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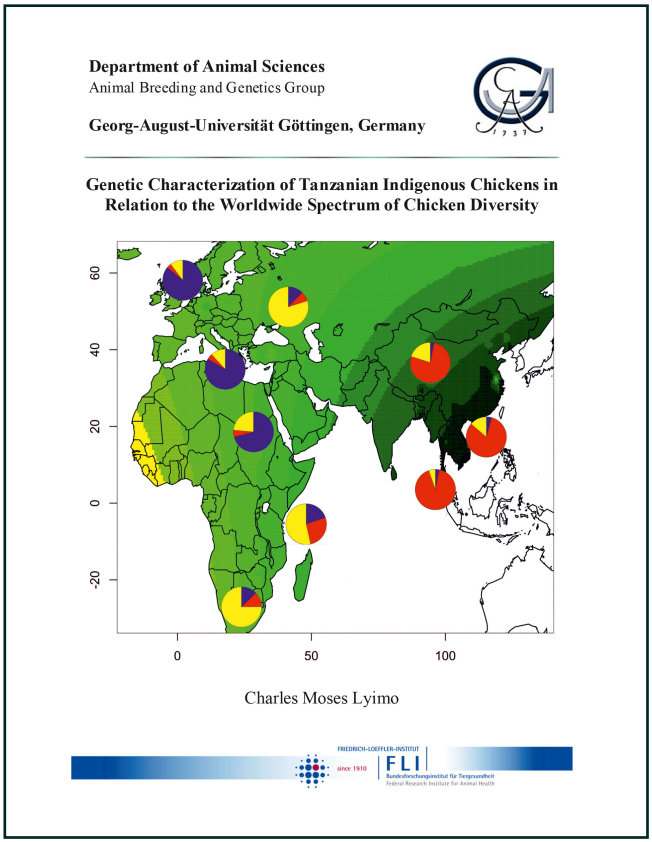
Genetic Characterization of Tanzanian Indigenous Chickens in Relation to the Worldwide Spectrum of Chicken Diversity



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CHAPTER ONE

1.0 General introduction

1.1. The United Republic of Tanzania

The United Republic of Tanzania is located in the Eastern coast of Africa just south of the equator between longitude 29° and 41° East, Latitude 1° and 12° South. It also incorporates several offshore islands, including Unguja (Zanzibar), Pemba, and Mafia. The country's eastern border is formed by the Indian Ocean coastline of approximately 1,400 km long. It has land borders with Kenya and Uganda to the north; Rwanda, Burundi and Democratic Republic of Congo to the west; and Zambia, Malawi and Mozambique to the south. Tanzania is the world's 31st largest country with a total area of 947,300 km^2 including 885,800 km^2 of the land surfaces and 61,500 km^2 of inland water bodies. It has a territorial sea limit of 22 km (12 nautical miles). Tanzania has a population of 45 million people with the annual growth rate of 2.7 % (NBS, 2013). There are over 120 ethnic groups, each with its own language or dialect. Swahili is the common and officially spoken language in all of Tanzania. However, English is the second official language and the language most often used in education, commerce and international affairs (Sa, 2007; Kanana, 2013; Development Education, 2014).

Source: Ministry of Lands, Housing and Urban Development (MLHUD, 2013).

Figure 1.1: Administrative map of the United Republic of Tanzania

1.1.1 Topography and General Climatic Condition of Tanzania

Tanzania is a country of highly varied physical-geographic features, including Africa's highest point at the snow-capped of Mount Kilimanjaro (5,895 m) in the northern border and Africa's lowest point at the floor of Lake Tanganyika (1,436 m) in the western border. Three of the African's Great Lakes are partly withithin the borders of Tanzania, namely Lake Victoria the African largest lake, Lake Tanganyika and Lake Nyasa. The country has a spectacular landscape of mainly three physiographic regions namely the Islands and the coastal plains to the east; the inland saucer-shaped plateau; and the highlands. The Central Plateau, covering over a third of the country, lies between the two branches of the Rift Valley. The East African Rift Valley runs from north to south leaving many narrow, deep depressions, often filled with lakes. A western branch of the Rift Valley runs along the western frontier and is marked by lakes Tanganyika and Rukwa. The eastern branch is the Great Rift Valley, from the Kenya border in the region of lakes Eyasi, Natron and Manyara to Lake Nyassa on the Mozambican border. Much of the country is above 900 meters and a small portion, including the islands and the coastal plains, lies below about 200 meters. The natural vegetation's are extremely varied, changing from coastal mangrove swamps to tropical rain forests; and from rolling savannas and high arid plateaus to mountain ranges. About a third of the country mainland is covered with wooded grassland savannas while two-thirds of Zanzibar Island is covered with bushes and grass.

