of age are presented in Table 15. Ecotype had a significant ($p<0.01$) effect on body weight gain per bird and mean body weight gain per bird per day**.** Of the local ecotypes, *Jarso* and *Tepi* had lowest body weight gains while *Chefe* and *Tilili* had largest.

Fig.1 Least Square Means (LSM) for K growth parameter of six groups of chicken by ecotype and sex.



The differences between the former ones are not significant whereas a significant difference was observed between the later ones. However, the *Horro* ecotype gained significantly less than both *Chefe* and *Tilili* ecotypes and significantly more than *Jarso* and *Tepi* ecotypes. The highest body weight gain per bird and mean daily body weight gain per bird per day was recorded for Fayoumi chicks. The Fayoumi chicks gained 12, 98 and 49% more than chicks from *Chefe* ecotype (heaviest locals), *Jarso* ecotype (least total body weight gain among the locals) and mean daily gain of all local ecotypes, at six weeks of age, respectively. *Chefe* chicks showed 77% positive deviation over chicks from *Jarso* market sheds in terms of body weight gain per bird.

Table 14 Means Squares from the analysis of variance for the performance of five local chicken ecotypes and Fayoumi under intensive management in Ethiopia (0-6 weeks of age)

Sources of variation	d.f	Parameters					
		Gain (gram/bird)	Average Daily gain (gram/bird)	Total feed intake/bird (gram/bird)	Average daily feed intake (gram/bird)	Feed conversion ratio (feed: gain)	Mortality € %
		MS	MS	MS	MS	MS	MS
Ecotype	5	67001.4**	37.9**	2028337.5***	1149.8***	143.2**	118.8*
Error	21	68.7	0.039	4557.2	2.6	0.34	0.86
r^2		0.99	------	0.96	------	0.96	0.96
CV %		25.3	------	35.4	------	27.1	15.2

d.f =Degrees of freedom; MS= Mean squares; Significant; €= Original data square root transformed;
*=p<0.05 **= p<0.01; ***= p<0.001; r^2 = adjusted value of coefficients of determination; CV= Coefficients of variation

Table 15 Least squares means for the performance of five local ecotypes and Fayoumi chicken under on station management conditions in Ethiopia (0-6 weeks of age)

Parameters	Ecotypes							
	Tilili (LSM ± SE)	Horro (LSM ± SE)	Chefe (LSM ± SE)	Jarso (LSM ± SE)	Tepi (LSM ± SE)	Mean (Local) (LSM ± SE)	Fayoumi (LSM ± SE)	Grand mean (LSM ± SE)
Gain (g/bird)	128.8±3.1^{c}	102.9±4.8^{d}	147.3±3.7^{b}	82.4±3.4^{e}	87.2±4.8^{e}	109.7±1.7	165.6±4.8^{a}	119.1±1.7
Average daily gain (g)	3.1±0.07^{c}	2.5±0.11^{d}	3.5 ±0.1^{b}	2.0 ±0.1^{e}	2.1±0.1^{e}	2.6 ±0.4	3.9±0.11^{a}	2.8±0.04
Total feed intake/bird(g)	637.4±52^{b}	539.3±39^{bc}	670.3±30^{b}	436.6 ±27^{c}	569.7±39^{bc}	570.7±9.5	939.9±39.1^{a}	688.6± 13.8
Average daily feed intake(g)	15.2±1.2^{b}	12.8±1.0^{bc}	15.9±0.7^{b}	10.4 ±0.7^{c}	13.6±1.0^{bc}	13.6 ±0.23	22.4±0.1^{a}	16.4±0.4
Feed intake; g DM /day X g $^{0.75}$	0.96± 0.07^{b}	0.93±0.11^{b}	0.92±0.09^{b}	0.88±0.08^{b}	1.11±0.11^{ab}	0.96±0.19	1.38±0.11^{a}	1.03±0.04
FCR (feed:gain)	4.9±0.4^{c}	5.7±0.3^{b}	4.5±0.3^{d}	5.2 ±0.2^{c}	6.4±0.3^{a}	5.3±0.1	5.7±0.3^{b}	5.8±0.12
Mortality %	32.4±3.2^{a}	15.8±4.8^{b}	27.0±3.7^{ab}	25.1±3.4^{ab}	18.7±4.8^{ab}	24.0±1.9	3.9±4.8^{c}	20.6±1.7

^{abcd} Means within a row followed by different superscripts are significantly different
FCR= Feed Conversion Ratio; at P<0.05.

Feed consumption levels of *Jarso* ecotype was the lowest with a daily average feed consumption of 10.4g followed by that of *Horro* and *Tepi* (12.8 and 13.6g/day). The mean daily feed intake for all local ecotypes was 13.6g/day while the Fayoumis consumed 22.4g/day per bird at this age. The *Chefe* and *Tilili* ecotypes consumed 14 and 12% more feed than the average of local ecotypes while *Jarso* and *Horro* ecotypes consumed 24 and 6% less feed than the average.

The Fayoumi chicks at six weeks of age consumed 41, 115 and 65% more feed than the *Chefe* ecotype (with highest feed intake among locals at this age), *Jarso* ecotype (least feed intake among the locals at this age) and mean of all local ecotypes, respectively. Feed conversion ratio was also significantly ($p<0.01$) affected by ecotypes. The highest feed requirement per unit of gain was recorded for the *Tepi* followed by Fayoumi and *Horro,* and the lowest feed requirements per units of gain were recorded for *Chefe* and *Tilili* chicks with conversion ratios of 4.5g and 4.9g feed per unit of gain, respectively.

Mortality rate was significantly ($p<0.01$) affected by ecotype. A very high survival rate was recorded for the Fayoumi breed (96%). The mean rate of survival for local chicks was 76%.

3.4.2 Eight to 12 weeks of age

The analysis of variance showing the effects of major factors in the model on different parameters from six to 12 weeks of age is presented in Table 16. The result from the analysis of variance showed a highly significant ($p<0.001$) difference on body weight gain per bird, average body weight gain per bird per day, feed intake per bird, average feed intake per bird per day and feed conversion ratio (feed: gain) among the different ecotypes from eight to 12 weeks of age. The analysis of variance showing the effects of ecotype-sex interaction on body weight gain per bird, average body weight gain per bird per day, total feed intake, average feed intake per bird per day and feed conversion ratio (feed: gain) at twelve weeks is presented in Table 16. Ecotype-sex interaction had a significant ($p<0.001$) effect on body weight gain per bird and mean body weight gain per bird per day.

The least squares means for the performance of five local ecotypes and Fayoumi chicken under on station management conditions by ecotype from eight to 12 weeks of age are presented in Table 17. Ecotype had a significant ($p<0.001$) effect on body weight gain per bird and mean body weight gain per bird per day. Among the local ecotypes *Tepi* and *Jarso*

had the lowest gain while *Tilili* and *Chefe* had highest gain. However, the fastest daily gain was observed in Fayoumi chicken.

The Fayoumi chicks were 28, 77 and 52% heavier than chicks from *Tilili* ecotype (heaviest locals at this age), *Tepi* ecotype (least total body weight gain among the locals at this age), and the average body weight gain of local birds, respectively. *Tepi* growers showed 39% negative deviation over growers from *Tilili* in terms of body weight gain per bird and mean daily body weight gain per bird per day.

The least squares means for the performance by sex from eight to 12 weeks of age is presented in Table 18. As expected, it is also observed in this study that male chicks exhibited significantly ($P<0.001$) higher body weight gain compared to females from the same ecotype. Male growers from *Tilili ecotype* (heaviest locals at this age), *Tepi* ecotype (least total body weight gain among the locals at this age) and mean body weight gain of local birds, were 22, 30 and 33% heavier in body weight gain per bird over female chicken at twelve weeks of age, respectively.

There was a highly significant ($p<0.001$) difference in total and mean feed intake per bird per day among the different ecotypes. Feed intake (total per bird and mean per bird per day) was highest for the Fayoumi chicks followed by growers from *Tilili, Chefe, Horro, Jarso* and *Tepi* market sheds, respectively, which actually followed the same trend as observed in body weight gain and daily body weight gain. Feed conversion ratio was significantly ($p<0.01$) affected by ecotypes. The highest feed requirement per unit of gain was recorded for the Fayoumi growers followed by growers from *Tepi* and *Jarso* ecotypes whereas the lowest feed requirement per units of gain was recorded for *Tilili*, *Horro* and *Chefe* growers with feed conversion ratio ranging from 4.9 to 5.3g feed intake per unit of gain. Although sex has significant effect on total and mean feed intake, the feed conversion ratio was not significantly ($p>0.05$) affected by sex. Among the local ecotypes, male growers from *Tilili* and *Horro* had the larger body weight gains at this age whereas female growers from *Horro* ecotype had the smaller body weight gain among all the local females. The highest feed requirement per unit of gain was recorded for female growers from *Horro* whereas

Table 16 Means Squares from the analysis of variance for the performance of five local chicken ecotypes and Fayoumi under on station management conditions in Ethiopia (8-12 weeks of age)

Sources of variation	d.f	Parameters					
		Gain (gram/bird)	Average Daily gain (gram/bird)	Total feed intake/bird (gram/bird)	Average daily feed intake (gram/bird)	Feed conversion ratio (feed: gain)	Mortality %€
		MS	MS	MS	MS	MS	MS
Model	12	273900.8***	155.5***	8205581.8***	4650.9***	75.1***	173.5*
Ecotype	5	26077.0**	14.9***	1090204.6***	617.5***	1.3***	121.8*
Sex	1	50073.4***	27.4***	1894160.2***	1073.6***	0.04NS	12.8NS
Ecotype * sex	5	2148.4***	1.2***	82193.6**	46.8**	1.2**	3.1NS
Error	18	0.005	0.001	13918.3	7.9	0.162	0.93
R^2		0.99	----	0.97	---	98	90
CV %		25.7	----	29.5	----	12.9	17.5

d.f =Degrees of freedom; MS= Mean squares; Significant **= P<0.01; ***= P<0.001; r^2 = adjusted value of coefficients of determination; €= Original
data square root transformed; CV= Coefficients of variation

Table 17 Least squares means for the performance of five local ecotypes and Fayoumi chicken under on station management conditions by sex and ecotype in Ethiopia (8-12 weeks of age)

Parameter	Ecotypes							
	Tilili (LSM ± SE)	Horro (LSM ± SE)	Chefe (LSM ± SE)	Jarso (LSM ± SE)	Tepi (LSM ± SE)	Mean (Local) (LSM ± SE)	Fayoumi (LSM ± SE)	Grand mean (LSM ± SE)
Both sexes:								
Gain (g/bird)	360.3± 0.4 [b]	289.4± 0.4 [d]	329.7± 0.4 [c]	277.2± 0.4 [e]	259.2± 0.4 [f]	303.1±0.02	459.6± 0.4 [a]	392.2± 0.02
Average daily gain (g)	8.6±0.01 [b]	6.9±0.01 [d]	7.9±0.01 [c]	6.6±0.01 [e]	6.2±0.01 [f]	7.2 0±0.01	10.9±0.01 [a]	7.8 ± 0.01
Total feed intake/bird(g)	1783.5±54 [b]	1393.3±54 [d]	1738.8±54 [c]	1511.4±54 [d]	1399.1±54 [d]	1632.0±24	2599.6±54 [a]	1793.3±21.9
Average daily feed intake(g)	42.0±1.3 [b]	33.2±1.3 [d]	41.4±1.3 [c]	35.9±1.3 [d]	33.3±1.3 [d]	38.9±0.6	61.9±1.3 [a]	42.7±0.5
FCR (feed:gain)	4.9± 0.2 [d]	5.0± 0.2 [cd]	5.3± 0.2 [b]	5.5± 0.2 [ab]	5.5± 0.2 [ab]	5.4 ±0.09	5.6± 0.2 [a]	5.5±0.08
Mortality (%)	30.6±3.5 [b]	37.3±2.7 [ab]	7.8±3.9 [c]	42.4±2.8 [a]	49.5±4.2 [a]	33.5±2.1	12.9±4.8 [c]	30.1±2.8
Male:								
Gain (g/bird)	382.2±0.5 [a]	365.5±0.5 [a]	349.5±0.5 [a]	311.8±0.5 [a]	304.1±0.5 [a]	342.6±0.03	512.4±0.5 [a]	370.9±0.2
Average daily gain (g)	9.1 ± 0.01 [a]	8.7± 0.01 [a]	8.3± 0.01 [a]	7.4± 0.01 [a]	7.2± 0.01 [a]	8.1±0.01	12.2± 0.01 [a]	8.8±0.01
Total feed intake/bird(g)	1996.6±83.4 [a]	1611.2±83 [a]	2013.3±83 [a]	1605.3±83.4 [a]	1572.9±83.4 [a]	1849.8±37.6	3049.3±83.4 [a]	2049.7±34.1
Average daily feed intake(g)	47.6±2 [a]	38.4±2 [a]	47.9±2 [a]	38.2±2 [a]	37.5±2 [a]	44.0±0.9	72.6±2 [a]	48.8±0.8
FCR (feed:gain)	5.2 ±0.3NS	4.4±0.3 NS	5.8±0.3 NS	5.2±0.3 NS	5.2±0.3 NS	5.4±0.14	5.9±0.3 NS	5.5±0.1
Female:								
Gain (g/bird)	338.3± 0.4 [b]	213.3± 0.4 [b]	309.9± 0.4 [b]	242.6± 0.4 [b]	214.2± 0.4 [b]	263.7±0.02	406.8± 0.4 [b]	287.5±0.18
Average daily gain (g)	8.1±0.01 [b]	5.1±0.01 [b]	7.4±0.01 [b]	5.8±0.01 [b]	5.1±0.01 [b]	6.3±0.01	9.7±0.01 [b]	6.9±0.01
Total feed intake/bird(g)	1530.5±66.1 [b]	1175.4±66 [b]	1555.8±66 [b]	1417.5±66.1 [b]	1225.2±66.1 [b]	1414.2±30.7	2149.9±66.1 [b]	1536.8±27.8
Average daily feed intake(g)	36.4±1.6 [b]	28.0±1.6 [b]	37.0±1.6 [b]	33.7±1.6 [b]	29.2±1.6 [b]	33.7±0.7	51.2±1.6 [b]	36.6±0.7
FCR (feed:gain)	4.5±0.2NS	5.5±0.2NS	5.0±0.2 NS	5.8±0.2 NS	5.7±0.2 NS	5.4±0.11	5.3±0.2 NS	5.4±0.1

[abcd] Means within a row (both sexes) and columns (sex) followed by different superscripts are significantly different, at $p < 0.05$.

the lowest feed requirement per units of gain was recorded for male growers from the same ecotype followed by male chicks from *Tilili, Jarso, Tepi* and *Chefe* ecotypes (Table 18).

There was a significant ($p<0.05$) difference in the mortality rate of the different ecotypes. All local ecotypes were inferior in health status and rate of survival compered to Fayoumi chicks. Generally, lack of interest in their environment, wing droppings and huddling at the corners of the pen were observed in all local ecotypes unlike the chicks from Fayoumi breed in the early ages. In later ages, starting from the 12 to 14th weeks of age there was a Mark's disease outbreak, which causes a huge mortality and morbidity in all ecotypes.

4.2.1.2.3 Day old to 12 weeks of age

The results of the analysis of variance (Table 19) show a highly significant ($p<0.001$) difference among ecotypes on total body weight gain per bird, average body weight gain per bird per day, total feed intake, average feed intake per bird per day and feed conversion ratio (feed: gain) from day old to twelve weeks of age.

Table 19 Means Squares from the analysis of variance for the performance of five local chicken ecotypes and Fayoumi under on station management conditions in Ethiopia (0-12 weeks of age)

Sources of variation	d.f	Parameters				
		Gain (gram/bird)	Average daily gain (gram/bird)	Total feed intake/bird (gram/bird)	Average daily feed intake (gram/bird)	Feed conversion ratio (feed: gain)
		MS	MS	MS	MS	MS
Ecotype	5	850173.1***	5.9***	1644817.9***	233.1***	0.55*
Error	18	7755.6	1.1	142657.6	20.2	0.8
R^2		0.96	----	0.97	----	0.97
CV %		27.9	---	27.0	----	14.8

d.f =Degrees of freedom; MS= Mean squares; Significant *=P<0.05; ***= P<0.001; r^2 = adjusted value of coefficients of determination; CV= Coefficients of variation

The least squares means for the performance of five local ecotypes and Fayoumi chicken under station management conditions from day old to 12 weeks of age are presented in Table 20.

Table 18 Least squares means for the performance of five local ecotypes and Fayoumi chicken under on station management conditions by ecotype-sex interaction in Ethiopia (8-12 weeks of age)

Parameter	Ecotypes							
	Tilili (LSM ± SE)	Horro (LSM ± SE)	Chefe (LSM ± SE)	Jarso (LSM ± SE)	Tepi (LSM ± SE)	Mean (Local) (LSM ± SE)	Fayoumi (LSM ± SE)	Grand mean (LSM ± SE)
Sex								
Male:								
Gain (g/bird)	382.2±0.5 [b]	365.5±0.5 [c]	349.5±0.5 [d]	311.8±0.5 [e]	304.1±0.5 [f]	342.6±0.03	512.4±0.5 [a]	370.9±0.2
Average daily gain (g)	9.1 ± 0.01[b]	8.7± 0.01 [c]	8.3± 0.01 [d]	7.4± 0.01[e]	7.2± 0.01[f]	8.1±0.01	12.2± 0.01[a]	8.8±0.01
Total feed intake/bird(g)	1996.6±83.4 [c]	1611.2±83.4 [d]	2013.3±83.4 [b]	1605.3±83.4 [d]	1572.9±83.4 [d]	1849.8±37.6	3049.3±83.4 [a]	2049.7±34.1
Average daily feed intake(g)	47.6±2 [c]	38.4±2 [d]	47.9±2 [b]	38.2±2 [d]	37.5±2 [d]	44.0±0.9	72.6±2 [a]	48.8±0.8
Feed conversion ratio(feed:gain)	5.2 ±0.3[bc]	4.4±0.3[c]	5.8±0.3[a]	5.2±0.3[bc]	5.2±0.3[bc]	5.4±0.14	5.9±0.3[b]	5.5±0.1
Female:								
Gain (g/bird)	338.3± 0.4 [b]	213.3± 0.4[e]	309.9± 0.4 [c]	242.6± 0.4[d]	214.2± 0.4 [e]	263.7±0.02	406.8± 0.4 [a]	287.5±0.18
Average daily gain (g)	8.1±0.01[b]	5.1±0.01[e]	7.4±0.01 [c]	5.8±0.01 [d]	5.2±0.01 [e]	6.3±0.01	9.7±0.01 [a]	6.9±0.01
Total feed intake/bird(g)	1530.5±66.1[b] [c]	1175.4±66.1[e]	1555.8±66.1[b] [c]	1417.5±66.1 [cd]	1225.2±66.1[de]	1414.2±30.7	2149.9±66.1[a]	1536.8±27.8
Average daily feed intake(g)	36.4±1.6 [bc]	28.0±1.6 [e]	37.0±1.6 [bc]	33.7±1.6 [cd]	29.2±1.6 [de]	33.7±0.7	51.2±1.6 [a]	36.6±0.7
Feed conversion ratio(feed:gain)	4.5±0.2[b]	5.5±0.2[a]	5.0±0.2[b]	5.8±0.2[a]	5.7±0.2 [a]	5.4±0.11	5.3±0.2 [a]	5.4±0.1

[abcd] Means within a column followed by different superscripts are significantly different; at P<0.05

Among the local ecotypes, *Jarso* and *Tepi* had the smaller body sizes while *Tilili* growers had larger total body weight gains. Chicks from *Jarso* and *Tepi* ecotypes (least total body weight gains among the locals at this age) showed a significantly ($p>0.01$) lower total body weight gain per bird and mean daily body weight gain per bird than local chicks from the other three agro-ecological regions and the reference breed. The highest body weight gain per bird and mean daily body weight gain per bird per day among the locals were recorded for *Tilili* growers. The Fayoumi growers showed 36, 85 and 63% more body weight gain than chicks from *Tilili* ecotypes (heaviest locals at this age), *Jarso* ecotype (least total body weight gain among the locals at this age) and mean body weight gain of local birds, respectively. *Jarso* growers showed a 35% negative deviation over growers from *Tilili* in terms of total body weight gain per bird from day old to twelve weeks of age.

Feed consumption levels of *Jarso* ecotype were the lowest with a daily average of 22.9g followed by *Horro* and *Tepi*, which are averaged 24.1 and 24.3g/day, respectively. The mean daily feed intake for all the local ecotypes was 25.6g/day while the Fayoumi's consumed 46.1g/day per bird. The *Chefe* and *Tilili* ecotypes on average consumed 12 and 10% more and *Jarso*, *Horro and Tepi* consumed 11, 6 and 5% less feed than the average feed consumption of the local ecotypes, respectively. The Fayoumi chicks consumed 64, 101 and 80% more feed than *Tilili chickens* (with highest feed intake among locals at this age), *Jarso* ecotype (least feed intake among the locals at this age) and all local ecotypes. Feed conversion ratio was also significantly ($p<0.01$) affected by ecotypes. The highest feed requirement per unit gain was recorded for the Fayoumi chicks followed by chicks from *Tepi* and *Horro* chicks. The lowest feed requirement per units of gain was recorded for *Tilili* and *Chefe* chicks (4.95g and 5.2g feed per unit of gain).

4.2.1.2.4 Carcass analysis

From the analysis of variance (Tables, 21 and 23) it was revealed that ecotype and sex affected significantly ($p<0.05$) the development of the different organs and tissues of growers as percentage of live body weight at 12 weeks of age. Feet weight and liver and heart weight and sex on gizzard and crop weights were not affected by ecotype. Sex had significantly ($p<0.05$) affected liver and heart weight.

Least squares means for various carcass traits are presented in Tables 22 and 24. The lowest average weight of carcass was 277.4g for the *Tepi* ecotype and with 425.3g, the highest for the

Tilili only exceeded by Fayoumi which had a mean carcass weight of 448.8g at 12 weeks of age. The mean carcass weights of Tilili and Tepi ecotypes were 94 and 62% of the mean carcass weight of Fayoumi chickens, respectively, while the mean carcass weight of all local chickens was 78 percent of that of the Fayoumi breed.

All local ecotypes except *Jarso* had a higher dressing percentage than Fayoumi chicken. Gizzard, crop and head with wattle weights as percentage of live body weight at 12 weeks of age were higher in local ecotypes than Fayoumi chicken. Among local chicken ecotypes *Tilili* and *Chefe* ecotypes, followed by *Tepi, Horro* and *Jarso* ecotypes gave the highest dressing percentage ranging from 64 to 62%. This shows that ecotypes with increased body weights also manifested increased dressing percentage, which was not true for Fayoumi chickens. Unlike the liver and heart weight, which were higher in females (3.5 Vs 3.9%) male growers had a higher dressing percentage (64.2%) in comparison to females (61.5%).

Table 20 Least squares means for the performance of five local ecotypes and Fayoumi chicken under on station management Conditions in Ethiopia (0-12 weeks of age)

Parameter	Ecotypes							
	Tilili (LSM ± SE)	Horro (LSM ± SE)	Chefe (LSM ± SE)	Jarso (LSM ± SE)	Tepi (LSM ± SE)	Mean Local (LSM ± SE)	Fayoumi (LSM ± SE)	Grand mean (LSM ± SE)
Day old body Wt (g)	30.7 ± 0.25 [c]	28.7± 0.37 [d]	32.4 ± 0.29 [b]	25.8 ± 0.26[e]	26.0 ±0.37 [e]	28.7± 0.15	41.04 ± 0.37 [a]	30.8± 0.13
Total gain (g/bird)	478.8±39.4[b]	428.8±50.9 [c]	466.1±39.4 [bc]	349.1±39.4[d]	369.8±50.9[d]	405.2±18.1	657.7±50.9[a]	458.4±18.6
Average daily gain (g)	5.7±0.5 [b]	5.1±0.6 [c]	5.6±0.5 [bc]	4.2±0.5 [d]	4.4±0.7 [d]	4.8±0.2	7.8±0.6 [a]	5.5.±0.2
Total feed intake/bird(g)	2360.4±168.9[b] [c]	2022.8±228. 1[c]	2409.1±168.9[b] [c]	1926.3±168. 9[c]	2038.1±218. 1[c]	2216.0±70. 5	3867.9±218. 1[a]	2541.6±79. 6
Average daily feed intake(g)	28.1±2.0 [bc]	24.1±2.6 [c]	28.7±2.0[bc]	22.9±2.0[c]	24.3±2.6[c]	25.6±0.8	46.1±2.6[a]	30.3±0.95
Feed intake ; g DM /day X g [0.75]	1.11±0.04[c]	1.31±0.05 [ab]	1.31±0.05 [ab]	1.18±0.05 [bc]	1.21±0.05 [bc]	1.22±0.02	1.44±0.05 [a]	1.26±0.02
Feed conversion ratio(feed:gain)	4.95±0.4[b]	5.72±0.5[a]	5.20±0.0.4[b]	5.63±0.4[a]	5.7 2±0.5[a]	5.62±0.16	5.93±0.0.5[a]	5.64±0.2

[abcd] Means within a row followed by different superscripts are significantly different; *=P<0.05.

Fig. 2 Average daily body weight gain (g) /day / bird of five local ecotypes and Fayoumi chicken under on station management conditions in Ethiopia (0-6, 6-12 and 0-12 weeks of age)

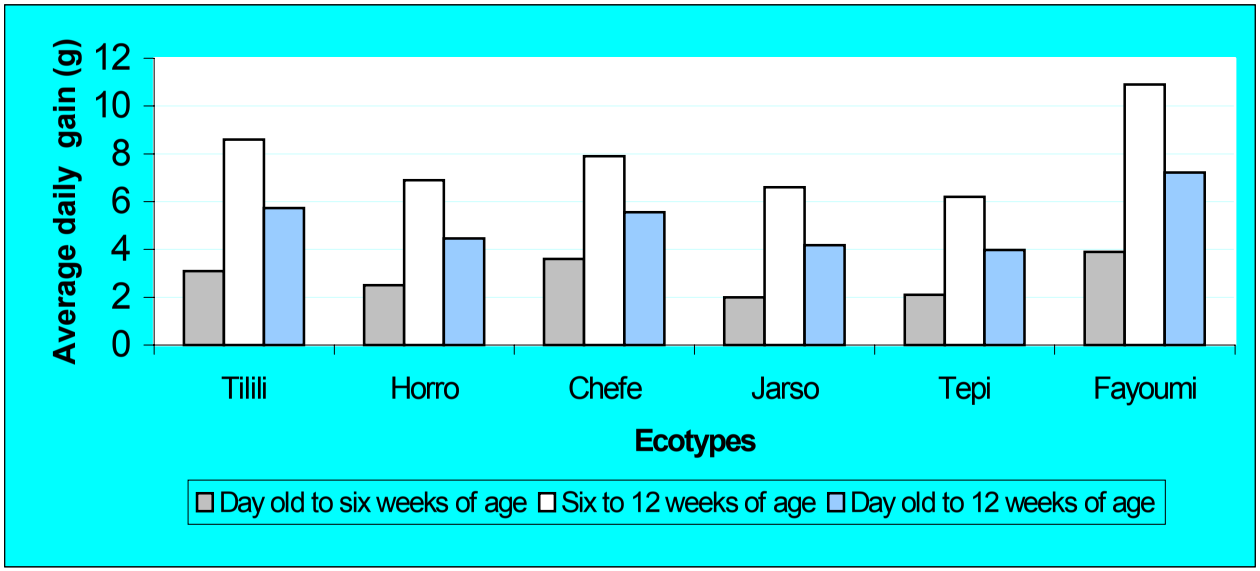


Table 21 Analysis of variance for organ and tissue development of growers as percentage of live weight at 12 weeks of age for six different genotypes of chicken in Ethiopia

Source Of variation	d.f.	Live weight(g) MS	Carcass Weight (g) MS	Percentage of live weight					
				Carcass weight MS	Gizzard Weight MS	Crop Weight MS	Head with wattle weight MS	Feet weight MS	Liver and heart weight MS
Model	12	1628332.3*	651363.1*	19777.9*	47.3*	0.89*	120.5*	24.3NS	71.0*
Genotype	5	134358.4*	55450.2*	5.3*	2.5*	0.09*	1.044*	0.06NS	2.3NS
Sex	1	127307.1*	79358.6*	108.4*	0.02*	0.01*	22.1*	1.8NS	2.7*
Genotype * sex	5	10611.1*	4469.1NS	2.1NS	0.7NS	0.009NS	0.2NS	0.1NS	0.5NS
Error	48	7286.6	3321.7	4.083	0.4	0.008	0.4	0.006	0.7
r^2		0.97	0.97	0.99	0.96	0.95	0.98	0.98	0.95

d.f= degrees of freedom; MS= Mean squares:; Significant *= P<0.05; NS= non-significant; r^2= adjusted value of coefficients of determination

Table 22 Least Square Means (LSM) for carcass traits 12 weeks of age for six different ecotypes of chicken in Ethiopia

Groups	Live weight (g)	Carcass Weight (g)	Percentage of live weight					
			Carcass Weight	Gizzard Weight	Crop weight	Head with wattle wt.	Feet weight	Liver and heart weight
	LSM (60)	LSM (60)	LSM (60)	LSM (60)	LSM (60)	LSM (60)	LSM (60)	LSM (60)
Genotype								
Tilili	662.9 ^{ab}	425.3 ^{ab}	63.9 ^{a}	2.7 ^{cd}	0.36 ^{bc}	4.9 $^{a b}$	2.1	3.5
Horro	478.5^{c}	299.5 ^{c}	62.4 $^{a b}$	3.4 ^{ab}	0.41 ^{b}	5.2 ^{a}	2.1	3.7
Chefe	587.9^{b}	373.9 ^{b}	63.5 $^{a b}$	3.1 ^{bc}	0.52 ^{a}	4.5 ^{b}	2.2	3.6
Jarso	460.7^{c}	287.5 ^{c}	62.1 ^{b}	2.8 ^{cd}	0.29 ^{c}	5.1 ^{a}	2.2	3.6
Tepi	440.4^{c}	277.4 ^{c}	63.0 $^{a b}$	3.8 ^{a}	0.54 ^{a}	5.1 ^{a}	2.3	3.7
Fayoumi	718.2^{a}	448.8 ^{a}	62.4 $^{a b}$	2.4 ^{d}	0.36 ^{bc}	4.4 ^{b}	2.2	3.2
s.e	26.9	18.2	0.64	0.19	0.03	0.19	0.08	0.27
Sex								
M	604.2 ^{a}	388.4 ^{a}	64.2 ^{a}	3.1 ^{a}	0.43 ^{a}	5.5 ^{a}	2.4	3.5 ^{b}
F	512.0 ^{b}	315.7 ^{b}	61.5 ^{b}	3.0 ^{a}	0.39 ^{a}	4.3 ^{b}	2.0	3.9 ^{a}
s.e	15.6	10.5	0.37	0.11	0.02	0.12	0.05	0.15
Overall mean	558.1± 11	351±7.4	62±0.26	3.03±0.08	0.4±0.01	4.9±0.08	2.2±0.33	3.7±0.11

*Figures in bracket represents number of observations; ^{abcd} Means within a column followed by different superscripts are significantly different; at P<0.05.

Table 23 Analysis of variance for Thigh Muscle Circumference (TMC), breast angle and GIT length of growers at 12 weeks of age for six different chicken ecotypes in Ethiopia

Sources of variation	d.f	TMC (cm)	Breast angle	GIT length (cm)
		MS	MS	MS
Model	12	288.4***	15.6***	101317.9***
Genotype	5	10.9***	0.2***	4039.5***
Sex	1	7.9**	0.16*	1369.2*
Genotype * sex	5	0.8NS	0.02NS	121.5NS
Error	48	0.4	0.02	200.5
r^2		94	93	96

d.f= degrees of freedom; MS= Mean squares:; Significant *= P<0.05; *= P<0.01; *= P<0.001; NS= non-significant; r^2= adjusted value of coefficients of determination

Table 24 Least squares means (LSM) of Thigh Muscle Circumference, breast angle and Gastro Intestinal Tract length of growers at 12 weeks of age for six different ecotypes of chicken in Ethiopia

Groups	Thigh Mussel Circumference (TMC) (cm)	Breast angle	Gastro Intestinal Tract (GIT) length (cm)
	LSM (60)	LSM (60)	LSM (60)
Genotype			
Tilili	8.8[a]	1.8[ab]	148.9[b]
Horro	6.8[c]	1.7[bc]	135.1[c]
Chefe	7.6[b]	1.8[ab]	128.9[cd]
Jarso	6.9[c]	1.5[d]	117.2[d]
Tepi	6.2[d]	1.6[cd]	140.3[bc]
Fayoumi	8.6[a]	1.9[a]	175.8[a]
s.e	0.19	0.05	4.5
Sex			
M	7.9[a]	1.8[a]	145.9[a]
F	7.2[b]	1.7[b]	136.3[b]
s.e	0.11	0.03	2.6
Overall mean	7.5±0.08	1.8±0.02	141±1.83

4. Discussions

The results of this study clearly show the existence of large variation in growth and feed utilization potentials between the different chicken ecotypes in Ethiopia. This result agrees with previous reports from Ethiopia and elsewhere in the tropics (Teketel, 1986; Olori, 1994; Sonaiya *et al,* 1999; Tadelle *et al* 2000 and Tadelle and Ogle, 2001) who state that there are many ecotypes, breeds and strains of indigenous poultry that are well adapted to their production environments. According to Teketel (1986) and Shanawany (1987), the hatching weights of chicks followed the egg weight pattern in the parental population. The mean hatching weight of

day old chicks from *Chefe* and *Tilili* ecotypes were higher than the other three local ecotypes. At increasing ages weight differences at hatching persisted and even grew throughout the growing period. A study at the Assela Livestock Farm revealed that the average egg weight of local chickens in Ethiopia is 38 g under scavenging conditions (Brännäng and Pearson, 1990) and according to Negussie (1999) the average egg weight of Fayoumi chicken was reported to be 46 g. The results of this study showed that a 1g difference in egg weight led to a 1.5g difference in body weight at hatch, to 7g at six weeks and to 32g at 12 weeks of age. This is in agreement with the findings of Al-Murrani (1978) and Teketel (1986) where it was reported that 1g difference in egg weight was reflected in about 8 to 10g difference in chick weight at 2 months of age.

The growth performance of ecotypes studied underlines the rather large difference between ecotypes, *Tilili* and *Chefe* ecotypes exhibiting a remarkably higher performance levels than the other three local ecotypes. Mathur *et al.* (1989) and Nwosu (1979) reported that whenever evaluation schemes were implemented, it has been found that there are highly productive indigenous birds. Even though there is no documented introduction of exotic blood in the *Chefe* region aimed at upgrading the indigenous chicken, some previous introduction should be assumed, mainly due to its proximity to research and extension centers in that region. The farming community in *Tilili* area is known for their chicken production culture and the Tilili ecotype (*Y-Tilili Doro)* is re known for its productivity and prolificacy. The higher growth performances of chicks from *Chefe* and *Tilili* market sheds tend to agree with above assertions. There exists a large variation in growth and feed utilisation potentials between individuals within ecotypes, indicated by the high coefficients of variations within ecotypes. According to Hammond (1999) large between bird variation for most traits is an important common feature of animal-level data from locally adapted family poultry populations, with coefficients of variation of 25-50% rather than the 5-15% found in the high input types and systems and it seems that this large variability exists for both intake and output traits.

The mean body weight gain of local ecotypes in this study at eight weeks of age was 212g which is higher than reported by Tadelle and Ogle (2001), who reported 157g average body weight gain under traditional management conditions in the central highlands of Ethiopia even though both studies reported almost similar average hatching weights. This indicates that changing the management could bring measurable changes in growth performances of local chicken ecotypes. Mixed sexed local chicken ecotypes from this study had a mean body weight gain of 405g with a range from 349 to 479g, which is lower than reported by Mafeni (1995) for indigenous chicken in Cameroon (538g) and higher than reported by Omeje and Nwosu (1984) for Nigerian chickens

(371g) and Teketel (1986) for southern Ethiopian chickens (351g) at 12 weeks of age. The AACMC (1984) reported that local male chicken in Ethiopia reach 1.5kg live weight at 6 months of age and females about 30% less. Males from this study were 36% heavier than their female contemporaries at 18 weeks of age. Teketel (1986) also found that local stocks reach 61% and 85% of Leghorn body weight at 6 months and at maturity, respectively, which is in agreement with results of this study where locals attain 66 to 74% of the body weight of the reference breed at eight to 18 weeks of age. Abebe (1992) reported that local chickens in eastern Ethiopia attain 71.5% of weights of Leghorns at 6 months of age. The carcass weight of local stocks at 12 weeks of age was significantly lower than that of the Fayoumi, however the local stock had a higher dressing percentage. This is also in agreement with other reports (Teketel, 1986; Abebe, 1992).

Buldgen *et al.* (1992) and Guèye *et al.* (1998) underlined the difficulty of obtaining information on the age and body weight of birds in the villages and markets of the tropics. The results of the present study showed the strong relation between live body weight and shank lengths as body measurements of the local chicken ecotypes. This agrees with reports of Ngou Ngoupayou (1990); Missohou *et al* (1997) in indigenous chickens and Hassan and Adamu (1997) in indigenous pigeons. The most direct way to determine an animal's body weight is to weigh it. However, under village circumstances, a scale is not available. An alternative is to measure a body part and relate the measurement to body weight. Hassan and Adamu (1997), for indigenous pigeons and Guèye *et al.* (1998) for indigenous chicken reported that body length as well as chest width are strongly and significantly correlated to live body weight. Shank length is the body part that is commonly measured in poultry to relate to body weight. The first attempt that related body weight and shank length in one breed of chickens had an R^2 =0.66 (Lerner, 1937 cited by Latshaw and Bishop, 2001). According to Latshaw and Bishop (2001) relating Pelvis width and body weight reported an R^2 value of 0.67. The above reports are in agreement with the results reported in the present work at 12 and 18 weeks of age (R^2 = 0.63 and 0.64). Developed prediction equations using shank length can easily be used to estimate live body weight of village chicken on-farm. Inclusion of more body measurements improved the quality of fit in estimating body weight. Adding the variables Thigh Muscle Circumference (TMC) and breast angle to shank length slightly improved the R^2 of the regression equation.

The average daily feed intake per bird among local ecotypes ranged between 23g for *Jarso* ecotype to 28g for *Tilili* ecotype illustrated the strong relationships with the average daily body weight gain in the different ecotypes. With an averrage daily body weight gain of 5.7 g *Tilili* were

the fastest growing chicken from the locals and recorded the highest feed intake per bird per day. The corelation coofficent (pooled) between body weight gain and feed intake in this study showed positive and significat relations. However, average feed intake per metabolic body weight showed the same trend except for *Chefe* and *Horro* ecotypes which consumed more feed per metabolic body weight. Local ecotypes have a higher feed conversion efficiency, which might be perhaps due to their smaller maintenance requirements as compared to the Fayoumi chicken. The growth performance of Fayoumi, the breed used as a reference breed in this study was in agreement with other study report in Ethiopia (Negussie, 1999).

The very high mortality rate and the activities of chicks that are reported in this study agrees with earlier reports by Teketel (1986) from Awassa, Brännäng and Persson, (1990) from Arsi, Abebe (1992) in Debre Zeit and Abebe (1992) from Alemaya. The most probable reason for the observed high mortality and morbidity of local chicks at the early age under intensive management could be due to the fact that they are not used to confinement and diseases which are important under confinement such as coccidiosis, chronic respiratory disease, Marek's disease, among others, could cause the situation. However, the high mortality and morbidity at the late age was due to Marek's disease as it was confirmed by symptoms and post-mortem analysis.

In the result of this study *Fayoumi* males were significantly more efficient than males of *Chefe* ecotype. Indeed, in all the other cases, local ecotypes showed similar or higher efficiency than the reference breed. Regardless of ecotype, males showed a higher efficiency of growth than females. This is expected and it would be related to the higher proportion of muscle (protein) in males than in females. According to Combs (1976) females consistently have a higher percentage of body fat than males, but the difference is especially pronounced after the seventh week of age. Therefore, males have a higher growth capacity. It is important to mention that exponential growth occurs only before the birds reached to maturity. Consequently, the results found in this study cannot be extrapolated to older animals.

Tepi represents an interesting case. *Tepi* has one of the lowest day-old body weight, the lowest 18^{th} week body weight, and the highest efficiency of growth. This high efficiency contrasts with the low weights found. Except for *Tepi*, all ecotypes decrease their growth rate up to 18^{th} weeks of age, only *Tepi* showed an increasing growth rate. This might be explained by the different physiological ages between ecotypes. Thus, *Tepi* was physiologically younger than the other ecotypes, and therefore *Tepi's* growth rate was still increasing when the experiment finished. This

result is in agreement with Rose (1997), who stated that time taken to reach mature body weight as another important variable that describes the growth of a bird. This shows that growth efficiency comparisons should consider the time taken to reach maximum growth rate an important variable. Indeed, the differences in physiological ages did not allow being conclusive regarding the relative efficiency of one ecotype to the others. Actually, data from some of the early maturing ecotypes (e.g. *Tilili*) would fit better to a growth model with an inflexion point than to the exponential model.

5. Conclusions

The growth, feed utilization and carcass production potentials of ecotypes studied underlines the rather large difference between ecotypes, *Tilili* and *Chefe* ecotypes exhibiting a remarkably higher performance levels than the other local ecotypes. In addition all local ecotypes have better feed conversion efficiency than Fayoumi chickens. Based on the results of this study it is possible to conclude that the local ecotypes have the genetic ability to grow and produce more and above their performance under village conditions if properly managed.

Virtually all the indigenous ecotypes have not been subjected to any selection process other than natural selection and from the results of this study there is a large variation in growth and feed utilisation potentials between individuals within ecotypes with higher coefficients of variations. Thus, there is potential for improving locally adapted ecotypes by selection. Given the short generation interval of chicken substantial gains in genetic progress within the existing production environment could be obtained through identifying and selecting the top performers for a given trait (s).

The exhibited positive and significant relationship between live body weight and shank length as a linear body measurement in this study could possibly be used to estimate the body frame and it could be used in conjunction with body weight to describe the growth type and potentials of the ecotypes.

Body weight development and feed efficiency are important determinants of productivity of chicken under heat stress and an inducer of genotype-environment interactions. Birds from different market sheds showed different growth characteristics and degrees of variability. Sampling of local birds on the basis of agro-ecological regions and market shed for the purpose of characterisation is appropriate.

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CHAPTER V

Measuring the genetic distance between and within the different chicken ecotypes

This paper is to be submitted in Poultry Science Journal

1. Introduction

In the past, indigenous chicken populations have been neglected and little attention has been given from researchers, development workers and policy makers to put them in the research and development agendas in the tropics. According to FAO (2000), about 34% of all avian breeds in Africa are at risk of being lost, however, the full picture in Ethiopia is not known. The genetic potential of indigenous poultry as a reservoir of genomes and major genes with relevance to improve adaptability and has been recognised by (Nwosu, 1979 and Horst, 1989). The regaining importance of traditional or family poultry production with indigenous poultry stock is addressing again the need to consider the value of indigenous poultry ecotypes (Traoré, 1997) as part of the genetic biodiversity pool and as a means to effectively use local poultry resources. in the face of loses of breeds and genetic variation.

The presence of considerable variation in feather cover, growth characteristics, body positions/ shapes and egg production of birds in different regions (Chapter III) and the existence of large variation in growth performance and feed utilisation potentials between the different chicken ecotypes (chapter IV) in Ethiopia gives an indication to the presence of genetically distinct ecotypes. The geographical location of Ethiopia which is near the historical entry point of many initial migratory livestock populations from Asia, its diverse topography, climate, the wide range of production systems and the huge livestock population size (Epstein, 1971; Epstein and Mason, 1984) coupled with the presence of different cultures, nations and nationalities are good reasons to assume genetic diversity. However, morphological traits have limited usefulness to study the genetic variation or the divergence between population since appearance is not necessarily a good guide to genetic variation (Kidd and Sgaramella-Zonta, 1972). Similarly the expression of economically important traits is strongly influenced by the prevailing production environment and have limited usefulness for genetic classifications (Hines, 1999). Methods used for genetic characterisation purposes should be largely independent of the environment. Genetic distance using the advent of DNA-level analyses is a more reliable measure of genetic difference within and between breeds. Thus, the objective of this study was, to asses the between and within genetic diversity of five indigenous chicken ecotypes of Ethiopia and of Fayoumi chicken as a reference breed using microsatllite Loci.