Tanzania is characterized by a tropical climate although it experiences a great effect on its climatic conditions due to its geometrical location and physical features. The coastal area is tropical and humid with average temperatures of about 27°C (81°F). Further inland, the central plateau is hot and dry with temperatures that vary by season and time of day. High humidity in the lake regions and temperate conditions in the highlands can also be experienced. In the highlands, temperatures range between 10^{o}C and 20^{o}C, during cold and hot seasons respectively. The rest of the country has temperatures never falling lower than 20^{o}C. The climate is governed by two monsoon periods. The north east monsoon from December to March brings the year's hottest temperatures, and when the winds shift to the south from March to May, they bring the heavy intermittent rains of the south west monsoon, which extends from June to September bringing relatively cool, dry weather. Generally Tanzania has two rainy seasons; a long heavy one from March to May, and a shorter, lighter one normally from November to January. Rainfall varies from an annual average of 1,250 mm in the wettest 3% of the land area, the south-eastern slopes of the great volcanoes, to below 600 mm in the central area of the country. The islands receive heavy rains in April and May with lighter rains in November and December. Drier weather occurs during the alternating monsoon seasons, which arrive from the northeast from December to March and from the southwest from June to October. Temperatures and rainfall are modified by altitude, with high elevations receiving more precipitation. In overall the rainfall period is usually short and is followed by a long dry season of six to eight months.

1.1.2 Tanzania Agro-ecological Zones

The country is divided into seven agro-ecological zones that are based on climate, physiography, soils, vegetation, land use and tsetse fly occurrence. All these factors are also the main physical agents, which influence opportunities and constrains for crop and livestock production. These agro-ecological zones are described as (i) Costal, (ii) Arid Lands, (iii) Semi-arid Lands, (iv) Plateaux, (v) Southern, South-western and Western Highlands, (vi) Northern Highland and Granitic Mountains and (vii) Alluvial Plains. Two of these zones, the arid and semi-arid zones together with the dry sub-humid areas constitute the dry-land areas of Tanzania. These dry-land areas cover about 61% of the total land area. The combinations of factors, which create the zones, are presented in the table (Table 1.1) below.