2. Materials and Methods

2.1 Sampling of animals and DNA extraction

Chicken ecotypes used in this study were collected from market sheds of five agro-ecological regions of Ethiopia and kept at Debre Zeit Agricultural Research Centre for performance characterization (Chapter IV). Sampling procedures were applied as suggested by Mathur (1995). DNA was isolated from blood of 25 individuals from each of the five chicken ecotypes *Tilili, Horro, Chefe, Jarso* and *Tepi* and from Fayoumi. Blood samples were collected in 2-ml tubes containing 80µl EDTA (final concentration: 0.5 M), and stored at –70°C until DNA-extraction. The DNA isolation was done according to Sambrook *et al.* (1989) and was extracted using a Qiagen DNA-extraction kit (Qiagen, Germany). DNA concentrations were quantified spectrophotometrically, and samples were diluted to a concentration of 10 ng/µl. The DNA was brought to Germany and the distance analysis was done using microsatellites at the molecular genetic laboratory of the Agricultural Faculty, Humboldt University of Berlin.

2.2 Microsatellites markers used

The microsatellite primers were selected from primers used by the EU funded project "Development of Strategy and Application of Molecular Tools to Assess Biodiversity in Chicken Genetic Resources, EC Contract Number BIO4-CT98-0342" and based on FAO's recommendation as outlined in MoDAD report (FAO, 1995) to use microsatellite loci as the core of a genetic biodiversity study. Information about each marker was obtained from Wageningen Agricultural University. This approach was chosen to allow the evaluation of genetic distance of the Ethiopian ecotypes in relation to the world-wide genetic resources in chicken. Details of the included breeds are published by Tixier-Boichard *et al.* (1999) and Hillel *et al.* (1999). Meanwhile, the ten microsatellite primers used in this study were chosen based on the degree of polymorphism and genome coverage (Crooijmans et al., 1997). As reported by Groenen et al. (1998), the characteristics of the markers used, including the chromosome location, expected range in base pairs and number of alleles are summarised in Table 1.

Tablle 1 Details (names, ch romosomal position and other characteristics) of microsatellite markers (primers)[1] used for the distance analysis of Ethiopian chicken ecotypes.

Number	Name of the primer	Chromosome number	Annealing temperature	Base pair	Number of alleles reported
1	MCW222	3	55	205-240	5
2	MCW248	1	55	205-235	6
3	MCW183	7	55	280-320	9
4	MCW294	Z	55	280-320	9
5	MCW295	4	55	85-120	6
6	MCW34	2	50	220-250	12
7	MCW78	5	50	130-150	6
8	MCW98	4	55	250-270	2
9	ADL268	1	-------	90-130	7
10	ADL278	8	-------	100-130	3

[1] Reference: MAM Groenen, 1998, http://www.zod.wau.nl/vf/research/cicken/body/-infotable.html).

2.3 Preparation of PCR reactions

PCR reaction for each animal DNA was prepared in a volume of 23 µl, containing 2.5µl 10X buffer, 0.75µl $MgCl_2$, 0.5µl dNTP, 0.5µl (10 pmol/µl) Forward primer (B), 0.5µl (10 pmol/µl) Reverse primer (A), 0.1µl DNA *Taq* polymerase (InViTek, Germany) and 18.15µl PCR water (to obtain 23 µl). The ingredients were thoroughly mixed by vortexing in order to produce a homogenous mix. The 23 µl mix was added to a PCR-tube containing 2µl target DNA and mixed thoroughly by vortexing. 40 PCR tubes with a homogenous mix were placed in to a Perkin-Elmer Cetus 9600 thermocycler in which the amplification of the Microsatellite DNA-fragments was done. The PCR cycles were programmed according to the following schemes: 4 min. at 94°C followed by cycles of 1min. at 94°C, 1min. at 55°C, 1 min. at 72°C, and an extension step of 4 min. at 72°C. This cycle has been repeated until a theoretical amplification factor of one million is attained. A specific program was used for every Microsatellite primer in the thermocycler based on the annealing temperature of the microsatellite. The sample program used for one of the microsatellite locus is presented in Table 2. Following the amplification the PCR product was checked before further applications for product formed, for the right size and quality of the product using gel electrophoresis. Some primers required further optimisation and PCR conditions until amplicons of a desirable quality were obtained.

Table 2 Sample program used for MCW00222

Temperature			Number of cycles
94^0C	55^0C	72^0C	
4 Min.	1 Min.	1 Min.	1X
1 Min.	1 Min.	1 Min.	29X
2 Min.	2 Min.	4 Min.	1X

2.4 Preparation of gel electrophoresis

The PCR products obtained were evaluated for efficiency, purification and amplification of the proper DNA fragments using gel electrophoresis. The liquid agarose gel solution was made by adding 1.5 gram powdered agarose to an Erlenmeyer flask and by adding 150 ml 1X Tris-borate (TBE) (pH 7.5) which is an electrophoresis buffer. The mix was heated to a boiling point in a microwave with a magnetic starrier to produce a homogeneous mixture. After the agarose was completely dissolved it was taken out from the microwave and allowed to cool down to approximately 50^0C. 15 µl Ethidium Bromide (EtBr) (10mg/ml) was added uniformly that helps to visualise the band by staining the gel, which fluoresces when exposed to ultraviolet light (UV). This solution was then poured into a Plexi-glas gel support system (gel cast containing a comb for slot formation) and allowed to cool and solidify for about 30 minutes, resulting in the formation of horizontal slab gel. After removing the comb, the gel was immersed in to a buffer tank, which was filled with 1XTBE electrophoresis buffer, which has EtBr. 6 µl PCR product with tracking dye bromophenol blue was loaded to each slot to monitor the electrophoretic mobility and band formation. Platinum electrodes were connected to a power supply (80 V) and an electric field established (~5V/cm). After 30 minutes, a picture of the gel was taken using UV transluminator and Polaroid camera for product quality and quantity analysis.

For the fragment analyses an automated A.L.F. ^{TM} DNA Sequencer was used designed for the automated electrophoresis and analysis of sequencing reactions by direct detection of fluorescently labelled DNA molecules and primers. Electrophoresis was carried out in a vertical gel cassette specially designed for easy and safe gel casting. After a PCR quality check, 2 µl PCR amplicons from each sample denatured and loaded onto a polyacrylamide sequencing gel. Samples were loaded into wells at the top of the gel and migrate downwards

through the gel during electrophoresis. The fixed laser beam passes through the glass light copler located between the notched glass plate and the thermoplate of the gel cassette, which is directed into the gel at right angles to the band migration. The laser beam excites the fluorescently labelled DNA bands and the light emitted is detected by photodetectors located behind the gel. The signals for each sample were collected and converted into serial digital data, which were stored in a computer. The A.L.F. ^{TM} DNA Sequencer has 40 photodetectors in which simultaneously 40 samples were loaded. The software used was the A.L.F. manager version 2.5, which operates under OS/2 operating system.

2.5 Methods of analysis

The output from the A.L.F. manager version 2.5 software was printed and fragment sizes in base pairs were made visible and data files were prepared in Microsoft Excel, for preparation of input files for statistical analyses. The statistical program Cervus 2.0 (Slate *et al.* 2000) was used for calculations of allele frequencies, heterozygosity and Mantel-test. Allele frequencies were calculated and a chi-square test was performed to test for Hardy-Weinberg equilibrium. Hetrozygosity per microsatellite marker was calculated according to (Rousset and Raymond 1995) using Genepop:

$$H_1 = [2n/2n-1]\ [1-i\ \square^{ml}\ (pl_i^2)]$$

Where: n = the number of individual chickens per population

ml= the number of alleles at locus 1

Pli =the frequency of the i^{th} allele at locus 1

The Polymorphic Information Content (PIC) values which describes the polymorpihc nature of the microsatellite markers tested were estimated according to (Rousset and Raymond 1995) using Genepop: PIC values were for all the microsatellites per chicken ecotype.

$$PIC = 1- (\Sigma^{n-1}_{i=1}\ pi^2) -\Sigma^{n-1}_{i=1}\ \Sigma^{n}_{j=i+1}\ 2pi^2\ pj^2$$

Where: n = number of different alleles for the specific locus
pi^2 and pj^2 = the population frequencies of the ith and jth allele

The standardized variance in allele frequencies over populations (F_{ST}) and microsatellite specific estimator (R_{ST}) values were calculated as estimators of genetic subdivision for each microsatellite marker across all populations. Fst-statistics was calculated using Genepop (Rousset and Raymond 1995) and R_{ST} calculations were made based on the fraction of the total variance of allele size between populations as proposed by (Slatkin 1995).

$$R_{ST} = \frac{S - s_w}{S}$$

Where: S is proportional to the total variance
s_w is proportinal to the within-population variance

Analysis of molecular variance (AMOVA) and Fis values were computed with the program package ARLEQUIN 2.000. As suggested by Barker (1994), describing the global protocol for determining genetic distances among domestic animal breeds or strains, in this study, Nei's (1978) unbiased standard genetic distance (Ds) was implemented. Bootstrap analyses were performed with 100 iterations in Microsat (Goldstein *et al.* 1995).

The standard genetic distance Ds, according to Nei (1978) is described as::

$$Ds = (1-J_{xy}) - ½ \{(1-J_x) + (1-J_y)\}$$

$$Ds = In [J_{xy}/☆ J_xJ_y]$$

Where: $J_x = (2n_x \Sigma X^2_i - 1)/(2n_X - 1)$
$J_y = (2ny \Sigma y^2_I - 1)/ (2n_y - 1)$
$J_{xy} = \Sigma xy$
n= population size (number of individuals)
x_iy_i = allele frequencies for x^{th} allele in population x and y

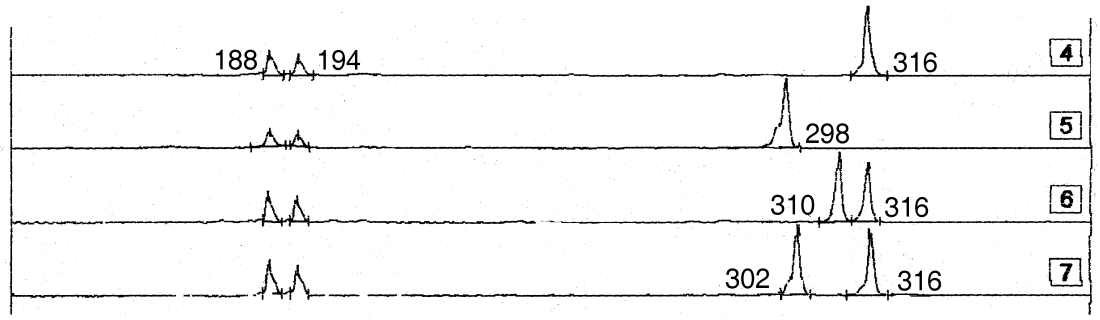
The results of these estimations were used to construct poylogenetic consensus tree. Both the Neighbour-Joining method (NJ) and Unweighted Pair-Group Method using Arithmetic Averages (UPGMA) were applied in the calculations for tree construction. Both these methds are considered to be useful in obtaining the correct tree topology, using standard genetic distances (Takezaki and Nei, 1996).

3. Results

3.1 Microsatellite Markers

The alleles observed from four individuals when genotyped using A.L.F. ^{TM} DNA Sequencer are illustrated in Fig. 1. It can be seen that from the four individuals two were heterozygotes and the other two were homozygotes, showing four different alleles (298, 302, 310 and 316) observed for the specific locus (MCW0183).

Fig. 1 Alleles observed from A.L.F. ^{TM} DNA Sequencer output (four individuals (*Tilili* ecotype) using microsatellite marker MCW0183)



The number of individuals genotyped and observed numbers of alleles for the different microsatellite markers by ecotype are shown in Table 3. About 98.6% of individuals has been genotyped, however DNA from some individuals (1.4%) failed to amplfy for specific markers, apparently because of failure of primers to amplify those loci (null alleles). The mean number of alleles from 10 microsatellite markers tested per ecotype varied from 4.2 (*Jarso*) to 5.3 (*Chefe*) with a range of 2 to 10 alleles in specific microsatellite marker in a specific ecotype.

Table 3 Observed numbers of alleles for the different microsatellite markers by ecotype and number of individuals genotyped.

Micro Satellite	Chicken ecotypes												Mean allele per loci (SD)
	Tilili		Horro		Chefe		Jarso		Tepi		Fayoumi		
	No.	All's	No.	All's	No	All's	No.	All's	No.	All's	No.	All's	
MCW0222	25	2	25	3	25	3	25	2	25	3	25	3	2.7 (0.52)
MCW0248	25	3	25	2	25	3	25	3	24	4	25	3	3.0 (0.63)
MCW0183	24	7	25	7	25	8	25	5	25	4	25	5	6.0 (1.55)
MCW0294	23	6	25	6	24	9	25	7	23	6	18	6	6.7 (1.21)
MCW0295	25	4	25	5	24	4	25	4	25	7	25	5	4.8 (1.17)
MCW0034	25	7	25	8	25	9	25	5	25	8	25	5	7.0 (1.67)
MCW0078	25	5	25	4	25	4	25	5	25	3	25	5	4.3 (0.82)
MCW0098	25	3	25	2	20	3	24	2	24	3	25	2	2.5 (0.55)
ADL0268	25	4	25	4	25	6	25	5	25	6	25	6	5.2 (0.98)
ADL0278	25	6	25	5	23	4	25	4	25	6	25	4	4.8 h(0.98)
Mean		4.7		4.6		5.3		4.2		5.0		4.4	
SD		1.8		2.0		2.5		1.5		1.8		1.3	

The observed characteristics of the 10-microsatellte markers used to test the six chicken populations and the different alleles observed are shown in Table 4. The number of alleles per loci varied from two (MCW0098) to 10 different alleles (MCW0294). Allele size ranged from a difference of four bp (219-223 bp; 253-257 bp) for locus MCW0222 and MCW0098, respectively, to a difference of 28 bp (298-326 bp) for locus MCW0183.

Table 4 Characterstics of microsatelite loci: observed number of alleles

Microsatellite	Number of alleles observed	Observed alleles
MCW0222	3	219 221 223
MCW0248	4	213 215 219 223
MCW0183	8	298 302 306 310 314 316 **322 326**
MCW0294	10	301 303 305 307 309 311 313 215 317 319
MCW0295	8	101 103 105 107 109 111 113 115
MCW0034	9	219 221 223 225 227 229 231 233 239
MCW0078	5	137 139 141 143 145
MCW0098	3	253 255 257
ADL0268	7	103 105 111 113 115 117 119
ADL0278	7	113 115 117 119 121 123 127

The individual allele frequencies estimated for all loci and ecotypes are shown in appendix 1-chapter V. Except for *Horro* and *Jarso* populations, alleles specific to a population were observed for five of the markers.

The Hardy-Weinberg equilibrium test for six of the chicken ecotypes and 10 of the microsatellite markers tested are presented in Tables 5 and 6. The Chi-square test result indicate that all the tested ecotypes showed no deviation from Hardy-Weinberg equilibrium. The result of the same test on 10 of the microsatellite markers tested showed that there were three microsatellite markers deviated ($p<0.01$) from Hardy-Weinberg equilibrium. Two of the markers (MCW0034 and MCW0294) tend to show a deviation in two populations (*Horro* and *Tepi*), however another marker (MCW0183) that deviated was specific to one population only (Fayoumi).

Table 5 Hardy-Weinberg equilibrium test for six of the chicken ecotypes tested using 10 microsatellite loci

Ecotypes	Mean number of alleles/locus	Mean H: Direct count	Mean H: Hardy-weinberg expected	proportion of individuals typed	Chi-square value	Sig.
Tilili	4.6	0.53	0.63	98.8	0.04	NS
Horro	4.5	0.47	0.54	100	0.37	NS
Chefe	5.3	0.55	0.63	96.4	0.41	NS
Jarso	4.2	0.38	0.52	99.6	0.04	NS
Tepi	4.9	0.43	0.58	98.4	2.77	NS
Fayoumi	4.4	0.45	0.60	97.2	1.39	NS

NS= not significant

Table 6 Hardy-Weinberg equilibrium test for 10 of the microsatellite loci tested in six chicken ecotypes

Microsatelite	Chi-square value	Significant level	Null allele frequency estimate
MCW0222	5.35	NS	0.082
MCW0248	1.75	NS	0.082
MCW0183	11.01	**	0.187
MCW0294	97.62	**	0.608
MCW0295	1.43	NS	0.037
MCW0034	18.47	**	0.118
MCW0078	0.01	NS	-0.013
MCW0098	0.58	NS	0.057
ADL0268	3.51	NS	0.024
ADL0278	5.35	NS	0.061

NS= not significant; *= $P<0.01$

3.2 Polymorpic Information Content (PIC) and Heterozygosity (H)

The Polymorpic information content (PIC) which describes the polymorpihc nature of the microsatellite markers tested is shown in Table 7. All the microsatellite markers tested were found to be highly polymorphic among all the tested ecotypes. On average, the PIC values per

marker varied from as low as 0.27 for MCW0098 (smaller number of alleles) to as high as 0.73 for MCW0294 (larger number of alleles) for the different microsatellite markers in all tested ecotypes. The highest PIC values were observed for markers MCW0183, MCW0294, MCW0034, ADL0268 and ADL0278. These markers also had the highest number of alleles (seven or more) and the observed alleles were more or less equally represented. However, marker MCW0295 gave low PIC value even though it had eight different alleles in which one of the alleles (103) was main (dominant). In Horro and Jarso ecotypes, for example, the dominant allele represented 83 and 80% of the four different alleles observed for marker MCW0295. The lowest PIC value was observed for marker MCW0098 in Fayoumi population in which the dominant allele accounted for 92% of the two alleles. Among the different ecotypes, the mean PIC values observed varied between the lowest PIC of 0.46 for the *Jarso* ecotype to the highest PIC of 0.55 for the Fayoumi chicken for all the microsatellite markers tested.

Table 7 Polymorphic information content (PIC) for microsatellite markers tested in the different fowl ecotypes

Microsatellite	Chicken ecotypes						Mean *	SD
	Tilili	Horro	Chefe	Jarso	Tepi	Fayoumi		
MCW0222	0.33	0.47	0.44	0.19	0.40	0.39	0.37	0.10
MCW0248	0.38	0.16	0.31	0.40	0.27	0.48	0.33	0.11
MCW0183	0.78	0.61	0.67	0.58	0.41	0.61	0.61	0.12
MCW0294	0.60	0.72	0.85	0.71	0.69	0.78	0.73	0.09
MCW0295	0.54	0.47	0.28	0.32	0.78	0.51	0.48	0.18
MCW0034	0.75	0.65	0.76	0.69	0.73	0.62	0.70	0.06
MCW0078	0.49	0.27	0.42	0.42	0.18	0.62	0.40	0.16
MCW0098	0.25	0.30	0.34	0.17	0.44	0.14	0.27	0.11
ADL0268	0.57	0.53	0.72	0.70	0.73	0.71	0.66	0.09
ADL0278	0.71	0.71	0.58	0.47	0.66	0.67	0.63	0.09
Mean**	0.540	0.489	0.537	0.465	0.529	0.553		
SD	0.180	0.194	0.206	0.202	0.215	0.185		

*Average PIC/ microsatellite marker; ** Average PIC/ecotype

The observed and expected Heterozigosity (H) indicating the gene diversity level for all microsatellite markers of the different chicken ecotypes under Hardy-Weinberg condition is presented in Table 8. The mean expected Heterozigosity varied between the lowest H of 55% for the *Jarso* ecotype to the highest H of 63% for *Tilili* and *Chefe* ecotypes for all the microsatellite markers tested. The observed Heterozigosity level per microsatellite in the ecotypes ranged from as low as 4% (MCW0078 in *Jarso*) to as high as 92% (ADL0268 in *Tilili*). The highest expected H values per markers were found in

Tilili, Chefe and *Horro* ecotypes, where 8 from 10 markers had H values above 50%. The *Tillili* (63%), *chefe* (63%), *Tepi* (61%) and Fayoumi (60%) showed higher variation, while the *Horro* (57%) and *Jarso* (55%) had a relatively lower variation. Significant differences were observed only between *Tilili* and *Jarso* and *Chefe* and *Jarso* populations for all the microsatelite markers tested.

Table 8 Heterozygosity values for microsatellite markers tested in the different chicken ecotypes

Micro Satellite	Chicken ecotypes											
	Tilili		Horro		Chefe		Jarso		Tepi		Fayoumi	
	H_o	H_e	H_o	H_e	H_o	H_e	H_o	H_e	H_o	H_e	H_o	H_e
MCW0222	0.44	0.50	0.60	0.56	0.40	0.56	0.24	0.25	0.48	0.50	0.36	0.46
MCW0248	0.36	0.43	0.20	0.25	0.36	0.35	0.36	0.55	0.32	0.38	0.56	0.57
MCW0295	0.76	0.61	0.52	0.52	0.32	0.39	0.24	0.38	0.84	0.83	0.20	0.47
MCW0294	0.12	0.72	0.12	0.79	0.40	0.90	0.24	0.79	0.12	0.80	0.24	0.86
MCW0034	0.84	0.80	0.72	0.70	0.72	0.81	0.36	0.78	0.56	0.79	0.56	0.72
MCW0078	0.44	0.52	0.36	0.39	0.52	0.51	0.60	0.49	0.20	0.19	0.44	0.49
MCW0098	0.32	0.31	0.52	0.46	0.36	0.60	0.04	0.29	0.24	0.58	0.16	0.19
ADL0268	0.68	0.63	0.60	0.59	0.80	0.79	0.80	0.75	0.64	0.79	0.64	0.76
ADL0278	0.92	0.80	0.76	0.78	0.64	0.70	0.44	0.56	0.48	0.72	0.64	0.73
MCW0183	0.44	0.86	0.40	0.70	0.76	0.73	0.52	0.68	0.32	0.47	0.56	0.71
Mean	0.53	0.63	0.48	0.57	0.53	0.63	0.38	0.55	0.42	0.61	0.44	0.60
SD	0.26	0.18	0.21	0.18	0.19	0.18	0.22	0.20	0.22	0.22	0.18	0.20

H_o =Observed Heterozigosity; H_e=Expected Heterozigosity

3.3 Genetic Distance

The genetic distances between and within ecotypes were further evaluated by estimating the genetic distance. Results of the Analysis of Molecular Variance (Amova) from haplotype frequencies of the six chicken ecotypes tested for 10 loci is presented in Table 9, and show that although there was considerable genetic variation between the different ecotypes, the within ecotype variation was higher than the between ecotype variation.