Table 1.1: Tanzania Agro-ecological Zones

Zones *(Altitude m)*	**Rainfall (mm)**	**Soil and Topography**
Costal Zone *(Under 300)*	***North***: Bimodal, 750-1200 ***South***: Unimodal, 800-200	***North***: Infertile sands on gently rolling uplands, Alluvial soils in Rufiji ***South***: Sands and infertile soil, fertile clays on uplands and river flood plains
Arid Lands *(**North:** 1300-1800)* *(**South:** 500 – 1500)*	***North:*** Unimodal and unreliable, 500-800 ***South***: Unimodal and unreliable, 600-800	***North:*** Volcanic ash and Sediments, Soils variable in texture and very susceptible to water erosion ***South:*** Rolling plains of reddish sandy clays of low fertility. Susceptible to water erosion. Pangani river flood plain with saline, alkaline soil
Semi-arid Lands *(**Central:** 1000-1500)* *(**Southern:** 200 -600)*	***Central:*** Unimodal and unreliable, 500-800 ***Southern:*** Unimodal 600-800	***Central:*** Undulating plains, rocky hills and low scarps. Well drained soil low fertility. Alluvial hardpan and saline soils in Erstern Rift Valley and Lake Eyasi, Black cracking soils in Shinyanga. ***Southeastern:*** Flat, or undulating plains w/rocky hills. Moderately fertile loams and clays in South (Morogoro), infertile sands in center.
Plateaux *(800 – 1500)*	***Western:*** Unimodal, 800-1000 ***Southern:*** Unimodal, very reliable, 900-1300	***Western***: Wide sandy plains and Rift Valley scarps. Flooded swamps of Malagarasi and Ugalla rivers have clay soil with high fertility ***Southern:*** Upland plains w/rock hills. Clay soils of low to moderate fertility in South, infertile sands in North
Southern, South-western and Western Highlands *(**Southern:** 1200-1500)* *(**Southwestern:** 1400-2300)* *(**Western:** 1000-800)*	***Southern:*** Unimodal, reliable, local rain shadows 800-1400 ***Southwestern:*** Unimodal, reliable 800-1000 ***Western:*** Bimodal 1000-2000	***Southern:*** Undulating plains to dissected hills and mountains, Moderately fertile clay soils, with volcanic soils in Mbeya ***Southwestern:*** Undulating plateaux above Rift Valley(s) Sandy soils of low fertility ***Western:*** North south ridges separated by swampy valleys, Loams and clay soils of low fertility in hills, with alluvium and ponded clays in valley
Northern Highland and Granitic Mts. *(**Northern:** 1000-2500)* *(**Granitic Mts:**1000-2000)*	***Northern:*** Bimodal, varies widely, 1000-2000 ***Granitic Mts:*** Bimodial and very reliable, 1000-2000	***Northern:*** Volcanic uplands, Volcanic soils from lavas and ash. Deep fertile loams and clays. Soils in dry areas prone to water erosion ***Granitic Mts:*** Steep mountain sides to highland plateux, Soil are deep, friable and moderately fertile on upper slopes; shadow and stony on steep slopes
Alluvial Plains	***Kilombero:*** Unimodal, very reliable, 900-1300 ***Wami:*** Unimodal 600–1800 ***Usangu:*** Unimodal, 500-800 ***Rufiji:*** Unimodal, often inadequate, 800–1200	***Kilombero:*** Central clay plain, with alluvial fans East and West ***Wami:*** Moderately alkaline black soils in East, and alluvial fans with well drained black loam in west ***Usangu:*** Seasonally flooded clay soils in North, alluvial fans in South ***Rufiji:*** Moderately alkaline black soils in East, and alluvial fans with well drained black loam in west

Sources: URT, (1999) and USAD, (2005).

1.1.3 Tanzanian natural resources and agriculture contributions

The country is endowed with abundant natural resources, which includes land, minerals, water bodies (rivers, lakes and ocean), waterfalls, gas reserves, forestry/woodlands, wildlife, forage and a large livestock resource base. The Gross Domestic Product (GDP) in Tanzania remained with an annual Growth Rate of 7% on average from 2002 until 2013 (The World Bank, 2014a; IFAD, 2014; NBS, 2014). Agriculture is still the foundation of the Tanzania economy that employs 80% of the Tanzanian workforce and it contributes half of the national income (URT, 2010). Agriculture also contributes around 80% of export earnings, and most industries in the country are linked to the agricultural sector in producing farm inputs and processing agricultural products. Tanzania agriculture is dominated by smallholder farmers (peasants) cultivating an average farm size between 0.9 to 3.0 hectors (ESRF, 2009). Smallholder farmers practice mainly subsistence farming and they commonly use rudimentary technologies which inevitably lead to the low yields. Only around 20% of farmers make use of animal traction for ploughing, and many are still using hand hoes for undertaking various operations such as land preparation and weeding. The use of advances in agriculture, such as improved seeds and fertilizer is still very low.

Tanzanian farmers grow a wide variety of food and cash crops. In terms of agricultural exports, coffee constitutes the most important cash crop (17.7%). Cotton is the second cash crop (16.3%), followed by cashew nuts (12.7%), tobacco (6.4%), tea (2.9%), and sisal (0.7%). The major importers of Tanzanian agricultural exports consist of the EU countries, especially the United Kingdom, Germany, and the Netherlands. For the food crop maize production dominate much of the county, particularly the highlands in the North and South. Bananas are grown much as a staple food in the Northern highland and in the Lake Zone at the western shore of Lake Victoria. The lush tropical coastal belt, always warm and humid, is dominated by cassava and rice. Drought resistant millet and sorghum are grown in the central plateau where temperatures and rainfall are highly variable. Tanzanian farmers also grow huge variety of fruits, vegetables and spices. Zanzibar, once a leading source of spices for the global market, continues to produce large amount of cloves.