The unbiased estimator averaging over variance components in pairwise ecotype comparisons and standard errors are presented in Table 10. The smallest distance was found between ecotypes from *Tilili* and *Horro* (0.047) and the largest distance among the local ecotypes were found between Chefe and Tepi ecotypes (0.19).

Table 9 Analysis of Molcular Variance (Amova) result from haplotype frequencies of six chicken ecotypes tested for 10 loci.

Sources of variation	d.f.	Sum of squares	Variance components	Percentage of variation
Between ecotypes	5	2.78	0.00116	0.23
Within ecotypes	294	146.66	0.49884	99.77
Total	299	149.44	0.50000	
Fixation index FST: 0.00231				

Fayoumi fowls had the largest genetic distance to all local chicken ecotypes. Jarso ecotype (0.35) followed by Chefe ecotype (0.336) were the most distant ecotypes from the Fayoumi breed and the smallest genetic distance to the reference breed was identified for the *Tilili* ecotype (0.251). The results of this study showed the presence of considerable genetic distance between *Tepi* and *Chefe* ecotypes, *Tepi* and *Jarso* ecotypes, *Tilili* and *Jarso* ecotypes and *Horro* and *Jarso* ecotypes. The genetic distance values between the different ecotypes were used for constructing a poylogenetic tree. A phenetic approach was followed for the constructing of a phylogenetic tree, as evolutionary pathways were not considered for this study.

Table 10 Values for Rho (unbiased estimator of slatkins R_{st}, Slatkin, 1995) averaging over variance components (below diagonal) in pairwise ecotype comparisons. Standard errors (above diagonal)*

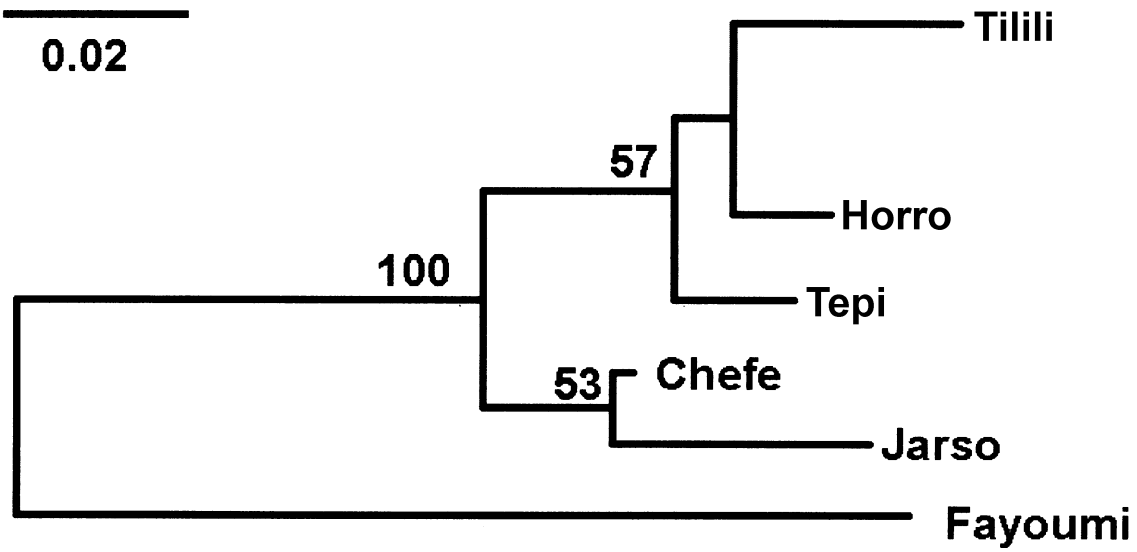
Ecotypes	**Tilili**	**Horro**	**Chefe**	**Jarso**	**Tepi**	**Fayoumi**
Tilili	***	0.0031	0.0044	0.0037	0.007	0.0078
Horro	**0.0469**	***	0.0042	0.0036	0.0060	0.0064
Chefe	**0.0952**	**0.0893**	***	0.0065	0.0051	0.0058
Jarso	**0.1022**	**0.1075**	**0.0805**	***	0.0053	0.0055
Tepi	**0.0936**	**0.0936**	**0.1926**	**0.1888**	***	0.0072
Fayoumi	**0.2510**	**0.2536**	**0.3360**	**0.3509**	**0.3069**	***

***** Retrieved using 100 permutations and 100 bootstrap replicates.

The Neighbour-Joining and UPGMA methods were applied for obtaining the trees. The standard Neighbour-Joining tree for six ecotypes studied is presented in Fig.2. The poylogenetic tree, obtained by using the genetic distance in the standard Neighbour-Joining (NJ) method, assorted the ecotypes according their agro-ecological origins. Bootstrapping values obtained were between 53 to 100%. The reference breed, Fayoumi population formed a distinct branch and is significantly different (100%) from all the local ecotypes. Tilili, Horro and Tepi populations formed a cluster with a significance level of 57%, however Tepi still tend to

form a separate branch from Tilili and Horro which showed a closer relationship. Chefe and Jarso ecotypes tend to form a cluster at 53% significance level and demonstrated a closer relationship.

Fig. 2 Neighbour-Joining tree based on Nei's (1978) standard genetic distance calculated in MEGA 2.1 (Kumar et al, 2001) for five Ethiopian fowl ecotypes and Fayoumi



The UPGMA tree for the six ecotypes studied is presented in Fig. 3. The tree obtained using the genetic distance in UPGMA method was similar in topography with lower significance level.

The Mantle test of correlation between genetic distances and geographic distances matrices between ecotype sampling sites is shown in Fig. 4. The isolation by distance analysis based on a normalised Mantel statistic showed a strong and positive matrix correlation (r= 0.62) between the genetic distances and geographic distances matrixes.

Fig. 3. UPGMA-tree for five local chicken ecotypes and the reference breed Fayoumi

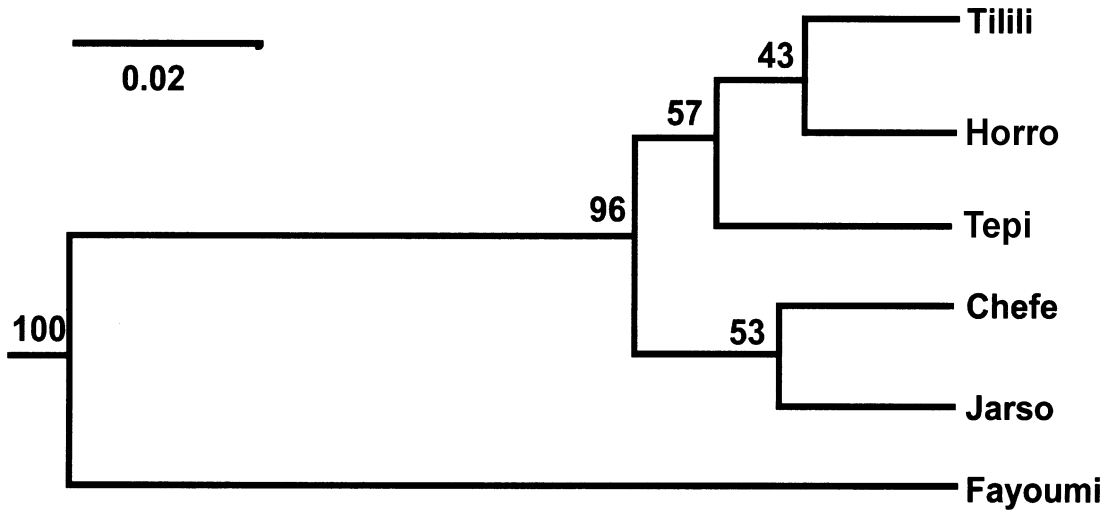
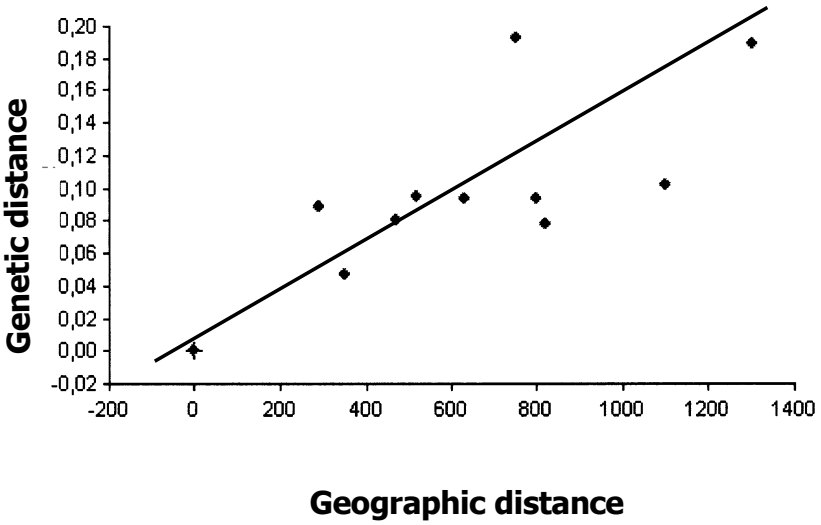


Fig. 4 The Mantle test of correlation between genetic distances (matrix 2) matrix and geographic distances (matrix 1) between ecotype sampling sites.



4. Discussions

4.1 Microsatellite markers

The results of this study showed that all the microsatellite markers tested were found highly polymorphic. When the characteristics of microsatellite loci used in this study were compared (Table 11) with earlier reports from the Wageningen Animal Genetics Group (Groenen *et al*, 1998) and Crooijmans, 2000), chicken ecotypes in this study had a higher number of alleles in four of the loci and equal number of alleles in five of the loci. However, Köster (2001), testing native populations of South Africa reported a higher number of alleles per locus in most of the markers except for MCW0294 and ADL0278, that gave five and four more numbers of alleles in this study, respectivelly.

Table 11 Characterstics of microsatelite loci: expected and observed number of alleles and ranges of base pairs

Microsatelite	*Chromo some	*Expected range (bp)	*Expected number of alleles	Number of alleles observed	Observed alleles
MCW0222	3	205-240	5	3	219 221 223
MCW0248	1	205-235	6	4	213 215 219 223
MCW0183	7	280-320	9	8	298 302 306 310 314 316 **322 326**
MCW0294	Z	280-320	9	10	301 303 305 307 309 311 313 215 317 319
MCW0295	4	85-120	6	8	101 103 105 107 109 111 113 115
MCW0034	2	220-250	12	9	219 221 223 225 227 229 231 233 239
MCW0078	5	130-150	6	5	137 139 141 143 145
MCW0098	4	250-270	2	3	253 255 257
ADL0268	1	90-130	7	7	103 105 111 113 115 117 119
ADL0278	8	100-130	3	7	113 115 117 119 121 123 127

*As reported by Groenen *et al* (1998); Crooijmans, (2000)

The alleles observed in this study failled in the expected ranges of microsatellite markers except for one of the locous (MCW0183), which had two more alleles not within the expected range. Microsatellite markers tested in this study showed that the average number of alleles per loci varied between 2.5 to 7, which gave more alleles than reported by Groen *et al.* (1994) and Crooijmans *et al.* (1996) for commercial broiler (3.6 to 5.9) and layer (2.0 to 3.1) lines.

However, Köster (2001) reported comparable number of alleles per loci (3.9 to 6.4) for native South African chicken populations. According to reports by Crooijmans *et al.* (1996), Ponsuksili *et al*. (1996), Vanhala *et al.* (1998), Köster (2001) and Wimmers *et al*. (2000), the different number of alleles per marker were between one and nine (commercial lines), four to 13 (inbred lines and hybrid), two to 11 (native lines), three to 14 (native South African) and two to 11 (for different breeds of Africa and Asia), respectivelly. The results from this study show that the number of alleles per loci varied from three to 10 different alleles. A number of criteria related to the concept of genetic uniqueness or distinctiveness have been put forward and the presence of distinct alleles (Petit *et al.* 1998) is among others. In this study, from the limited number of markers tested alleles specific to a population were observed for five of the markers. Since the most general genetic criterion apart from genetic diversity (expected heterozygosity) is allelic diversity (Petit *et al.* 1998; Barker 2001). These unique alleles should be further investigated as measures of the distinctiveness for the different populations.

Three of the 10 markers showed a deviation from the Hardy-Weinberg equilibrium. Two of the markers tend to show deviation in two populations; however, the third one deviated in one specific population only. Deviations from expected Hardy-Weinberg may be due to a variety of causes. An excess of heterozygotes may indicate the presence of overdominant selection or the occurrence of outbreeding. Alternatively, if an excess of homozygotes may be due to four factors:

-first, the locus is under selection

-second, 'null alleles' may be present which are leading to a false observation of excess homozygotes; null alleles are usually caused by a mutation in the primer binding site leading to an allele that will not amplify (Callen *et al.* 1993; Paetkau and Strobeck 1995). In this study, DNA from some individuals failed to amplify for specific markers, apparently because of failuer of primers to amplify in those loci which resulted in null alleles, however, the detection of null alleles were not specific to the deviated markers.

-third, inbreeding may be common in the population.

-fourth, the presence of population substructure which may lead to Wahlund's effect, where there is a reduction in observed frequency of heterozygotes (increase in homozygotes) from the expected because of lumping of subpopulations or conversely, the joining together of genetically isolated subpopulations increases the observed heterozygosity (Hartl, 1988).

The likelihood of each of these explanations must be assessed from additional data, such as demographic information, i.e. population distribution. However, the possible explanation based on the information from this study result might be inaccurate genotyping due to poor gel conditions, PCR-amplicon quality, DNA-quality etc.

4.2 Polymorpic Information Content (PIC) and Heterozygosity (H)

In this study, lower PIC values were observed for all the microsatellite markers tested in all the ecotypes when compared to the expected Heterozygosity (H_e) values for the same markers and ecotypes. PIC values always tend to be lower than H_e values, as the PIC is calculated for the number and the frequency of the different alleles, whereas the H_e calculation considers the number of hetrozygous animals in a population (Botstein *et al.,* 1980; Buchanan *et al.*, 1994). Unlike Heterozygosity, PIC is more valuable as an indicator of marker polymorphism than of variability in the populations. The highest PIC and H values were observed for markers MCW0183, MCW0294, MCW0034, ADL0268 and ADL0278. These markers also had the highest number of alleles (seven or more). However, MCW0295 gave a low PIC value even though it had eight different alleles of which two of the alleles (103 and 105) were dominant. This result agrees with the assertions made by Buchanan *et al.* (1994), that loci with a large number of different alleles may have a high PIC value, but if one or two alleles dominate, then the PIC value may still be relatively small. PIC values found in this study varied from 0.27 to 0.73 for the different microsatellite markers and those values are in agreement with PIC values reported for chickens ranging from 0.25 to 0.83 (Ponsuksili *et al.,* 1996) and from 0.33 to 0.66 (Köster, 2001). PIC values for all tested markers in all ecotypes showed a much smaller variation of 0.47 to 0.55, which are in a similar range as PIC values reported for native South African chicken populations for all the 23 microsatellite markers tested (0.46 to 0.57) (Köster, 2001).

The heterozygosity values found in this study range from 55% to 63% and are in agreement with the range (53% to 64%) of values reported for native South African chicken populations (Köster, 2001). Wimmers *et al.* (2000), reported a rather wide range from 45% to 67% from 22 local chicken populations tested. The heterozygosity values were highest for *Tilili* and *Chefe* ecotypes (63%) showing a higher degree of genetic variation which is in agreement with highly variable phenotypic performance reported earlier (chapter III and chapter VI). The lowest heterozygosity values were obtained for *Jarso* (55%) and *Horro* (57%) ecotypes.

However, those low values for both ecotypes are unexpected as they are of local ecotypes. The reference breed, Fayoumi exhibited a relatively high (60%) heterozygosity level compared to the reported value of 35.1% for a laboratory line (Ponsuksili *et al.,* 1996). The high heterozygosity value obtained for Fayoumi from this study may have not been expected; since it is believed to be a relatively well established breed. Study reports for Heterozygosity level of natural populations of chicken are limited. Different reports are available for tropical chicken populations, Ponsuksili *et al.* (1996) reported 33.5% for Dandarawi chicken from Egypt, 62.9% for Kadaknath chicken from India, and 50% for Nunakan chicken from Indonesia. However, it is not specified if the animals were subjected to selection. Vanhala *et al*. (1998) report a range of 37.8 to 67.1% heterozygosity values for broiler hybrids. Groen *et al.* (1994) reported a genetic variability for commercial broiler and layer lines ranging 28 to 44% heterozygosity. Local ecotypes tested in this study showed a relatively higher genetic variability than broiler and layer lines. This is expected, since native fowl ecotypes have not been subjected to selection for specific traits in the past, which is also demonstrated by a highly variable growth performances (chapter IV).

The results of this study and other studies from different species using a similar methodology produce a comparable range of genetic variation measured as heterozygosity. In this study, between 2.5 to 7 alleles per marker were observed, which is comparable to values reported by Groen *et al.* (1994); Ponsuksili *et al.* (1996); Takahashi *et al*. (1998) and Köster (2001). However, 8 to 17 different alleles per locus were reported from six sheep breeds (Buchanan *et al.,* 1994). Arranz *et al.* (1996) reported 79 different alleles among tested markers with an average of 15 alleles per marker and a maximum of 27 alleles per marker from two studies with European cattle breeds. MacHugh *et al.* (1997), studying Taurine and Zebu cattle in Africa, reported 168 unique alleles for 20 loci, even though the Heterozygosity varied between 44% to 65%, which is comparable to most results reported for chicken including this study. It appears, however, that there are fewer alleles per locus in fowl than in cattle and sheep.

4.3 Genetic distance and relatedness

The smallest distance (0.047) was found between *Tilili* and *Horro* ecotypes and the largest distance (0.19) between Chefe and Tepi ecotypes. The reference breed used in this study, the Fayoumi breed, was the most distant from all local chicken ecotypes. Jarso ecotype (0.35)

followed by Chefe ecotype (0.34) were the most distant ecotypes from Fayoumi chicken and the smallest genetic distance with the reference breed was identified for the *Tilili* ecotype (0.251). Köster (2001), testing the genetic distance of six native South African native chickens and other three populations from Botswana, Mozambique and Zimbabwe, reported larger genetic distances between the South African populations than those obtained in this study.

Matrix distances among populations are graphically represented by distance trees. The most widely known methods are the standard Neighbour-Joining (NJ) and the UPGMA (Takezaki and Nei 1996). The poylogenetic trees based on the genetic distance obtained from both the NJ and the UPGMA methods, assorted the ecotypes according their agro-ecological origins. While the topography of both trees remained the same, the NJ tree produced a higher significance level. The NJ-method has been shown to be useful for obtaining correct tree topologies in other studies including native fowl, commercial poultry and cattle (MacHugh *et al.,* 1997; Takahashi *et al.,* 1998; Vanhala *et al.;* 1998). Bootstrapping values were between 53 to 100% in NJ trees and 43% to 100% in UPGMA trees. In both trees, the Fayoumi population formed a distinct branch on it's own with a high significance (100%) level. In NJ and UPGMA trees, the local chicken ecotypes formed two distinct groups, the *Tillili, Horro* and *Tepi* cluster and the *Chefe* and *Jarso* cluster. The association of the *Tepi* ecotype with *Tilili* and *Horro* was unexpected considering the geographic distance and isolation and the human culture, thus the formation of a distinct branch with a bootstrapping values of 57% is not surprising.

The presence of a strong correlation between agro- ecologies (corresponding market sheds) where those ecotypes are originated and genetic classifications agrees with the assumption that markets are the main cause of genetic admixture of chicken ecotypes in the Ethiopian context and that each of the regions and market shades are genetically more homogenous than the overall population. However, Wimmers *et al.* (1999) using 20 microsatellites to group Nigerian ecotypes according to their genetic similarity as a contribution to the identification of genetic resources, found that even between ecotypes from different geographical origin the genetic distances were unexpectedly low. They recommended to regroup the ecotypes based on their marker information in order to identify valuable genetic resources.

5. Conclusions

Even though the genetic distance between the different ecotypes is moderate different ecotypes form branches of different bootstrapping values. The fact that the populations were assorted according to their geographical origin and the presence of distinct alleles to a specific populations support the reliability of the results and the evidence that ecotypes are genetically distinct. However, the within-ecotype variation is found to be very high, which is supported by high heterozygosity level of microsatellite markers tested in all ecotypes. The results of this study showed the presence of considerable genetic distance between *Tepi* and *Chefe* ecotypes, *Tepi* and *Jarso* ecotypes, *Tilili* and *Jarso* ecotypes, and between *Horro* and *Jarso* ecotypes and *Tilili* and *Chefe*. These pairs of populations might be regarded as the most interesting for any direct use in appropriate breeding programs aiming at the generation of genetic stocks with improved productive adaptability or conservation efforts.

Having in mind the manifold advantages of using microsatellite markers for studies of genetic variation, it is not yet clear to what extent the variation found in microsatellites loci is related to genetic variation in traits of interest. It is recommended to combine the genetic distance estimates together with information on phenotypic characteristics in order to judge on the possible future usefulness of a population. Based on this assertion *Tilili* and *Chefe* ecotypes show better performance in growth and feed utilisation potentials, show higher heterozgosity levels and exhibited considerable genetic distance warranted a further use of this two ecotypes in selection but also crossbreeding designed to create genetic stocks with improved productivity. However, further and detailed studies of the degrees of variability among the different ecotypes using more microsatellite markers with better genome coverage for fully elucidating the within and between variation of the different ecotypes followed by Quantitative Trait Loci (QTL) analysis for trait (s) of interest is recommended.

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CHAPTER VI

General Discussion

1. Concept of the study

Ethiopia is one of the important location of genetic diversity in flora and fauna due in large part to its geographical location near the historical entry point of many initial migratory populations from Asia, its diverse topography, climate, the wide range of production systems and the huge domestic animal population size (Epstein, 1971; Epstein and Mason, 1984). The diversity is also embodied in the numerous breed types and ecotypes known to exist within each species. Available published and grey literature shows that there are at least 22 breed types in cattle, 12 in goats and 7 in sheep (DAGRIS, 2002). Very few comprehensive efforts have been exerted to systematically manage (identify, characterise, utilise and conserve) these genetic resources, least in chicken since it is the most neglected animal from the point of view of livestock improvement in Ethiopia.