Tanzania has vast animal genetic resources with a wide variety of indigenous farm animals. Available Animal Genetic Resources in 2012 included 22.8 million cattle, 15.6 million goats, 7.0 millions sheep, 2.1 million pigs and 60 million chickens (Njombe, 2013). Livestock industry contributes 18% of the total GDP, which is about 30% of the agricultural GDP and the poultry sub-sector contributes 16% of the livestock GDP (URT, 2010; PASS Trust, 2012). Within the livestock sector, village chickens are often the most common type of livestock and they are more frequent owned than larger livestock species. In the Tanzanian mainland, Shinyanga, Mbeya, Mwanza, Tabora, Morogoro, Iringa and Tanga regions accounted for 51.4% of the total chicken populations (NBS, 2012). According to FAO database the average consumption of chicken products in Tanzania is about 0.75 kg of meat and 13 eggs per year, which is far below the worldwide average consumption level of 6.8 kg of meat and 108 eggs capital per year (RLDC, 2010; PASS Trust, 2012).

1.2 Origin and dispersal of domestic chickens

The chicken (*Gallus domesticus*) is a domesticated fowl descending from wild junglefowls originating around Southeast Asia, the Southwestern part of China and the India subcontinent. Through domestication, migration, mutation, selection and management process, the specie has undergone several modifications from its wild ancestors in order to suit the adaptation to a new environment and its usefulness to humans. These processes led to remarkable evolutionary changes in morphology, physiology and behaviour of domesticated chickens (Price, 2002; Sawai *et al.*, 2010; Rubin *et al.*, 2010). The domestic chickens' ancestry can be traced back from the four species of wild junglefowls namely; Red junglefowl *(Gallus gallus),* Grey junglefowl *(Gallus sonneratii),* Ceylon junglefowl *(Gallus lafayetii)* and may be Green junglefowl *(Gallus varius).* Recent research studies suggested multiple domestication events of chickens over the last 8,000 years (West and Zhou, 1988; Fumihito *et al*. 1996; Liu *et al*., 2006; Sawai *et al.*, 2010; Tixier-Boichard *et al.*, 2011), mainly from the wild ancestor red junglefowls *(Gallus gallus gallus)* in South-eastern Asia with some hybridizations of *Gallus sonneratii* and *Gallus lafayetii* (Groeneveld *et al.*, 2010; Tixier-Boichard *et al.*, 2011). Although domestic chickens are closely related to red junglefowls, the genetic contributions from other junglefowls remain uncertain (Sawai *et al.*, 2010). It is still not very clear how many of these subspecies have contributed to the origin of domestic chickens (Liu *et al.*, 2006). The absence of the yellow skin gene in the wild red junglefowl suggests the possibility of hybridization with the grey junglefowl (*Gallus sonneratii*) during the domestication of the species (Eriksson *et al.*, 2008; Clutton-Brock, 2012). The presence of yellow skin colour in many domestic chickens supports the theory of multiple progenitors as the foundation of several domestication events that occurred independently across Southeast Asia, Southwestern part of China and India subcontinent. A culturally significant hybrid between the red junglefowl and the green junglefowl in Indonesia is known as Bekisar (Hutagalung, 2000).

1.2.1 Classification and geographic distributions of wild junglefowls

The classifications of wild junglefowls are mainly based on the phenotypic traits and geographical distributions of the populations. The four species of junglefowl inhabited at different geographical regions of Asia (Figure 1.2) and display different morphological features (Sibley and Monroe, 1990; Nishibori *et al*., 2005; Tixier-Boichard *et al.*, 2011). The conformation and body shape of *Gallus gallus* have the features of Mediterranean egg type breeds (Crawford, 1990). The vibrant male has long, golden-orange to deep-red crown and neck feathers, and a dark metallic-green tail with a white tuft at the base. The under-parts are a dull black while the upper-parts are a combination of glossy blue-green, rich dark red, maroon-red, fiery orange, rufous and blackish brown. The presence of a complete eclipse plumage in the summer and a shrill, short crow, which ends suddenly, are exclusively intrinsic in the male red junglefowl. Pure hens show neither comb nor wattles and both pure sexes hold

their tails almost horizontal (Appendix 1). The *Gallus sonneratii* has body plumage on a grey background colour and is endemic in India, distributed from Southwest to central India. *Gallus lafayettei* fowl inhabits only in Sri Lanka, morphologically resembles with RJF but exhibits an orange-brown colour of the breast with a purple spot on top of the neck, yellow spot on the comb and red legs. *Gallus varius* is morphologically distinct greenish plumage junglefowl limited to Java Island in Philipine and immediately vicinity of Bali and Lombok Islands. It thought to be the most primitive of the four gallus species, boasting sixteen tail feathers and short hackle feathers, whereas other species possess fourteen tail feathers and long pointed hackle feathers. *Gallus varius* also characterized by several morphological peculiarities including a single three-coloured wattle (red, yellow and blue), the lack of indentations of the comb and two additional feathers on the tail.