Althogh poultry are an important source of food (both meat and eggs) and a means of investment that is important to the welfare of women and childeren in traditional and low-input systems in Sub-Saharan African, an alarming 34% of all avian breeds in Africa are at risk of being lost (FAO, 2000). The situation in Ethiopia is not different. Understanding the genetic differences amongst populations provide the basis for both sustainable genetic improvement and maintaining genetic diversity. This requires a system oriented concept for identification, characterization, evaluation and improved utilisations of chicken ecotypes with the goal to increase the productivity and sustainability of smallholder poultry through improved understanding and enhanced use of indigenous chicken genotypes. This study contrbute to improve the overall understanding of small holder poultry systems, of the productivity of local fowl ecotypes on-farm and on-station and of the genetic relation and varability within and between the different local populations.

2. Implemented methodologies

Lack of detailed studies targeting at comprehensive description of indigenous chicken in their respective production environments and characterisation of the associated village production systems and the animals in Ethiopia demands attention on the methodological aspect. According to Peters (1988) and Bruns (1999), the assessment of indigenous genetic resources should have the following components in order to establish the required information for understanding the genetic resource and its sustainable use:

-the production system (current conditions and prospects),

-the morphological and other phenotypic traits, performance evaluation, economic appraisal of traits, and breeding objectives, and

-assessment of population parameter to identify appropriate breeding strategies.

However, the further development of molecular techniques has opened additional and new doors for phenotypic, genetic, genomic and gene level studies and it has become the additional tool for answering the various genetic, breeding and physiological questions in farm animals. Therefore, in this study an on-farm investigation of poultry systems and poultry ecotypes, phenotypic diversity of indigenous chicken ecotypes and analysis of the genetic distance on the basis of molecular markers were three inter linked modules implemented.

In module I of this study an on-farm investigation on the soci-economic aspects of village chicken production systems were conducted in five different agro-ecological regions and 10 corresponding market sheds in Ethiopia involving a total of 250 households (HH) from 10 villages (two villages from each region). The selection of market sheds was made on the basis of information from previous studies (AACMC, 1984; Teketel, 1986 and Tadelle and Ogle, 1996) and based on their importance for the supply of chicken and chicken products to a sub-regional market and urban centre (regional Agricultural bureauxs). The assumption was that markets allow to measure diverse functions and for assessing opportunities and perspectives of village poultry. Villages were selected and considered for the present study on the basis of the relevance of chicken production in the village

economy, of no prior improvement programs (distribution of exotic birds) undertaken, and of villagers being willing to participate in the study

The data collection process in this study was based on a structured questionnaire survey integrated with Participatory Rural Appraisal (PRA) techniques relevant to village chicken production systems. Methodologies used for base line surveys using questionnaires, focus group discussions, participant observation, formal and informal interviews and other participatory methods that are usually applied in social science research (Sonaiya, 2002). Information was gathered from individual farmers, extension officers, key informants and village groups, which aim at assessing the perspectives of the poultry sub-system, its contribution to farm economics and the economic valuation of performance traits. As it is suggested by Verschuren and Doorewaard (1999), rather than collect data in a single cross-sectional survey from households where record keeping is absent, follow-up surveys were conducted to improve the reliability of the information. To this end, a transect walk was made involving 10 households in each of the 10 study villages. In depth visits in and around the residential quarters of the villages were then made in order to obtain first hand observation and achieve empirical strength on all aspects of poultry production in individual households.

Participatory methodologies and their associated tools and techniques were found to be quite effective in communicating with the right section of the population (Sharland, 1989) and lead to more relevant and realistic results in an attempt to understand the system. Different household members are affected by enterprise development in different ways. Participatory methods enable better identification of who is affected in which ways and the involvement of the very poor, women, children and vulnerable groups to be heard (Rietbergen-McCracken and Narayan, 1998), who often have a close link to poultry keeping and a different level of knowledge. Based on the assumption that each women farmer has an idea on the performance of her animals, a recall survey was conducted to establish specific hen performance history in relation to production and productivity, which afterwards was used for an economic analysis based on the performance of breeding females from all the study areas. In addition, the sources of present breeding

females (as replacement) and foundation stock in the household and use patterns of poultry products were assessed. Subsequently, the information obtained during the recall and repeated survey provided the basis for a quantitative characterisation of the poultry production system and the actual performance of chicken ecotypes included in the survey (Chapter, III).

Module II of this study was aimed at performance evaluation of the five indigenous chicken ecotypes under on-station and improved management conditions with the objective of evaluating the quantitative performance for growth potentials (Chapter IV). In conducting this experiment it was assumed that an on-station management in a controlled environment, a balanced ration and disease control serves as an standardized environment to test for differences in growth, feed efficiency and carcass traits among the tested populations as it is very difficult to set up uniform management and obtain optimum data in field tests.

The growth and meat production performance evaluation was conducted at the Debre Zeit Agricultural Research Centre (DZARC), Ethiopia. This study involved chicken ecotypes from five ecological regions, *Tilili, Horro, Chefe, Jarso* and *Tepi* and their corresponding market sheds. The Fayoumi chicken breed originating from Egypt, was included as a reference breed for comparison (metapopulation). Eggs were obtained from one representative village per market shed from each of the five regions. The assumption is that markets as the main cause of genetic admixture of chicken populations and that chicken from each of the regions and market sheds are genetically more homogeneous than that of the overall population.

Eggs were purchased directly from households to assure the collected eggs are from local genotypes. Eggs were transported to the respective nearest hatchery for hatching and consecutively hatched chicks were transported to DZARC. Chicks from each ecotype were further randomly sub-divided into replicates based on the number of chicks available and placed in deep litter pens heated by electric bulbs until 6 weeks of age. At the age of 6 weeks, chicks were sexed, wing banded and kept at a rearing house till they were 18

weeks of age. Chicks were fed standard starter and grower rations. All birds were vaccinated against Newcastle Disease (at day old and 21 days of age).

Body weight was taken every two weeks until 12 weeks of age and then at 18 weeks of age. From day old to six weeks of age group body weight of the replications were taken but individual body weight was recorded until 18 weeks of age. Ten chickens (five male and female) were selected from each ecotype for measuring the body weight and shank length every two weeks starting from two weeks of age, with the objective of testing the prediction of live body weight on the basis of shank length measurements at different ages. Feed supplied and feed refusals were measured and recorded daily. At 12 weeks of age, a sample of 10 birds (5 male and 5 female) from each genotype were taken randomly and slaughtered. Separate weight measurements were taken on carcass, crop, gizzard, feet, head with wattles, liver and heart. The Gastro Intestinal Tract (GIT) length and Thigh Mussel Circumference (TMC) were measured using close measuring tape. The Breast angle was taken with calipers. The weights of these parts were calculated as percentages of live weight (Chapter, IV).

Understanding the genetic variability within and between subpopulation is important for formulation strategies for conservation and utilisation of local resources. The development of molecular biology techniques (DNA-fingerprinting, DNA microsatellite markers, mitochonddrial sequencing, single nucleotide polymorphism etc) assist in this objective. An estimation of genetic variablity of chicken, using markers based techniologies were found to be useful. Genetic variablity in chicken (commercial and indignous) has mostly been studied by using DNA-Finger Printing technique and microsatellite markers (Table 5 of chapter II). However, in recent years there is a tendency towards microsatelite markers as the preferred markers in genetic studies of poultry and other mammalian species. In a study reported by Ponsuksili et al., (1996), using both mictosatellite and DNA-fingerprinting techniques in analysing the genetic distance of native breeds from Egypt, India, Indonesia, Thailand and Taiwan, a higher hetrozygosity among the lines was detected by using microsatellite markers, compared to the DNA-fingerprinting. Meanwhile, microsatelite markers have been successfully

applied in characterisation of waterfowl (Fields and Scribner, 1997), chicken (Wimmers *et al.,* 2000; Köster, 2001) and are frequently used in studying genetic variability in other mammalian species such as sheep, pigs and cattle (Buchanan *et al.,* 1994; Van Zeveren *et al.,* 1995; MacHugh *et al.,* 1997). Microsatellite markers were also found to be accurate and reliable for characterisation of highly inbred lines (Zhou and Lamont, 1999). Different study results were reported using different numbers of microsatellite markers that ranges from 8 to 27. According to Takahashi et al, (1998), the study results on genetic relationships among Japanese native chicken breeds based on eight microsatellite markers were reliable and accurate. Thus, in this study the multilocus microsatellite markers were used for the characterisation of the within and between genetic relatednes and distance among the different chicken ecotypes of Ethioppia (Module III; Chapter V).

DNA was isolated from blood of 25 individuals from each of the six ecotypes established earlier (Chapter IV) to asses genetic diversity between and within the different local chicken ecotypes originated from different agro- ecological regions and corresponding market sheds using 10 microsatellite markers. The microsatellite markers used in this study were selected from primers used by the EU funded project "Development of Strategy and Application of Molecular Tools to Assess Biodiversity in Chicken Genetic Resources, EC Contract Number BIO4-CT98-0342" and based on the degree of polymorphism and genome coverage. This approach was chosen to allow the evaluation of genetic distance and variability of the Ethiopian ecotypes in relation to the world-wide genetic resources (Chapter V).

3. Findings

3.1 The production systems

Village poultry production in Ethiopia represents a significant part of the national economy in general and the rural economy in particular and contributes about 90% and 92% of the national egg and poultry meat production. The low productivity of local birds coupled with the infancy of the commercial sector has resulted in a low supply of poultry

meat and eggs to the domestic market. Village chicken production system is characterised by its low input-output levels. This low output of local birds is expressed as low egg production/bird, small sized eggs, slow growth and low survivability of chicks (Smith, 1990a; Tadelle, 1996). While making one of the best uses of available natural resources, chicken production constitutes an important component of the agricultural and household economy, a contribution that goes beyond direct food production for the fast-growing human population as well as employment and income generation for resource-poor small farmers, especially women (chapter III).

The traditional poultry production based on low input-output levels represents a part of a balanced farming system, has a unique position in the rural household economy as supplier of high quality protein to the family food supply system, provides small cash income and plays a significant role in the religious and cultural life of the society in Ethiopia (Tadelle and Ogle, 2001). However, it contributes only about 32% of the animal protein needs of rural households (chapter, III). Households also keep birds for purposes other than for reproduction, sale, and consumption, in particular for their socio-religious functions at home. Additionally, chicken have played a role in cleaning the environment and livestock tick and other external parasite (Chapter, III).

Unlike specialised chicken breeds for either an egg or meat production, indigenous birds are dual purpose performer and are non-uniform waving different plumage colour, comb type and down colour. Feather cover and body positions or conformation are variable from region to region (chapter III). Differences in body conformation were particularly manifested in male chicken. This system of production, although appearing primitive can be economically efficient even if the output from the individual birds is low since inputs are even lower or virtually non-existent (chapter III). The feed resource base for rural poultry production is made up of scavenging feed in and around the house, household waste, anything edible found in the immediate environment and small amounts of grain supplements provided by the household women (chapter III). As indicated by Cumming (1992); Tegene (1992); Tadelle and Ogle (1996); Tadelle and Ogle (2000); Tadelle et al. (2002), the scavenging feed resource base (SFRB) for village chickens is highly variable

in quality and quantity, depending on the season and rainfall. The portion that comes as a grain supplement and from the environment varies with activities such as land preparation, sowing, harvesting, grain availability in the household, season of the year and the life cycles of insects and other invertebrates (Tadelle and Ogle, 2000). The extremely high chick mortality (about 50%) during rearing (unsuccessful brooding time spent by the mother hen (because most of the broods died)) and high rates of mortality caused by disease and predation reduces the efficiency of the system and necessitates a rigorous replacement strategy, which affects hen efficiency, the potential egg output and live bird off-take rate (chapter III). Huchzermeyer (1973), and Kingston and Cresswell (1982) suggested that more protein would be available for human consumption if the eggs were harvested instead of being incubated, which eventually leads to unsuccessful brooding and a low holding rate.

The system is sustained through egg laying, incubating and brooding, which indicates reproduction for replacement and sales of fowls as the major purpose of keeping village chicken (chapter III). Different measures are taken by households to improve laying performance of hens, health management and preferential treatment to newly hatched chicks. Traditionally, households in all the study area attempts to increase egg production by stimulating broody birds to resume egg laying. Regular stimulation of birds to resume egg laying is reported to increase egg production by 62% (chapter III). However, it would appear that simple changes in management practices (e.g. preferential provision of feed to newly hatched chicks), home remedies (e.g. in-door management of chicks) and including attention to small details (e.g. control of predators) followed by vaccination of birds for common infectious diseases (e.g. Newcastle disease) are believed capable of bringing losses well below the reported high mortality and in turn improve the offtake rate from traditional chicken farming (chapter III).

Losses in village chickens are largely reducible by applying better management practices and also through improved uptake of vaccine against Newcastle disease (Ahlers *et al.,* 1999) and better level of confinement (Smith, 1990b and Sonaiya, *et al.* 1999). Above all it is important to make poultry producers aware that there are options and that is possible

to increase the benefits from local birds with small additional inputs and improvements in management as the first step for improvement, then thinking about breeding strategy to improve the genetic potential of the local birds.

Indigenous chickens are not always the best option under optimal conditions. The performance of high-input high-output breeds may appeal to intensive urban or peri-urban production systems. However, under less-intensive production situations the unique characteristics and added advantages of local chicken breeds will guarantee its long-term stability and sustainable use (chapter III). A comparison of exotic and indigenous chicken breeds under different conditions such as farm management, commercialization, ecological and cultural aspects is summarized in appendix 1-chapter VI. Currently there is an awareness and understanding that introducing high-yielding breeds of animals and specialised modes of production can lead to a loss in genetic diversity among indigenous animals. In developing countries, the present less intensive production systems are the mainstay of the existing ecotypes. Moreover there exists a strong and close relationship between native breeds and less-intensive systems of production, which needs to follow an evolutionary improvement process (chapter III).

The evolutionary development of the present system to a more productive and efficient one is outlined by a number of authors (Bessei, 1990; Sonaiya, 1990 and Guye, 2002). The potentials, constraints and possible solutions for improved production have been identified (chapter III). The systems suffer from a number of constraints such as effective diseases control, lack of supplementary feed, sub-optimal management and inappropriate or absence of extension services. Research, training and education generally do not address these problems (chapter III). Despite the many problems, almost every poor household, including the land less, owns chicken. Thus, if production could be improved, poultry would create an opportunity to improve livelihood and economic development of the poor. According to Kitalyi (1998), the present production system forms the basis for transforming from subsistence to a more economically productive base. However, understanding the integrated nature of the system, an interdisciplinary and evolutionary approach is imperative using community based ND control as an entry-point for

developing the village chicken production system, followed by strategic feed supplementation and other management improvements. Breed improvement can be incorporated into this transformation process. Local farmers understanding and knowledge about poultry production can be used as a base for such an integrated improvement strategy.

What are the possible fuelling agents for transformation of village chicken production to a more productive system? Firstly, an increase in rural unemployment, which forces the government to come up with appropriate policies targeted at the right clients (e.g. land less farmers, youths, Women) and the individual farmers to support output oriented village chicken production. Secondly, appropriate technology development (the research system) and dissemination (the extension system) as a support for the sector that should end in developing practical and market oriented packages based on local resources. Thirdly, increasing demand in urban areas gives better marketing opportunities for poultry and poultry products.

3.2 Phenotypic and genetic variation

Although indigenous birds have a number of adaptive traits and genes with special utility in the tropics (Horst, 1989), the real value of indigenous chicken breeds is often under-estimated mostly due to their poor appearance, relatively low productivity and alleged low "commercial" values. To this effect, they have been neglected and little attention has been given from researchers, development workers and policy makers to put them in the research and development agendas. As it is stated by Hodges (1990), developing countries in most cases opt for high performing commercial breeds from developed countries to increase animal productivity through crossbreeding or if conditions allow by breed substitution without properly investigating the production potential of the indigenous birds.

Body size is a trait required by poultry producers, since egg production and increased meatiness depend on increased body weights within a given range. Various investigations

have been conducted to show that differences in rates of growth exist in different strains (Savory, 1975; Cherry *et al*., 1978; Marks 1980; Becker *et al*., 1981; Teketel, 1986; Abebe, 1992). The existence of large variation in feather cover, body conformation and egg production (e.g. *Tilili*) of birds from different regions (Chapter III), in growth potentials between the different chicken ecotypes (chapter IV) and the presence of considerable genetic distance between the different ecotypes and the presence of unique alleles (chapter V) show the presence of genetically distinct ecotypes. A number of criteria related to the concept of genetic uniqueness or distinctiveness have been put forward including genetic distance, heterozygosity level and the presence of distinct or unique alleles (Petit *et al.* 1998). From the limited number of markers tested alleles unique to a population were observed for five of the markers (chapter V). This result agrees with previous reports from Ethiopia and elsewhere in the tropics (Teketel 1986; Olori 1994; Sonaiya *et al.* 1999; Tadelle and Ogle 2000, Wimmers 2000; Köster 2001) who state that there are many ecotypes, breeds and strains of indigenous poultry that are well adapted to their production environments in the tropics. However, besides the genetic differences causing variation in growth rates of birds, a larger proportion of the performance variablity is caused by environmental factores such as types of feed (Savory, 1974), rearing methods (Savory, 1975), climattical factors like temperature (Bohreen et al., 1982) and types of housing (Lee and Craig, 1981).

According to Teketel, (1986) and Shanawany (1987), the hatching weights of chicks follow the egg weight pattern in the parental population. The mean hatching weight of chicks from *Chefe* and *Tilili* ecotypes were bigger as compared to other three local ecotypes. Weight differences at hatching persisted and incrase during the growth process (chapter IV). The egg weight also varies according to the size of the mother hen. (chapter III). *Chefe* and *Tilili* chicks showed 20 and 19% positive deviation over chicks from *Jarso* market sheds in terms of day old body weight. A study at the Assela Livestock Farm revealed that the average egg weight of local chickens in Ethiopia is 38 g under scavenging conditions (Brännäng and Pearson, 1990) and according to Negussie (1999), the average egg weight of Fayoumi chicken was reported to be 46g. A 1g difference in

egg weight increased to a 1.5g difference in body weight at hatch, to 7g at six weeks and to 32g at 12 weeks of age based on hatching weight and mean body weight gains of local ecotypes and Fayoumi chicken (chapter III). This result showed similarity to the findings of Al-Murrani (1978) and Teketel (1986) where it was reported that 1g difference in egg weight was reflected in about 8 to 10g difference in chick weight at 2 months of age.

The mean body weight gain of local chicken ecotypes from Ethiopia at eight weeks of age was 212g (chapter IV) which is higher than the 157g average body weight gain under traditional management conditions in the central highlands of Ethiopia (Tadelle and Ogle, 2001). This indicates that changing the management could bring measurable changes in the growth performances of local chicken ecotypes. Mixed sexed local chicken ecotypes had a mean body weight gain of 405g ranging from 349 to 479g (chapter IV), which is lower than reported by Mafeni (1995) for the Cameroon indigenous chicken (538g) and higher than reported by Omeje and Nwosu (1984) for Nigerian chickens (371g) and Teketel (1986) for southern Ethiopian chickens (351g) from day old to at 12 weeks of age. The AACMC (1984) reported that local males reach 1.5kg live weight at 6 months of age and females have 30% lower body weight. However, males from this study were 36% heavier than their female contemporaries at 18 weeks of age (chapter IV). Teketel (1986) also found that local stocks reach 61% and 85% of Leghorn body weight at 6 months and final body weight and Abebe (1992) reported that local birds in eastern Ethiopia attain 71.5% of weights of Leghorns at 6 months of age which is in agreement with results of this study in which local ecotypes attain 66 to 74% of the body weight of the reference breed at eight to 18 weeks of age (chapter IV).

The gain in weight of a bird is composed of increases in weight of its different body parts (Rose, 1997). Thus, according to Havet (1955), the different body organs of the bird based on thire growth process could be classified as follows: early maturing (head, heart, liver, blood, alimentary canal and gizard) , intermediate maturing (legs, lungs, wings, feathers and kidneys) and late maturing (ovary, oviduct, spleen, dressed carcass and body fat). The early maturing organs are considered to be essential links for the physiological welfare of the bird, whilst the late maturing are mainly used for production and

reproduction, the intermediate maturing ones being organs of locomotion. The carcass weight of local stocks at 12 weeks of age was significantly lower than that of the Fayoumi however, the local ecotypes had a higher dressing percentage (chapter IV). This report is also in agreement with other reports (Teketel, 1986; Abebe, 1992). The local chicken ecotypes ranked as follows in relative size of carcass to the live body weight, Tilili (63.9), Chefe (63.5), Tepi (63.0), Horro (62.4) and Jarso (62.1), in ascending order (chapter IV). Unlike the percentage contribution of liver and heart weight, which was higher in females (3.5 Vs 3.9%), male growers had gave a highest dressing percentage (64.2%) than females' (61.5%) (chapter IV).

Feed consumtion rates for each ecotype ranged between 23g in the Jarso ecotype to 46.1g/day in the Fayoumis. The average daily feed intake per bird among local ecotypes ranged between 23g for *Jarso* ecotype and 28g for *Tilili* ecotype illustrated the strong relationships existing in average daily body weight gain in the different ecotypes. The *Tilili* ecotype, with the average daily body weight gain of 5.7 g was the fastest growing and recorded highest feed intake per bird per day. Feed consumtion (FC) rates for local ecotypes on average measured only 56 percent of FC of Fayoumi, which was only slightly lower than the difference in body weight gain (62 %). The Tilili ecotype which was closest in body weight to the Fayoumi chicken (73 %) consumed only 61 percent of the feed consumed by fayoumi (chapter IV). The highest feed requirement per unit gain was recorded for the Fayoumi chicks followed by chicks from *Tepi* and *Horro* chicks and the lowest feed requirement per units of gain was recorded for *Tilili* and *Chefe* chicks with feed conversion ratio of 4.95g and 5.2g feed per unit of gain, respectively (chapter IV). Local ecotypes have a higher feed conversion efficiency, which might be perhaps due to their smaller maintenance requirements as compared to the Fayoumi chicken (Teketel, 1986), adaptation to low feed requirement (chapter III) and better production environment (chapter IV).

The growth and feed utilization performances of ecotypes studied underlines the rather large difference between ecotypes. *Tilili* and *Chefe* ecotypes exhibited a remarkably higher performance levels than the other three local ecotypes (chapter IV) and these two

ecotypes exhibited considerable genetic distance forming a distinct branch with a bootstrapping value of 100% in a NJ-tree and also a higher heterozgosity (63%) levels (chapter V).

Virtually all the indigenous ecotypes have not been subjected to any selection process, other than natural selection and from the results of this study there is a large variation in growth, feed utilisation, meat production traits within ecotypes (chapter IV) which is manifested by high Heterozygosity values from all tested ecotypes (55 to 63%) showing a higher degree of genetic variation within each ecotypes than between (chapter V).

The presence of strong correlation between agro-ecologies (corresponding market sheds) where those ecotypes are originated with their associated distinct growth performance (chapter IV) and genetic classifications (chapter V) agrees with the assumption that marketing is the main cause of genetic admixture of chicken ecotypes and that each of the regions and shades are genetically more homogenous than that of the overall population.

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Conclusions and recommendations

Local chicken ecotypes in rural Ethiopia are characteristically, an indigenous and integral part of the farming system which are accessible at both interhousehold and intrahousehold levels and a means of converting low-quality feed which has no other use into high-quality protein. Moreover, land and capital investment, the critical production resources for other agricultural activities, are not limiting factors in village chicken production systems. Consequently, disadvantaged groups in the community can be direct beneficiaries of village chicken improvement programmes.

The system is characterised by its massive mortality rate of chicks, growers and adult birds, which is caused by mismanagement, lack of supplementary feeding, predators and diseases. Newcastle Disease (ND) is regarded as the principle disease causing high mortality. The other current pressing problem is the massive losses that occur during brooding in which the causes have yet to be specified. The magnitude of the loss, which occurs among chicks, growers and adult has not been precisely determined in Ethiopia, calling for an extensive, detailed, long-term and cohort studies on the causes, risk factors, control, preventive measures and the associated magnitude of losses. Indigenous knowledge on poultry production and health management needs to be closely assessed. Developing a specific scientific thrust for rural poultry, aimed at improving the understanding of the biological and socio-economic factors affecting the input-output relationships and the economic efficiency of the production systems is recommended. To maximize production efficiency it is important to review and identify intrinsic and extrinsic constraints, which should include the village poultry farmer (owner), the village chicken (subject) and the village (environment), since all these factors interact together, so more focus is required on 'owner-subject' and 'subject-environment' interactions.

It is concluded that village chicken production forms the basis for transforming the rural sector from subsistence to a more economically productive system. There exists considerable opportunities for changing the inefficient system using the available animals and other resources to more efficient system based on a semi-scavenging model that combined technical improvements with institutional and organisational support aiming at increasing flock productivity instead of individual animal productivity.

Based on growth performance results and estimated genetic distance between the different ecotypes test crossing is recommend to see the combining ability of ecotypes (among best performing ecotypes and among ecotypes with widest genetic distance) for a better growth. In the mean time, evaluating the egg production potentials of the different chicken ecotypes is recommended. More detailed studies of the degrees of variability among the different ecotypes using more microsatellite markers with better genome coverage which provides powerful tool for elucidating the within and between variation of the different ecotypes aimed at combining the genetic distance estimates with information on phenotypic characteristics in order to judge on the possible future usefulness of the populations and develop breeding strategy is recommended.

Summary

This study had three inter linked program modules that were conducted in five agro-ecologies and corresponding market sheds (on-farm) and at Ethiopian Agricultural Research Organisation's (EARO) Debre Zeit Agricultural Research Centre (on-station) and at Humboldt University of Berlin (HU-Berlin), molecular genetics laboratory with the objectives of a system oriented identification, characterisation and evaluation of chicken ecotypes using different methodological approaches with the aim of developing sustainable utilisation and conservation strategy.

Module I of the study, was conducted in five different agro-ecological regions in Ethiopia involving a total of 250 households (HH) from 10 villages (two villages from each region) and followed the objectives to assess the socio-economic functions, importance and constraints of village chicken production in the different study areas. A structured questionnaire survey integrated with Participatory Rural Appraisal (PRA) techniques relevant to village chicken production systems was applied. Information was gathered from individual farmers, extension officers, key informants and village groups which aim at assessing the perspectives of the poultry sub system, its contribution to farm economics and the economic valuation of performance traits. A transect walk was made involving 10 households in each of the 10 study villages. In depth visits in and around the residential quarters of the villages were then made in order to obtain first hand observation on all aspects of poultry production in individual households. A recall survey was used to establish specific bird hen performance history in relation to production and productivity. Economic analysis based on the performance of breeding females from all the study areas was made. Qualitative data sets were analysed employing a computer-based statistical software program, Statistical Package for Social Sciences (SPSS 10.05). Quantitative data analysis were carried out by different statistical procedures in SAS version 6.12

In module II, an on-station growth, feed utilisation and meat production performance evaluation was conducted at the Debre Zeit Agricultural Research Centre (DZARC), Ethiopia. This study involved all chicken ecotypes from the five ecological regions, *Tilili, Horro, Chefe, Jarso* and *Tepi* and corresponding market sheds. The Fayoumi chicken breed was included as a reference breed. Eggs were obtained from one representative village per market shed from each of the five agro-ecologies. Eggs were purchased directly from households to

avoid possible inclusion of eggs with exotic blood. Day old chicks from the nearest hatchery were transported to DZARC. Even though the number of eggs purchased from each region were similar (about 850 eggs/village), the hatchablity was highly variable and the number of chicks hatched and used in the trial were 484, 89, 227, 343, 132 and 315 chicks from *Tilili, Horro, Chefe, Jarso*, *Tepi* and Fayoumi ecotypes, respectively. Chicks from each ecotype were further randomly sub-divided into replicates based on the number of chicks available and placed in deep litter pens heated by electric bulbs (250W) until 6 weeks of age where group body weight was taken. At the age of 6 weeks, chicks were separated based on sex, wing banded and transferred to a rearing house till they were 18 weeks of age. Chicks were fed a diet containing 21.7% CP and 2784.1 Kcal ME/Kg from day one, while the growers' ration containing 16.2% CP and 2920.2 Kcal ME/Kg was fed from six to 18 weeks of age. Birds were provided daily with a known amount of feed *ad libitum*. Feed refusals was measured and recorded daily.

Body weight was taken every two weeks until 12 weeks of age and then at 18 weeks of age. Ten chicken (five male and female), selected from each ecotype, body weight and shank length was measured every two weeks starting from two weeks of age with the objective of testing the prediction of live body weight on the basis of shank length measurements in different ages.

At 12 weeks of age, a sample of 10 birds (5 male and 5 female) from each genotype were taken randomly and slaughtered. At slaughter, birds were bled and feather plucked before evisceration. Separate weight measurements were taken on carcass, crop, gizzard, feet, head with wattles, liver and heart. The Gastro Intestinal Tract (GIT) length and Thigh Mussel Circumference (TMC) were measured using measuring tape. The Breast angle was taken with calipers. The weights of these parts were calculated as percentages of live weight. Mortality was recorded as it occurred. In order to summarise the live weight information in a single variable, the live weight data were fitted to growth models. Data analysis were carried out by different statistical procedures in SAS version 6.12 and the resulting K values from the growth models were analysed using Statistica 6.1 release in 2002.

In module III, genetic diversity between and within the five different local chicken ecotypes (*Tilili, Horro, Chefe, Jarso* and *Tepi*) and the reference breed, Fayoumi were assessed using 10 microsatellite markers. DNA was isolated from blood of 25 individuals from each of the

five local ecotypes and the reference breed. The DNA was extracted using a Qugine DNA-extraction kit. DNA was brought to Germany and the distance analysis was done at HU-Berlin. The microsatellite primers used in this study were selected from primers used by the EU funded project "Development of Strategy and Application of Molecular Tools to Assess Biodiversity in Chicken Genetic Resources, EC Contract Number BIO4-CT98-0342" and based on the degree of polymorphism and genome coverage. PCR reaction for each animal DNA was prepared in a volume of 23 µl, containing 2.5µl 10X buffer, 0.75µl $MgCl_2$, 0.5µl dNTP, 0.5µl Forward primer (B), 0.5µl Reverse primer (A), 0.1µl *Taq*, 18.15µl PCR water (to make up to 23 µl) and mixed with 2µl DNA. Amplification was performed with 30 cycles of the following steps: 1 min at 94°C, 1 min at 55°C, 1 min at 72°C and a 4 min final extension at 72°C. The size of alleles was determined using an automated DNA Sequencer A.L.F. ^{TM} with internal standards. Basic population genetic statistics such as allele frequencies, heterozygosity, Mantel-test were computed using a computer program Cervus 2.0. Analysis of molecular variance (AMOVA) and Fis values were computed with the program package ARLEQUIN 2.0. Heterozygote deficiency or excess, Hardy-Weinberg equilibrium and Fst-statistics were calculated using web based software Genepop. Poylogenetic trees construction (the neighbour-Joining (NJ) and Unweighted Pair-Group Method using Arithmetic Averages (UPGMA)) using unbiased minimum genetic distance values were made in a software called MEGA 2.1. Bootstrap analyses were performed with 1,000 iterations in the program package Microsat.

Results of module I. Study regions and corresponding market sheds differed significantly in the number of chicken owned per household. The mean number of mature birds and breeding females per household was 7.4±0.22 and 5.4±0.17, respectively, with a male to female ratio of 1:2.5. Purchase was the main source of stock for foundation and while hatching and purchase were the main sources of replacement stocks. Mean egg laying performance of hens were 17, 21 and 25 eggs for the first, second and third and higher clutches, respectively. Mean clutch number was 2.6±0.06 per year. The mean number of eggs set per bird was 13.5±0.19. Hatching rate was 70.5±10.6% ranging from 30-90% (n=250). High mortality of chicks (average survival rate of 51.3±13.3%, ranging from 12-75%.) were reported and occurred between hatching and the end of brooding at 8 weeks of age. About 50% of the eggs produced are incubated in order to replace birds that die. This makes the reproduction for replacement as the main focuses of chicken keepers. However, farm households reported taking different

measures to improve laying performance of hens. Regular stimulation of broody birds to resume egg laying and about 80% increase in egg production was reported.

The results from the analysis of variance showed significant ($p<0.01$) differences in use patterns of chicken and chicken products among the different study regions. About 50, 27 and 23% of the eggs produced were reported to be used for hatching, sale and home consumption, respectively, while 5.5, 3.8 and 3.1 birds were used for sale, replacement and consumption. A strong and inverse correlation ($p<0.01$) was evident between wealth status and use of chicken and chicken products for sale and home consumption. The over all Gross Return (GR) as percent of initial values (IV) and GR per breeding female per year were 67.5% and 12.48 Birr, respectively.

Results of module II. Ecotype had a significant effect ($p<0.01$) on body weight development. The highest day old body weight was recorded for Fayoumi chicks followed by chicks from *Chefe, Tilili, Horro, Tepi* and *Jarso* market sheds. Chicks from *Tepi* and *Jarso* market sheds showed a significantly ($p<0.05$) lower day old body weight than local chicks from the other three ecological regions and corresponding market sheds. The Fayoumi chicks were 31.3, 21.1 and 37.1% heavier than mean day old body weight of local chicks, chicks from *Chefe* (heaviest locals) and Jarso (least day old body weight), respectively. *Chefe* Chicks showed 20.4% positive deviation over chicks from *Jarso* market sheds in terms of day old body weight. Local chicks had a significantly ($p<0.01$) lower body weight at two, four and six weeks of age than chicks of the Fayoumi breed. Fayoumi chicks had the highest mean live body weight at two weeks of age followed by chicks from *Chefe* and *Tilili* having 71.2g, 68.1g and 57.2g, respectively.

The results from the analysis of variance showed also a significant ($p<0.01$) effect of ecotype and highly significant ($p<0.001$) effect of sex on live body weights of chicken at eight, 10, 12 and 18 weeks of age. The ecotype-sex interaction had a non-significant ($p>0.05$) effect on live body weight at all ages. The overall mean live body weight at eight, 10, 12 and 18 weeks of age were 273.4$\pm$3.2g, 377.8$\pm$4.6g, 479.1$\pm$6.3g and 760.8$\pm$9.4, respectively. Fayoumi chicken had the higher live body weights followed by chicken from*, Tilili, Chefe, Horro*, *Tepi* and *Jarso* market sheds, respectively. Chicken ecotypes from *Tilili* and *Chefe* market sheds showed a significantly ($p<0.01$) higher live body weight than local chicken ecotypes from the other three ecological regions and corresponding market sheds at eight, 10, 12 and 18 weeks

of age, respectively. There was no statically detectable ($p>0.05$) live body weight differences among chickens from *Jarso* and *Tepi* regions at this age. The *Tilili* chicken (heaviest locals) attained 78, 74, 78 and 81% of the mean live body weights of Fayoumi chicken at eight, 10, 12 and 18 weeks of age, respectively, while chicken from *Tepi* (lightest body weight among the locals) showed only 74, 61, 60 and 74% of the body weight of *Tilili* chicken at eight, 10, 12 and 18 weeks of age, respectively. Male chicken were 36, 35, 39 and 36% heavier in mean live body weight than female chicken at eight, 10, 12 and 18 weeks of age, respectively. Coefficients of variations (%) based on individuals live body weight were high for all local ecotypes.

Ecotype had a significant ($p<0.05$) effect on shank length in all ages (2 to 12 weeks). The over all mean shank length at two, four, six, eight, 10, 12 and 18 weeks of age were 2.3, 2.9, 3.4, 3.7, 4.2, 5.2 and 8.9 cm, respectively. The mean shank length at all ages were highest for *Fayoumi* and *Tilili* chicks followed by chicks from *Chefe and Tepi* regions as ecotypes with medium sized shank length ecotypes whereas chicks from *Horro* and *Jarso* regions had shorter shank length. Male chicks had significantly longer ($P<0.01$) shank compared to females from the same ecotype. The growth model study shows that most efficient (highest K) groups were *Tepi*, *Fayoumi* and *Tilili*, the second group involves *Tepi*, *Tilili* and *Chefe*. Whereas, *Jarso* and *Horro* represents the least efficient (lowest K) and third group.

The highest body weight gain per bird was recorded for Fayoumi chicks. The Fayoumi chicks gained 11.9, 97.7 and 49.4% more than chicks from *Chefe* (heaviest locals at this age) ecotype, *Jarso* (least total body weight gain among the locals at this age) ecotype and mean daily gain of all local ecotypes, respectively at six weeks of age. *Chefe* chicks showed a 76.8% positive deviation over chicks from *Jarso* market sheds in terms of total body weight gain per bird at this age. The Fayoumi chicks consumed 41, 115 and 65% more feed than chicks from *Chefe* ecotype (highest body weight gain and feed intake among locals at this age), *Jarso* ecotype (lowest body weight gain and least feed intake among the locals at this age) and the mean feed intake of all local ecotypes, at six weeks of age, respectively. Among the local ecotypes, *Jarso* and *Tepi* had the smaller body weight gains while *Chefe* and *Tilili* had larger weight gains.

The analysis of variance showed a highly significant ($p<0.001$) difference in body weight gain per bird, average body weight gain per bird per day, feed intake per bird, average feed intake

per bird per day and feed conversion ratio (feed: gain) among the different ecotypes and sex from six to 12 weeks of age. The highest body weight gain per bird and mean daily body weight gain per bird per day among the locals were recorded for *Tilili* growers. The Fayoumi chicks were 28, 77 and 52% heavier than chicks from *Tilili ecotypes* (heaviest locals at this age), *Tepi* ecotypes (least total body weight gain among the locals at this age) and mean body weight gain of local birds, respectively. Male growers from *Tilili ecotype* (heaviest locals at this age), *Tepi* ecotype (least total body weight gain among the locals at this age) and mean body weight gain of local birds, were 22, 30 and 33% heavier in body weight gain per bird over female chicken at twelve weeks of age, respectively. Feed conversion ratio was also significantly ($p<0.01$) affected by ecotypes. The highest feed requirement per unit gain was recorded for the Fayoumi chicks followed by chicks from *Tepi* and *Horro* chicks and the lowest feed requirement per units of gain was recorded for *Tilili* and *Chefe* chicks with feed conversion ratio of 4.95g and 5.2g feed per unit of gain, respectively.

Results of module III. All microsatellite markers tested were highly polymorphic for all the tested ecotypes. The mean number of alleles from all microsatellite markers tested per ecotype varied from 4.2 (*Jarso*) to 5.3 (*Chefe*). The number of alleles detected per locus varied from 2 to 10 alleles. The calculated expected heterozygosity level showed high genetic variability in all tested populations. Heterozigosity varied between the lowest value of 55% (*Jarso* ecotype) and highest value of 63% (*Tilili* and *Chefe* ecotypes) for all the microsatellite markers tested. The genetic distance analysis result showed the presence of considerable genetic variation between the different ecotypes, however, the within ecotype variation was higher than the between ecotypes variation. Poylogenetic trees obtaining using the genetic distance in both standard Neighbour-Joining (NJ) and UPGMA methods assorted the ecotypes according their agro-ecological origins. The topography of both trees remained the same, but with higher significance level in NJ tree. Bootstrapping values were between 53 to 100% in NJ tree and 43% to 100% in UPGMA tree. In both trees, Fayoumi population formed a distinct branch on it's own with high significance (100%) level. The isolation by distance analysis based on normalised Mantel statistic showed a strong and positive correlation ($r= 0.62$) between the genetic distances and geographic distances matrixes.

Zusammenfassung

Ziel dieser Arbeit war, eine systemorientierte Identifikation, Charakterisierung und Evaluierung von Hühner-Ökotypen Äthiopiens durch Verwendung unterschiedlicher methodischer Ansätze durchzuführen, um nachhaltige Nutzungstrategien zu entwickeln. Hierzu wurden die Untersuchungen in drei miteinander vernetzte Versuchsabschnitte unterteilt:

Versuchsabschnitt I der Studie hatte zum Ziel, die sozioökonomische Funktion und Wertigkeit der dörflichen Hühnerproduktion in den fünf unterschiedlichen agroökologischen Regionen Äthiopiens am Beispiel von insgesamt 250 Haushalten (HH) in 10 Dörfern (zwei Dörfer in jeder Region) einzuschätzen. Dazu wurde eine strukturierte Befragung unter Einbindung von Participatory Rural Appraisal (PRA) Techniken in Bezug zur dörflichen Geflügelproduktion angewendet. Es wurden Informationen von einzelnen Bauern und Dorfgemeinschaften gewonnen, um die Perspektiven der Geflügelhaltung als Subsystem und deren Beitrag zur Betriebsökonomie, sowie die ökonomische Bewertung der Leistungsmerkmale abzuschätzen.

Im Versuchsabschnitt II wurden das Wachstum, Futterverwertung und Fleischansatz der unterschiedlichen Hühner-Ökotypen unter Stationsbedingungen am *Debre Zeit Agricultural Research Centr* (DZARC) in Äthiopien erfasst. Diese Studie schloss sämtliche Ökotypen der Hühner aus den fünf ökologischen Regionen, *Tilili, Horro, Chefe, Jarso* und *Tepi* ein. Die *Fayoumi* Hühnerrasse wurde als Referenzrasse zusätzlich aufgenommen. Aus den fünf agroökologischen Zonen wurden von jeweils einem repräsentativen Dorf die Eier besorgt, wobei sie direkt vom Hof gekauft wurden, um eine mögliche Vermengung mit Eiern fremder Rassen zu vermeiden. Aus der nächstgelegenen Brüterei wurden die geschlüpften Eintagsküken daraufhin zum DZARC transportiert. Trotzdem die Anzahl gesammelter Eier aus jeder Region gleichgroß war (ca. 850 Eier/Dorf), war der Schlupferfolg sehr unterschiedlich und die Anzahl geschlüpfter und in der Untersuchung verwendeter Küken betrug 484, 89, 227, 343, 132 und 315 für die verschiedenen Ökotypen *Tilili, Horro, Chefe, Jarso, Tepi* und *Fayoumi*. Die Küken eines jeden Ökotyps wurden nach dem Zufallsprinzip je nach Ausgangszahl in gleichgroße Gruppen aufgeteilt und in Bodenhaltung aufgezogen. Im Alter von sechs Wochen wurde das Körpergewicht der Tiere gemessen, geschlechterabhängig mit einer Flügelbinde markiert und anschließend in die Aufzuchtställe überführt, in denen sie bis zum Alter von 18 Wochen gemästet wurden. In der ersten Aufzuchtperiode vom Schlupf bis zur sechsten Woche enthielt das Futtermittel 21,7 % Rohprotein bei einem Energiegehalt

von 2784,1 kcal ME/kg. In der zweiten Aufzuchtperiode vom Umstallen in der sechsten Woche bis zur 18. Woche wurde den Hühnern ein Futtermittel mit 16,2 % Rohprotein und 2920,2 kcal ME/kg verabreicht. Die tägliche Futtermenge wurde so bemessen, dass den Hühnern eine *ad libitum* Aufnahme möglich war. Über die Rückwaage der Futterreste wurde die aufgenommene Futtermenge pro Tag bestimmt.

Das Körpergewicht aller Tiere wurde bis zur 12. Lebenswoche in einem Zwei-Wochen-Rhythmus und abschließend im Alter von 18 Wochen erfasst. Zusätzlich wurden von jedem Ökotyp jeweils fünf Hähne und fünf Hennen ausgewählt, von denen im Abstand von zwei Wochen sowohl das Körpergewicht als auch die Beinlänge gemessen wurden, um auf Grundlage dieser Daten eine Korrelation dieser Merkmale zu ermitteln.

Im Alter von 12 Wochen wurden von jedem Ökotypen jeweils fünf Hähne und fünf Hühner für eine Probeschlachtung zufällig ausgewählt und folgende Gewichte erfasst: der Schlachtkörper im Ganzen, sowie Kropf, Muskelmagen, Füße / Ständer / Beine, Kopf mit Kehllappen, Leber und Herz. Außerdem wurden mit Hilfe eines Maßbandes die Länge des Magen-Darmtraktes und der Umfang des Oberschenkelmuskels ermittelt. Der Brustwinkel wurde mit einem Tastzirkel ausgemessen. Die Gewichte der Schlachtkörperteile wurden als Anteil am Lebendgewicht ausgedrückt. Die Mortalitätsrate wurde kontinuierlich erfasst. Um die Lebendgewichtsinformationen in einer Variablen zusammenfassen zu können, wurden die entsprechenden Daten in einem Wachstumsmodell zusammengefügt.