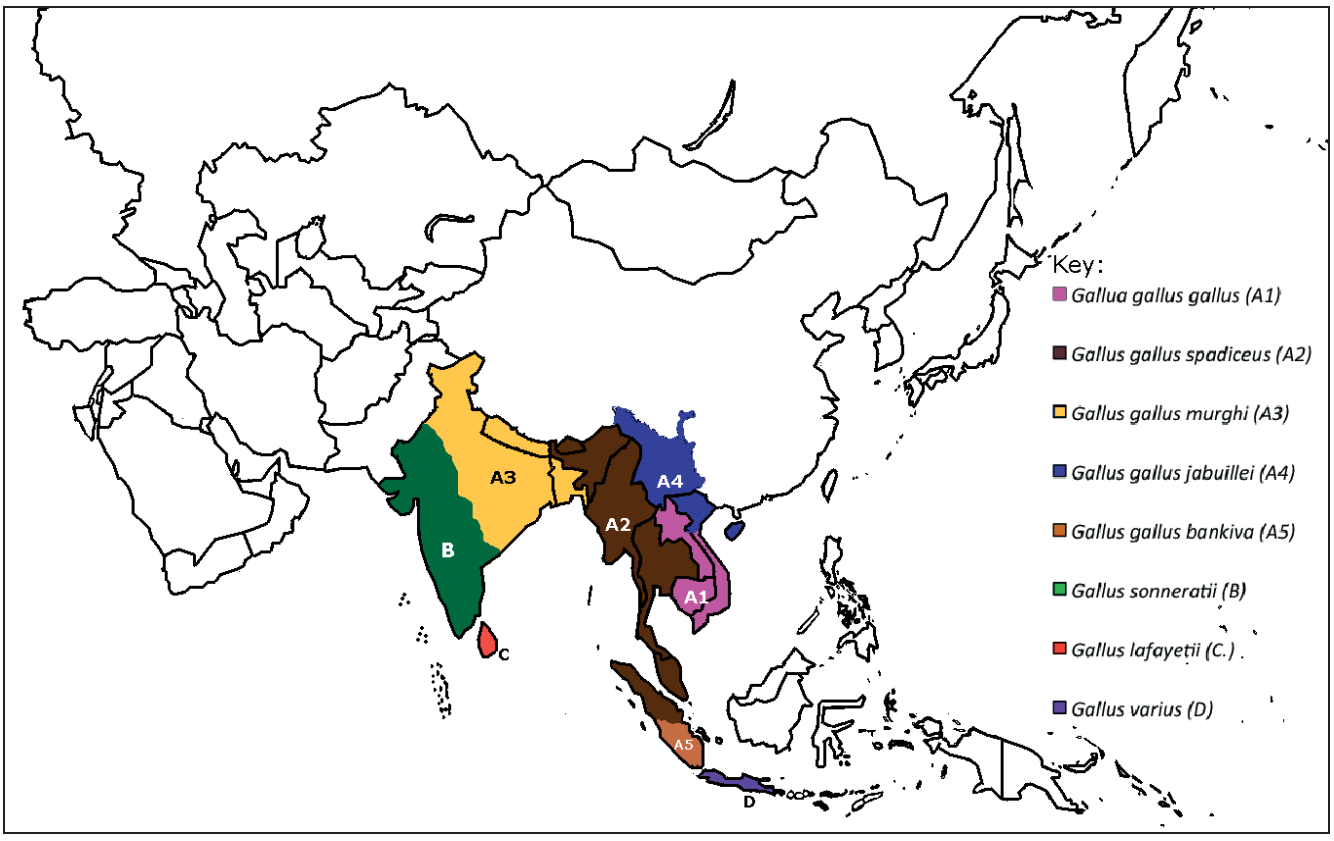

Figure 1.2: Origin distribution of the wild red junglefowl adopted from West and Zhou, (1988); and Tixier-Boichard *et al.,* (2011)

Red junglefowl is classified into five subspecies based on variation in home range, earlobes colour, comb size, facial wattles, length and colour of the male hackle feather. In general red junglefowl has a strong sexual dimorphism with males having red fleshy wattles (Sawai *et al.*, 2010) *Gallus gallus gallus* from South Vietnam, Cambodia, Thailand and Laos, characterized with white earlobes. *Gallus gallus spadiceus* from Myammar, North Sumatra, Thailand, Malaysia and Southwest China, is characterized with red earlobes. *Gallus gallus murghi* from Northern India, Nepal, Bhutan and Bangladesh, posseses white earlobes Males have extensive bare reddish skin on their face and throat,

dominated by large, deeply indented red fleshy corona combs. *Gallus gallus jabouillei* from South China and North Vietnam are characterized with red earlobes and have short facial wattles. *Gallus gallus bankiva* found in Java and Sumatra possess red earlobes. Beside the current wide dispersal and production of domestic chickens, wild populations of red junglefowl still exist in Southeast Asia, inhabiting in the forests areas and the domesticated chicken can be regarded as a subspecies (Collias and Collias 1967; Nishida *et al.* 1992; Fumihito *et al.* 1996; Potts, 2012).