Im Versuchsabschnitt III wurde der genetische Abstand zwischen den fünf Ökotypen (*Tilili, Horro, Chefe, Jarso* und *Tepi*) und der Referenzrasse, *Fayoumi* mit Hilfe von 10 Mikrosatelliten Markern ermittelt. Dazu wurde DNA aus Blutproben von jeweils 25 Tieren der einzelnen Ökotypen und der Referenzrasse verwendet. Die DNA wurde mit Hilfe von Qugine-DNA-Extraktions-Baukästen isoliert und an der Humboldt-Universität zu Berlin analysiert. Die Mikrosatelliten-Primer, die in dieser Studie verwendet wurden, entstammten einer Liste von Primern aus dem EU geförderten Projekt „Development of Strategy and Application of Molecular Tools to Assess Biodiversity in Chicken Genetic Resources, EC Contract Number BIO4-CT98-0342“ und wurden aufgrund ihres Polymorphismus und der Verteilung über das Genom ausgewählt. Die Polymerasekettenreaktion (PCR) für jede Tier-DNA wurde in einem Volumen von 23 µl mit dem Inhalt von 2,5 µl 10X-Puffer, 0,75 µl $MgCl_2$, 0,5 µl forward primer (B), 0,5 µl reverse Primer (A), 0,1 µl Taq, 18,15 µl PCR Wasser (zum Auffüllen auf 23 µl insgesamt) und 2 µl eingemischter DNA durchgeführt. Die Vermehrung der Bruchstücke wurde mittels 30 Wiederholungen nach folgendem Muster erreicht: 1 Min bei 94°C, 1 Min bei 55°C, 1 Min bei 72°C und abschließen mit einer

4minütige Erwärmung auf 72°C den Zyklus beenden. Die Größe der Allele wurde mit Hilfe eines standardisierten DNA Sequenzers A.L.F.^{TM} bestimmt. Grundlegende populationsgenetische Statistik, wie beispielsweise Allelfrequenzen, Heterozygotie, Mantel-Test wurden mit dem Computer Programm CERUS 2.0 berechnet; Molekularvarianzanalysen (AMOVA) und Fis-Werte mit dem Programmpaket ARLEQUIN 2.0, und Heterozygotiemangel oder –überfluss, Hardy-Weinberg-Gleichgewicht und Fst-Statistik mit der über das Internet erhältlichen Software GENEPOP. Die Poylogenetischen Stammbaumkonstruktionen (die neighbour-Joining (NJ) und die ungewichtete Paar-Gruppen Methode mittels arithmetischem Mittel) wurden unter Verwendung von unverzerrten Minimum-Genetischer-Abstand-Werten mit der Software MEGA 2.1 erstellt. Bootstrap Analysen wurden mit 1000 Iterationen durch das Programmpaket MICROSAT ausgeführt.

Ergebnisse zum Versuchsabschnitt I. Die Regionen der Datenerhebung und die zugehörigen Einzugsgebiete haben sich in der Anzahl Hühner pro Haushalt (HH) signifikant voneinander unterschieden. Die durchschnittliche Anzahl ausgewachsener Tiere und zuchtreifer Hennen pro HH lag bei $7,4 \pm 0,22$ beziehungsweise $5,4 \pm 0,17$ mit einem Verhältnis von männlichen zu weiblichen Hühnern von 1 : 2,5. Der Zukauf war die Hauptquelle zur Gründung eines Bestandes oder zum Ersatz, sowie zum Erwerb während der Brut. Die durchschnittliche Legeleistung der Hühner lag bei 17, 21 und 25 Eiern in der ersten, zweiten und dritten Legeperiode. In einem Jahr erreichten die Hennen durchschnittlich $2,6 \pm 0,06$ Legeserien. Im Durchschnitt lag die Anzahl Eier bei $13,5 \pm 0,9$ Stück pro Henne. Die mittlere Aufzuchtsrate von $70,5 \pm 10,6$ % lag zwischen 30 % und 90 % ($n = 250$). Es wurden hohe Mortalitätsraten vom Schlupf bis zum Alter von 8 Wochen festgestellt. Etwa 50 % der produzierten Eier wurden zur Bestandserhaltung ausgebrütet. Das Hauptaugenmerk der Hühnerhalter war demnach auf die Reproduktion zur Bestandserhaltung gerichtet. Nach eigenen Angaben der Bauern wurden unterschiedliche Maßnahmen ergriffen, um die Legeleistung der Hühner zu verbessern. Dazu gehört für gewöhnlich die Legestimulation der Hennen, um die Legeperiode zu verlängern. Insgesamt wurde von einer Verbesserung der Legeleistung von bis zu 80 % berichtet.

Die Varianzanalyse zeigte signifikante ($p < 0,01$) Unterschiede bezüglich der Verwendung der Hühner und Hühnerprodukte zwischen den Regionen auf. Ungefähr 50, 27 und 23 % der produzierten Eier wurden den Angaben zufolge zur Aufzucht, zum Verkauf bzw. für den Eigenbedarf verwendet, während 5,5, 3,8 und 3,1 Tiere zum Verkauf, zur Bestandserhaltung bzw. für den Konsum bestimmt waren. Eine enge negative Korrelation ($p < 0,01$) bestand zwischen dem Vermögensstatus und der Verwendung von Hühnern und Hühnerprodukten für

den Verkauf und den Eigenbedarf. Der Bruttogewinn (GR) als Prozent des Kaufwertes oder der GR pro Zuchthenne und Jahr lag bei 67,5 % bzw. 12,48 Birr.

Ergebnisse des Versuchsabschnittes II: Die Ökotypen hatten eine signifikanten Einfluss ($p < 0,01$) auf die Körpergewichtsentwicklung. Das größte Eintagskükengewicht wurde für die Rasse *Fayoumi* gefolgt von *Chefe, Tilili, Horro, Tepi* und *Jarso* festgestellt. Küken aus *Tepi* und *Jarso* zeigten signifikant ($p < 0,05$) kleinere Gewichte als die der übrigen drei ökologischen Zonen. Die *Fayoumi* Küken waren ducrhschnittlich 31,3, 21,1 und 37,1 % schwerer als die Eintagsküken der verschiedenen Ökotypen. Von den untersuchten Ökotypen zeigten Die *Chefe* Küken wiesen als schwerste der untersuchten lokalen Ökotypen eine 20,4 %ige Überlegenheit gegenüber den Küken der *Jarso*-Region (leichtester lokaler Ökotyp) auf. Im Alter von zwei, vier und sechs Wochen wiesen die lokalen Ökotypen ein signifikant geringeres Lebendgewicht als die *Fayoumi*-Rasse auf. *Fayoumi*-Hühner hatten im Alter von zwei Wochen mit 71,2 g das höchste durchschnittliche Lebendgewicht, gefolgt von *Chefe* mit 68,1 g und *Tilili* mit 57,2 Gramm.

Die Ergebnisse der Varianzanalysen zeigten außerdem einen signifikanten ($p < 0,01$) Effekt des Ökotyps und einen hochsignifikanten ($p < 0,001$) Effekt des Geschlechts auf das Lebendgewicht im Alter von acht, 10, 12 und 18 Wochen. Die Ökotypen-Sex-Interaktion hatte in jedem Alter keinen signifikanten ($p > 0,05$) Effekt auf das Lebendgewicht. Das allgemeine Mittel für das Lebendgewicht im Alter von acht, 10 12 und 18 Wochen betrug $273,4 \pm 3,2$ g, $377,8 \pm 4,6$ g, $479,1 \pm 6,3$ g bzw. $760,8 \pm 9,4$ Gramm. *Fayoumi* Hühner hatten das höchste Körpergewicht, gefolgt von Küken aus den Regionen *Tilili, Chefe, Horro, Tepi* und *Jarso*. Hühner der Ökotypen *Tilili* und *Chefe* zeigten im Alter von acht, 10, 12 und 18 Wochen signifikant ($p < 0,01$) höherer Lebendgewichte gegenüber den Hühnern der anderen drei ökologischen Regionen und zugehörigen Einzugsgebieten. Zwischen den Hühnern aus den *Jarso* und *Tepi* -Regionen konnte in diesem Alter kein statistisch signifikanter ($p > 0,05$) Unterschied für das Lebendgewicht festgestellt werden. Die *Tilili* Hühner (schwerste Lokalrasse) erreichten durchschnittlich 78, 74, 78 und 81 % des mittleren Lebendgewichts der *Fayoumi* Hühner im Alter von acht, 10, 12 bzw. 18 Wochen während die *Tepi* Hühner (leichteste Lokalrasse) nur 74, 61, 60 und 74 % des Körpergewichts der *Tilili* Hühner erreichten. Das Lebendgewicht männlicher Hühner war im Alter von acht, 10, 12 bzw. 18 Wochen durchschnittlich 36, 35, 39 bzw. 36 % höher als das weiblicher Tiere. Der Varianzkoeffizient (%) hinsichtlich des individuellen Lebendgewichtes war bei allen Ökotypen sehr groß.

Der Ökotyp hatte einen signifikanten ($p < 0,05$) Einfluss auf die Unterschenkellänge/Beinlänge in allen Altersgruppen (von zwei bis 12 Wochen). Das allgemeine Mittel der Beinlänge im Alter von zwei, vier, sechs, acht, 10, 12 und 18 Wochen lag bei 2,3; 2,9; 3,4; 3,7; 4,2; 5,2 bzw. 8,9 cm. Die durchschnittliche Beinlänge über die gesamten Altersstufen war für die *Fayoumi* und *Tilili* Hühner am größten, gefolgt von Hühnern der *Chefe* und *Tepi* Regionen mit mittellangen Beinen und Tieren aus *Horro* und *Jarso* mit den kürzesten Beinen. Die Beinlänge männlicher Tiere war signifikant ($p < 0,05$) größer als die weiblicher Tiere desselben Ökotyps. Das Wachstumsmodell zeigte, dass *Tepi*, *Fayoumi* und *Tilili* Hühner die effizienteste (größter K-Wert) Gruppe und *Tepi*, *Tilili* und *Chefe* die zweiteffizienteste Gruppe bildeten während *Jarso* und *Horro* die ineffizienteste (kleinster K-Wert) Gruppe bildeten.

Die größten Lebendgewichtszunahmen pro Huhn wurden bei den *Fayoumi* Tieren beobachtet. Im Alter von sechs Wochen lag deren Zunahme um 11,9; 97,7 bzw. 49,4 % über der Lebengewichtszunahmen der Hühner aus *Chefe* (größte Zunahme in diesem Alter), *Jarso* (geringste Gesamtzunahme unter den Lokalrassen) und dem gemeinsamen Mittel aller Lokalrassen. In Bezug auf die Gesamtzunahme bis zu diesem Alter lag das Mittel der *Chefe* Hühner um 76,8 % über dem der Hühner aus dem *Jarso* Region. Im Alter von sechs Wochen verbrauchten die *Fayoumi* Hühner 41, 115 und 65 % mehr Futter als Hühner des *Chefe* (größte Körpergewichtszunahme und Futteraufnahme unter den Lokalrassen in diesem Alter) sowie des *Jarso* Ökotyps (kleinste Lebendgewichtszunahme und geringste Futteraufnahme unter den Lokalrassen in diesem Alters) und im Vergleich zum Mittel aller Ökotypen zusammen. Bei den Ökotypen lag die Lebendgewichtszunahme der Lokalrassen *Jarso* und *Tepi* unter denen von *Chefe* und *Tilili*.

Die Varianzanalyse zeigte hochsignifikante ($p < 0,001$) Unterschiede zwischen den unterschiedlichen Ökotypen und Geschlechtern im Alter von sechs bis 12 Wochen für die Merkmale Zunahme pro Tier, durchschnittliche Zunahme pro Tier und Tag, Futteraufnahme pro Tier, durchschnittliche Futteraufwand pro Tier und Tag sowie Futterverwertungsrate (Futter : Zunahme). Die höchste Lebendgewichtszunahme pro Tier sowie durchschnittliche Zunahme pro Tier und Tag wurden für Masthähnchen der Lokalrasse *Tilili* verzeichnet. Die *Fayoumi* Hühner waren mit 12 Wochen 28, 77 und 52 % schwerer als Tiere der Ökotypen *Tilili* (schwerste Lokalrasse in diesem Alter) und *Tepi* (kleinste Gesamtzunahme unter den Lokalrassen in diesem Alter) sowie dem gemeinsamen Mittel aller Ökotypen. Mit 12 Wochen war die Lebendgewichtszunahme männlicher Masthähnchen des *Tilili* Ökotyps (schwerste Lokalrasse in diesem Alter) und des *Tepi* Ökotyps (geringste totale Lebendgewichtszunahme

unter den Lokalrassen in diesem Alter) sowie der gesamten mittleren Lebendgewichtszunahme aller Lokalrassen denen der weiblichen Hühner um 22, 30 bzw. 33 % überlegen. Die Futterverwertungsrate wurde ebenfalls signifikant ($p < 0,01$) durch die Ökotypen beeinflusst. Der höchste Futterbedarf pro Einheit Zunahme wurde für die *Fayoumi* gefolgt von *Tepi* und *Horro* Hühnern verzeichnet. Die kleinste Futtermenge pro Zunahmeeinheit wurde für die *Tilili* und *Chefe* Ökotypen ermittelt. Für sie lag die Futterverwertungsrate bei 4,95 g bzw. 5,2 g Futter pro Zunahmeeinheit.

Ergebnisse des Versuchsabschnittes III: Alle getesteten Mikrosatelliten waren hoch polymorph für alle getesteten Ökotypen. Die durchschnittliche Anzahl getesteter Allele aller Mikrosatelliten pro Ökotyp lag zwischen 4,2 (*Jarso*) und 5,3 (*Chefe*). Die Anzahl festgestellter Allele pro Genlokus variierte zwischen 2 und 10 Allelen. Der berechnete erwartete Heterozygotiegrad zeigte eine hohe genetische Variabilität in allen getesteten Populationen. Der Heterozygotiegrad variierte zwischen dem kleinsten Wert von 55 % (*Jarso* Ökotyp) und dem größten Wert von 63 % (*Tilili* und *Chefe* Ökotypen) über alle getesteten Mikrosatelliten. Das Ergebnis der Analyse auf genetische Differenz zeigte eine beträchtliche genetische Variation zwischen den verschiedenen Ökotypen. Die Variation innerhalb der Ökotypen war jedoch größer als die Variation zwischen den Ökotypen. Polygenetische Stambäume nach der genetischen Distanz führten nach beiden Methoden Standard Neighbour-Joining (NJ) und UPGMA zur Sortierung der Ökotypen nach deren agroökologischen Ursprung. Der Aufbau beider Stammbäume blieb gleich, wobei das Signifikanzniveau für den NJ-Stammbaum höher lag. Die Bootstrapping-Werte lagen zwischen 53 und 100 % für die NJ-Stammbäume und zwischen 43 bis 100 % für die UPGMA-Stammbäume. In beiden Stammbäumen formte die *Fayoumi*-Population mit hoher Signifikanz (100 %) einen eigenständigen signifikant entfernten Zweig. Die Isolation nach der Distanz/Entfernungs- Analyse für die normaliserte Mantel-Statistik zeigte eine enge positive Korrelation ($r = 0,62$) zwischen der genetischen Distanz und der geographischen Distanzmatrix.

Appendix 1-chapter III

The checklist adopted and used in an on-farm data collection process

1. Flock Characteristics:Number, species, sex ratio, foundation stock. replacement stock.
2. Housing: type, construction, materials.
3. Performance: egg production, hatching, brooding, survival rate.
4. Management and Feeding:

Feeding system: - scavenging only
- with regular supplementation
- feed in containers

Feeding habits and rules:
- frequency of feeding
- quality fed
- speed of consumption

Feed Resources:- vegetation, grains, oil seeds, kitchen wastes, agricultural by-products, concentrates, water, minerals, vitamins.

Feed composition: (obtain samples for laboratory analysis).

5. Health, Management and Diseases:
   - general hygiene and intervention, first aid, external and internal parasites and their control (drugs and herbal remedies, drug table);
   - diseases: comprehensive list and ranking;
   - losses: accidents, predators, theft
   - type of bird, reason, time, no
   - diseares: type, frequence.

6. Marketing and Economics:
   - Poultry products markets, channels, marginal,strengths and weaknesses;
   - Processing: boiled eggs, dry meat, etc.

7. Significance of poultry in rural economy:
   - income, expenditure, labour used and "wages"
   - nutritional significance
   - household consumption
   - for marketing: primary economic activity or secondary economic activity.

8. Extension service:
   - technical know-how and extension services
   - availability of vet drugs and supplies.

9. Constraints in Rural Poultry Production
   - capital
   - availability of feed
   - others

10. Farmers ……. solutions (Farmer`s recommendations) for (9):

Appendix 2-chapter III

Formal survey questionnaire for study on poultry production systems in Ethiopia (Adopted from ANRPD and modified for the project)

Methods for performance assessment and development of breeding strategies for poultry ecotypes of Ethiopia

INSTRUCTION TO THE ENUMERATOR

Please introduce yourself before starting to question the farmer by name and the institution you are working for and its purpose and objective. Pleas ask each question patiently until the farmer gets the point. For open questions, fill the farmer response in short and for closed once circle or mark ( ) where necessary.

ENUMERATOR:----------

QUESTIONNAIRE ON RURAL POULTRY PRODUCTION

A. SOCIO-ECONOMIC CHARACTERISTICS

1. FARMERS NAME :----------

WOREDA :----------

PEASANT ASSOCIATION:----------

FARMER NUMBER:----------

2.Level of Education of Respondent.....

3.Age group of Respondent:.....

(a) Less than 20 ( ) (b) 20-30 ( ) (c) 31-40 ( )
(d) 41-50 ( ) (e) 51-60 ( ) (f) Above 60 ( )

4. Sex of the respondent:

(a) male ( ) (b) female ( )

5. Crop and Livestock production by the household last year:

	Total Production /No	Consumption	Sold
Crops			
Livestock			

6. Who takes care of the poultry ? (state age group in the bracket)

(a) Men ( ) (c) Female children ( )

(b) Women ( ) (d) Male children ( )

(e) Others (specify) :.....

7. How long has poultry been kept in the household ?

(a) Less than 2 years ( ) (b) 2-5 years ( )

(c) 5-10 years ( ) (d) Over 10 years ( )

8. What poultry types do you raise ?

Poultry Species	ownership *	male	female	chicks	Source of foundation stock **	source of replacement stock **

*state age group of the owner

**a= purchase, b = inherited, c = custody, d= hatched

9. For what purpose and objective do you raise poultry ?

Species	consumption		Sale		Ceremonies	Gift	others(specify)	Rank*
	Meat	Egg	Live	Egg				
Chicken								
Guinea fowl								
Duck								
Others								
Rank *								

*can you rank those different uses and benefits by order of importance?

10. State the unit price of any of the following products that you sell:

Poultry species				
	Male bird	Female bird	chicks/Growers	Eggs
Period of highest sale*				

* X= Christian festivals, M= Muslim festivals,
T= Traditional festivals, A= Year round.

11.Which of the following items do you spend money on ?
(a) None at all ( ) (b) Purchase of birds ( )
(c) Purchase of feeds ( ) (d) Purchase of veterinary products ( )
(e) Others (specify):.....

12. Where do you get money to finance your poultry farming ?
(a) Personal income ( ) (b) Money lender ( ) (e) Family or friends ( )
(c) Bank ( ) (d) Cooperatives ( )

13. How much time do you spend to take care of the birds every day ?
.....

14. What determines your personal interest in poultry farming ?
Sacrifices ( )
Self consumption ( )
Sales ( )
Others (specify) ( )

15. Do you feel the need to improve your poultry production ?
(a) Yes ( ) (b) No ( )

16 . Is there any taboo/ regulation concerning the rising of a special type of birds ?
(a) Yes ( ) (b) No ( )

17. If yes , state precisely the taboo/ regulation, and to which type of birds and category of people it applies.
.....
.....

18.Is there any taboo/ regulation concerning the consumption of any bird or poultry product?
(a) Yes [ ] (b) No [ ]

19. If yes, state precisely the taboo/ regulation, and to which type of birds and category of people it applies.

.....
.....

20. Is there any taboo/regulation concerning the sale of any type of birds ?
(a) Yes [ ] (b) No [ ]

21. If yes, state precisely the taboo/ regulation, and to which type of birds and category of people it applies.

.....
.....

B. TECHNICAL/ BIOLOGICAL DATA

I. HOUSING

22.What management system do you practice ?
(a) Extensive [ ]
(b) Semi- intensive [ ]
(c) Intensive [ ]
(d) Others [ ]

23. Where do your birds rest at night?

(a) Don't know	[ ]	(d) Perch on trees	[ ]
(b) Kitchen	[ ]	(e) Hand woven basket	[ ]
(c) A room inside the house	[ ]	(f) Bamboo cages	[ ]
		(g) Others (specify):.....	

24.How frequently do you clean the cages or place ?
.....

II-FEEDING

25.Do you give supplementary feed to your birds ? (1)Yes [ ] (2) No [ ]
If yes what?----------
If no, reasons----------

26. How frequently do you feed your birds daily? (ref. Q. 25)

	Morning	Afternoon	Evening
(a) Once	[ ]	[ ]	[ ]
(b) Twice	[ ]	[ ]	[ ]
(c)Thrice or more	[ ]	[ ]	[ ]

27. How do you feed your birds ?

(a) Put feed in containers. [ ]
(b) Throw on the ground for collective feeding [ ]
(c) Others (precise): .....

* 28.-what do you feed to your birds? Please list:

....
---------- ----------
---------- ----------
---------- ----------

* 29.What household by - products do you also feed? Please list:

---------- ----------
---------- ----------
---------- ----------
---------- ----------

30, According to you, what do your birds scavenge upon?

---

31. Do you give them water to drink?
(a) yes ( ) (b) No ( ) If no why?----------

32. If yes, where do you get water for the chickens from?
(a) Borehole [ ] (b) well [ ]
(c) Rainwater [ ] (d) Rivers [ ]
(e) Tap borne [ ] (f) Other

33. In what container is it supplied? .....

34. How frequently do you wash the container?

III. CULLING

35. Do you purposely cull your birds at any time?
(a) Yes [ ] (b) No [ ]

36. For what purpose do you cull them?

(a) for consumption [ ] (b) For sale [ ]
(c) For sacrifice [ ] (d) Other (specify).....

37. What factors determine which bird you will cull ?
(a) Poor productivity [ ] (b) Old age [ ]
(c) Sickness [ ] (d) Other (specify) .....
.....

38. If (b) is your answer, at what age of the bird do you decide to cull it? .....
.....

39. If (c) is your answer, do you cull to:

(a) avoid expected disease outbreak [ ]
(b) when the bird is already sick [ ]

IV. HEALTH AND DISESE CONTROL

40. Do you experience serious disease outbreaks?
(a) Yes [ ] (b) No [ ]

41. What do you do when birds fall sick?

(a) Treat them myself[ ]
(b) Call in the vet. doctor [ ]
(c) Kill them immediately [ ]
(d) Sell them immediately [ ]
(e)Nothing [ ]

42. Describe the common diseases you have experienced in your flock,.
Please include common predators (in orders of importance).

Symptoms	Name	Species	Season	Severity Death	which type survive	Local Treatment

*** V. PRODUCTIVITY
43. State the productivity of your birds in the following table:

Species	Age at sexual maturity		No of times the hen hatches in a year	Average No of eggs per clutch	No of chicks hatched per clutch	No chicks surviving to adulthood
	H	C				

*** separate questionnaire used

C. MARKETING

44. What are the problems relating to poultry marketing in your experience?
    (a) Price [ ] (b) Availability of substitute [ ]
    (c) Poor Sales [ ] (d) Others (specify).....
    .....
    .....

D. EXTENSION CONTACT AND SERVICES

46. Do you discuss your poultry production problems with extension agents?

    (a) Yes [ ] (b) No [ ]

47. If no , state the reasons:

    (a) Have not heard of them [ ]
    (b) Cannot easily reach them [ ]
    (c) There is no need [ ]

48. If you , where do you meet?

    (a) Agents office [ ] (b) Farm house [ ]
    (c) At fortnightly meetings [ ] (d) At co-operative meetings [ ]
    (e) At the demonstration station [ ]

49. How frequently do you see the agent?
    .....

50. What is your major source of information on improved poultry production practices?

I do not get such information	[ ]	Radio	[ ]
Television	[ ]	Newspapers	[ ]
Other farmers	[ ]		
Extension agents	[ ]	co-operative leaders	[ ]
Market women	[ ]	Neighbours	[ ]
Relatives	[ ]		

E. GENERAL

51. Do you intend to expand poultry production?
    (a) Yes [ ] (b) No [ ]
52. If yes, to what size?
    .....

53. If no, why not? .....

54. Which of these are barriers to future expansion
    (a) Capital [ ]

(b) Land [ ]
(c) Labour [ ]
(d)Technical information [ ]
(e) Feed [ ]
(f) Marketing [ ]
(g) Diseases [ ]
(h) Theft [ ]
(I) Traps [ ]
(j) Others (specify): .....

55, What are the problems facing poultry farmers in this areas?.

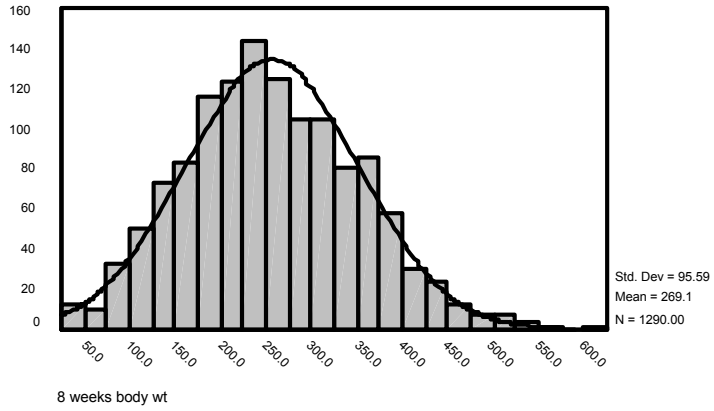
.....
.....
.....

56. What do you think the government should do to improve poultry keeping, particularly in rural areas?

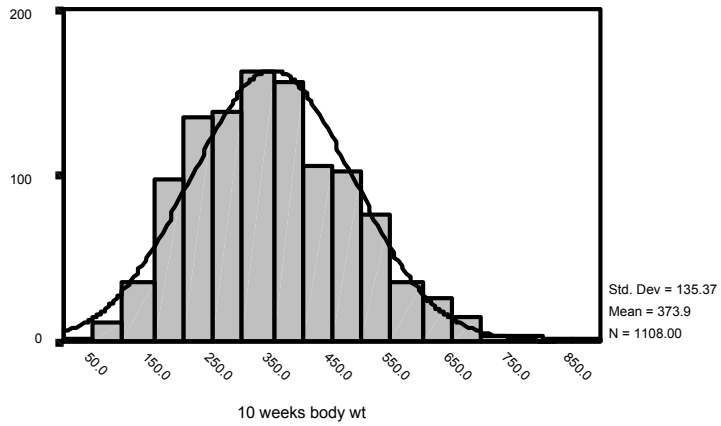
.....
.....
.....

THE QUESTIONNAIRE IS COMPLETE. THANK THE FARMER AND LEAVE.

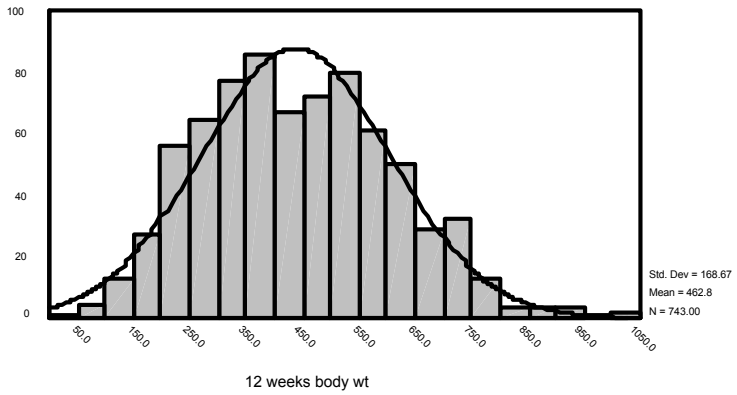
Appendix 1-chapter IV Normal curve for body weight at eight weeks of age



Appendix 2-chapter IV Normal curve for body weight at ten weeks of age

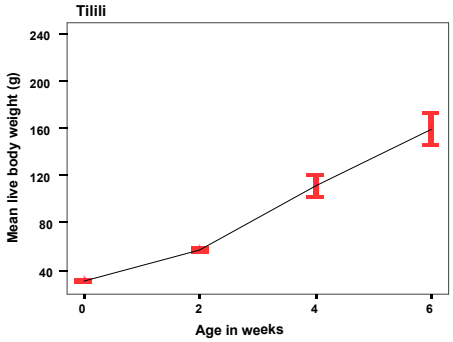


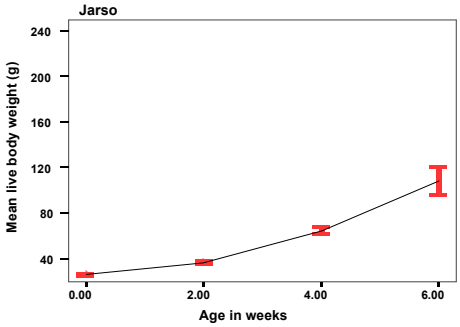
Appendix 3-chapter IV Normal curve for body weight at twelve weeks of age

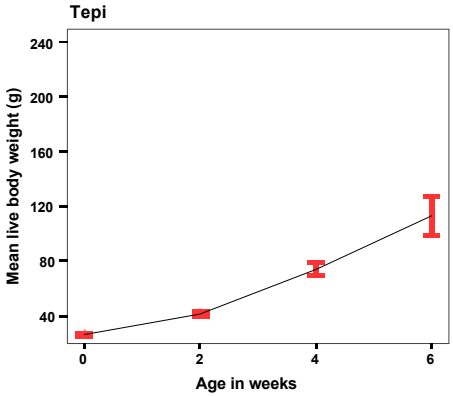


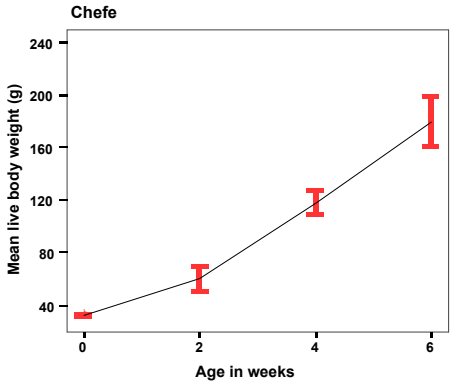
Appendix 4-chapter IV

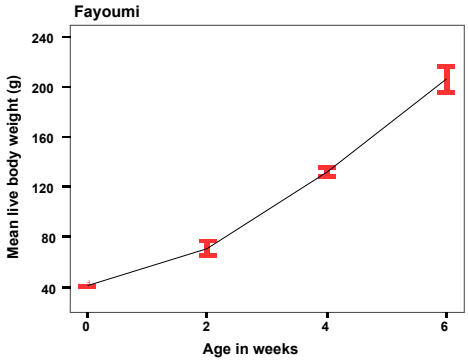
Mean (± SE) live body weight of six ecotypes of chicks in Ethiopia (day old to six weeks of age)





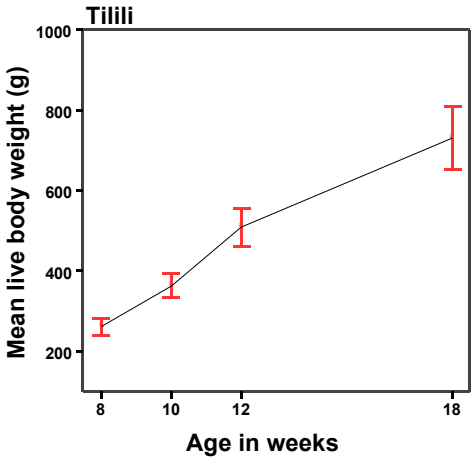


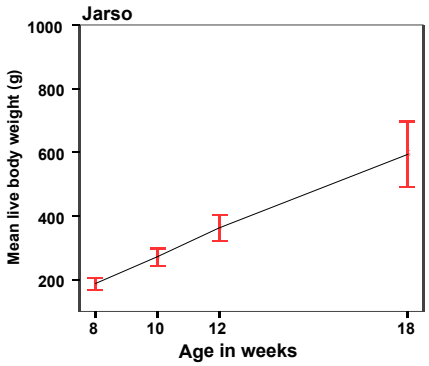


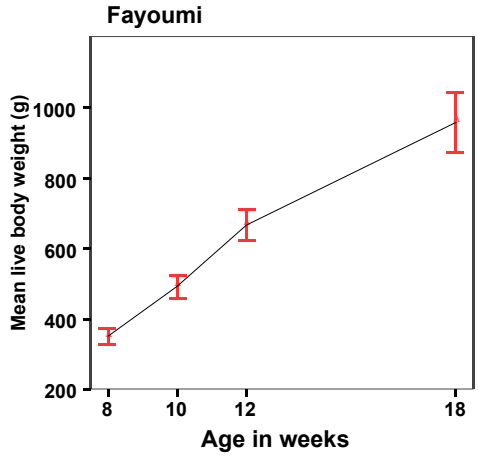


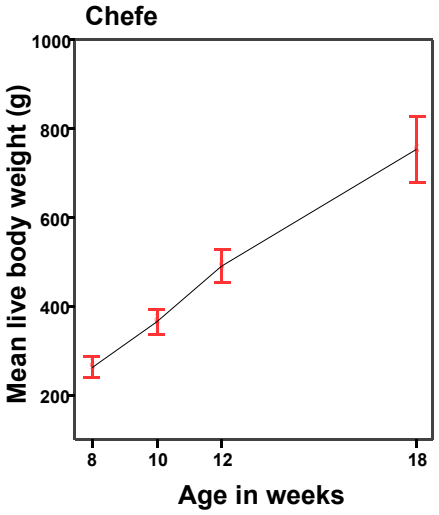
Appendix 5-chapter IV

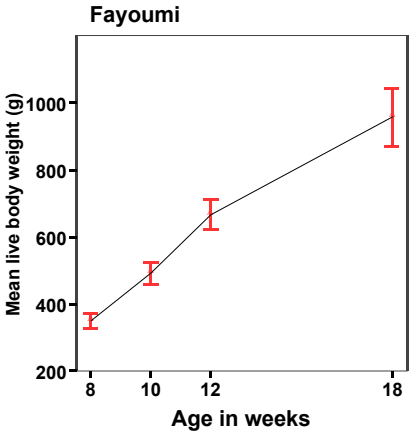
Mean (±SE) live body weight of six chicken ecotypes in Ethiopia (eight to 18 weeks of age)











Appendix 6-chapter IV

Analysis of variance showing the effects of ecotype, sex and ecotype-sex interaction on shank length for six of the chicken ecotypes from two to 18 weeks of age

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	2 wks shank length	321.245[a]	12	26.770	747.081	.000
	4 wks shank length	494.611[b]	12	41.218	1163.352	.000
	6 wks shank length	705.441[c]	12	58.787	1620.810	.000
	8 wks shank length	845.979[c]	12	70.498	1747.890	.000
	10 wks shank length	1074.778[d]	12	89.565	2190.385	.000
	12 wks shank length	19548327.3[e]	12	1629027.279	229.026	.000
	18 wks shank length	4709.296[d]	12	392.441	2301.709	.000
GENOTYPE	2 wks shank length	1.301	5	.260	7.260	.000
	4 wks shank length	4.151	5	.830	23.431	.000
	6 wks shank length	8.617	5	1.723	47.514	.000
	8 wks shank length	11.620	5	2.324	57.617	.000
	10 wks shank length	18.341	5	3.668	89.710	.000
	12 wks shank length	656633.379	5	131326.676	18.463	.000
	18 wks shank length	9.845	5	1.969	11.549	.000
SEX	2 wks shank length	1.944	1	1.944	54.251	.000
	4 wks shank length	1.890	1	1.890	53.355	.000
	6 wks shank length	1.873	1	1.873	51.631	.000
	8 wks shank length	1.667	1	1.667	41.322	.000
	10 wks shank length	1.670	1	1.670	40.841	.000
	12 wks shank length	127307.077	1	127307.077	17.898	.000
	18 wks shank length	6.403	1	6.403	37.552	.000
GENOTYPE * SEX	2 wks shank length	.140	5	2.800E-02	.781	.568
	4 wks shank length	.136	5	2.717E-02	.767	.578
	6 wks shank length	.127	5	2.547E-02	.702	.625
	8 wks shank length	.155	5	3.107E-02	.770	.576
	10 wks shank length	.144	5	2.872E-02	.702	.624
	12 wks shank length	76553.492	5	15310.698	2.153	.075
	18 wks shank length	.775	5	.155	.909	.483
Error	2 wks shank length	1.720	48	3.583E-02		
	4 wks shank length	1.701	48	3.543E-02		
	6 wks shank length	1.741	48	3.627E-02		
	8 wks shank length	1.936	48	4.033E-02		
	10 wks shank length	1.963	48	4.089E-02		
	12 wks shank length	341416.278	48	7112.839		
	18 wks shank length	8.184	48	.171		
Total	2 wks shank length	322.965	60			
	4 wks shank length	496.311	60			
	6 wks shank length	707.182	60			
	8 wks shank length	847.915	60			
	10 wks shank length	1076.741	60			
	12 wks shank length	19889743.6	60			
	18 wks shank length	4717.480	60			

a. R Squared = .995 (Adjusted R Squared = .993)

b. R Squared = .997 (Adjusted R Squared = .996)

c. R Squared = .998 (Adjusted R Squared = .997)

d. R Squared = .998 (Adjusted R Squared = .998)

e. R Squared = .983 (Adjusted R Squared = .979)

Appendix 1-chapter V

Individual allele frequencies of polymorphic loci observed in different chicken ecotypes of Ethiopia

Microsatellites	Allele	Chicken ecotypes					
		Tilili	Horro	Chefe	Jarso	Tepi	Fayoumi
MCW0222	219	0.300	0.580	0.360	0.120	0.320	0.560
	221	0.700	0.320	0.580	0.880	0.640	0.420
	223	0	0.100	0.060	0	0.040	0.020
MCW0248	213	0	0	0	0	0.021	0
	215	0.740	0.900	0.800	0.540	0.833	0.240
	219	0.160	0.100	0.100	0.440	0.021	0.140
	223	0.100	0	0.100	0.020	0.125	0.620
MCW0183	298	0.167	0.580	0.440	0.540	0.700	0.460
	302	0.083	0.060	0.020	0	0.020	0
	306	0.042	0.080	0.020	0.120	0	0.300
	310	0.167	0.080	0.240	0.240	0.220	0.040
	314	0	0	0.060	0	0	0
	316	0.312	0.080	0.020	0.020	0.060	0
	322	0.167	0.060	0.180	0.080	0	0.040
	326	0.062	0.060	0	0	0	0.160
MCW0294	301	0.087	0.080	0.021	0.400	0.065	0.250
	303	0.022	0.320	0	0	0.043	0
	305	0.087	0.060	0.104	0	0.087	0.167
	307	0.543	0.040	0.146	0.160	0.435	0.167
	309	0.217	0.200	0.167	0	0.239	0.139
	311	0.043	0.300	0.146	0.220	0.130	0.222
	313	0	0	0.083	0.080	0	0.056
	315	0	0	0.104	0.100	0	0
	317	0	0	0.188	0.020	0	0
	319	0	0	0.042	0.020	0	0
MCW0295	101	0	0.060	0	0.080	0	0
	103	0.540	0.680	0.833	0.800	0.220	0.620
	105	0.020	0.000	0	0.020	0.060	0.200
	107	0.160	0.120	0.062	0.100	0.200	0.140
	109	0.280	0.120	0.083	0	0.280	0.020
	111	0	0.020	0.021	0	0.120	0.020
	113	0	0	0	0	0.060	0
	115	0	0	0	0	0.060	0
MCW0034	219	0.260	0.040	0.240	0.240	0.200	0.400
	221	0.260	0.520	0.220	0	0.400	0.100
	223	0.040	0.060	0.040	0	0.120	0
	225	0.020	0	0	0.060	0.060	0
	227	0.260	0.200	0.260	0.300	0.100	0
	229	0.060	0	0.020	0.320	0.020	0.380
	231	0.100	0.120	0.160	0.080	0.100	0.080
	233	0	0	0.020	0	0	0
	239	0	0.060	0.040	0	0	0.040
MCW0078	137	0.160	0.080	0.300	0.240	0	0.080
	139	0.040	0.040	0.040	0.020	0	0.060
	141	0.700	0.840	0.640	0.680	0.900	0.080
	143	0.060	0.040	0.020	0.020	0.060	0.360
	145	0.040	0	0	0.040	0.040	0.420
MCW0098	253	0.140	0.240	0.150	0	0.208	0.920
	255	0.840	0.760	0.775	0.896	0.667	0.080
	257	0.020	0	0.075	0.104	0.125	0
ADL0268	103	0	0	0	0	0	0.020
	105	0	0	0.020	0	0.100	0
	111	0	0	0.100	0.080	0.120	0.040
	113	0.540	0.620	0.080	0.280	0.400	0.180
	115	0.180	0.140	0.360	0.320	0.100	0.220
	117	0.220	0.120	0.240	0.260	0.200	0.380
	119	0.060	0.120	0.200	0.060	0.080	0.160
ADL0278	113	0.300	0.300	0.522	0.640	0.140	0.240
	115	0.060	0.020	0	0	0.020	0
	117	0	0	0	0	0.040	0.400
	119	0.100	0.240	0.174	0.020	0.100	0.00
	121	0.240	0.200	0.239	0.240	0.460	0.200
	123	0.260	0.240	0.065	0.100	0.240	0.160
	127	0.040	0	0	0	0	0

Appendix 1-chapter VI

Comparison of exotic and indigenous chicken breeds under the different criteria's such as farm management, commercialization, ecological and cultural aspects

EXOTIC CHICKEN BREED	INDIGENOUS CHICKEN BREED
Farm management criteria	
High production -high risk	Low production -low risk
High production cost	Production cost -very low or non-existence
Mostly one product (e.g. Egg or Meat)	Several products (e.g. egg, meat, hatching etc)
Sensitive to diet, special feed demands	Adapted to local feed supplies, moderate diet and feed demands
Generally not hardy	Generally hardy
Highly vulnerable to disease	Disease resistance and tolerance
High veterinary input (e.g. vaccination to infectious chicken diseases)	Low veterinary input
Often not adopted to the farming system	Traditionally adopted and parts of the farming system
Extension of new techniques necessary (e.g. Some sorts of hatching facilities are a must)	Self sustained (e.g. The hen hatch her own eggs)
Needs mating partner of the same breed -to keep the breed in its pure form	Stock exchange and selection on community and household level
Commercialisation criteria	
Product corresponds to "modern" nutrition habits (e.g. Broiler meat -not accepted in local dish)	Product corresponds to local nutrition habits (e.g. Aged chicken meat preferred for local dish)
High privet sector interest	Low private sector interest
Internationally and nationally promoted and often subsidised (Aggressively promoted by the privet sector)	Mostly neglected by the international and national research systems; and international donor community
Poor longevity (e.g. reduce egg production after one production year)	High longevity (e.g. Sustainable production even after one year egg production) and less costly to the system
Ecological criteria	
Highly sensitive to stress (low nutrition, disease, temperature, water etc)	Locally adopted and fit to a range of stresses in their production environments
Low genetic variability	High genetic variability
No tropically important genes	Tropically important genes (e.g. nk: Necked neck gene)
High input demanding	Low input demanding and efficient
Cultural criteria	
No cultural and religious importance to local people	Often cultural and religious importance
Usually one plumage colour and comb type	With different plumage colour and comb type
With recognised names and breed standards	Vernacular names for different phenotypes (may correspond to different geno- or eco-types)
Traditional role of women may be undermined	Traditional role of women promoted

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