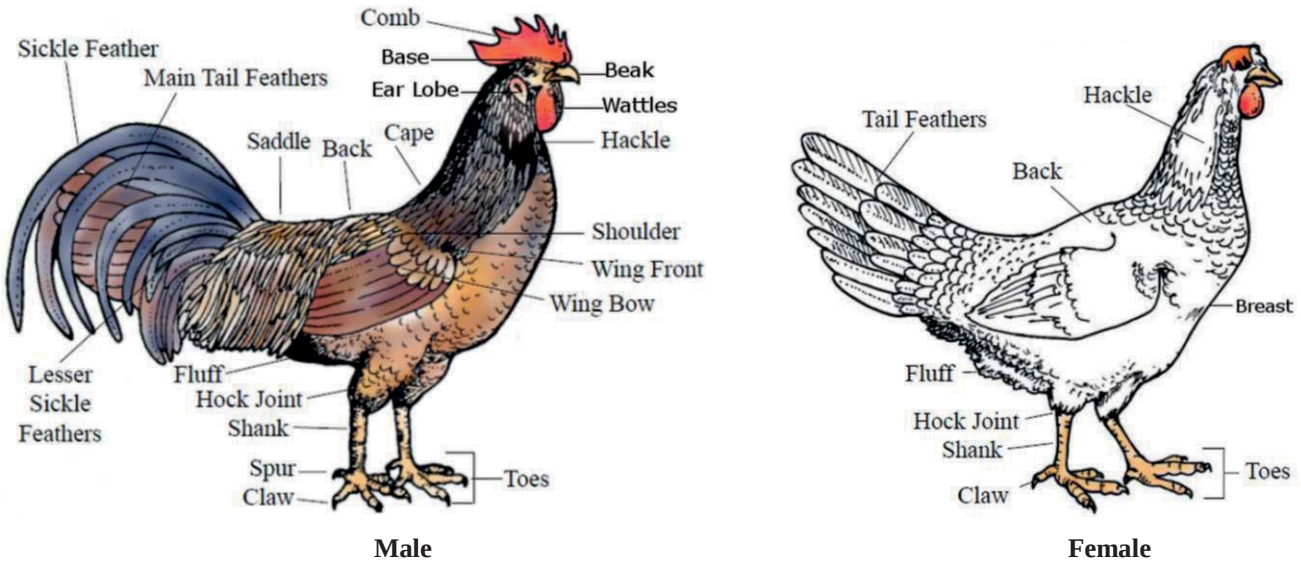

Figure 1.3: Male and female chickens body parts (Source: Extension, 2012)

1.2.2 Chicken dispersal from domesticated region

The domesticated chickens are thought to have then spread rapidly across Asia and then into Europe, Africa and America through human migration, along trade routes, colonization and expansion of agriculture (Liu *et al.*, 2006; Kanginakudru *et al.*, 2008; Groeneveld *et al.*, 2010; Wragg *et al*, 2012; Storey *et al.*, 2012; Mwacharo *et al.* 2013a). Although some evidence illustrates the existence of chickens in Europe by the late Neolithic (4000 B.C.) and early Bronze Age, the Iron Age (3000 B.C.) was the main period for dispersion of chickens throughout Europe. They mainly came from China via Russia on the northern route, and from Indus Valley via Persia on the southern route (West and Zhou, 1988; Tixier-Boichard *et al.*, 2011; Flink *et al.*, 2014).

The chickens were introduced to Africa from Asia by way of the Indian Ocean, and from Europe and Arabian Peninsula via the Mediterranean and Red Sea (MacDonald and Edward 1993, Masonen, 1995; Boivin *et al.*, 2009). As early as 1500 B.C. depictions of chickens emerge in Egyptian hieroglyphic art. At this time a rooster is visible in a scene in the tomb of Rekhmara (Pott, 2012). Dabry *et al.* (1977) reported the existence of a painted limestone ostracon from the tomb of Tutankhamun and other images that suggests the presence of chicken as exotic in Egypt during the New Kingdom era (1425-1123 B.C.). Chami (2001) has reported chicken bones from a Neolithic context on Zanzibar, dated to

800 B.C. Osteological and pictorial evidence for chickens in Africa become more common around 650 B.C. (Coltherd, 1966). Gifford-Gonzales and Hanotte (2011) reported two main waves of chickens being introduced to Africa. The first wave was from the Mediterranean Sea via Egypt during the Ptolemaic period (300 B.C.), later spreading through the Nile valley and to the West Africa along the Sudano-Sahelian corridor (MacDonald and Edward, 1993; Fuller *et al.,* 2011). The second wave came across the Indian Ocean when chickens were introduced to the East Coast of Africa by means of the existed trade networks during the beginning to middle of the 1st millennium A.D. (Adelaar, 1996; Chami, 2005; Blench, 2006; Boivin and Fuller, 2009; Fuller *et al.,* 2011). Chami (2001) and Chami and Kweakason (2003) have presented the archaeological evidence of chicken bones spread in the East African Islands as early as the 8th century B.C. The linguistic evidence strongly suggests multiple introductions of chickens across the Sahara, via the Berbers, on the east coast and possibly a separate introduction to Ethiopia via the Red Sea coast (MacDonald and Blench, 2000). Unlike cereals and other domestic plants, livestock are older and are apparently more linguistically stable in Africa. Species such as the chicken, introduced over 3000 years ago, have created a complex trail of loanwords that clearly indicate the routes whereby they entered and diffused across the continent (Blench, 2006). Williamson (2000) reported the linguistics and ethnographic evidence for domestic fowl in Africa that suggests chickens were moved from East to West Africa. In another pioneering study, Johnston (1886) used the words for chicken in Bantu languages to show that chicken cannot be reconstructed to Proto-Bantu because of its irregular reflexes and he considered it likely that the chickens were introduced into the Bantu area from the East.

Numerous suggestions have been made concerning the introductions of chickens to America. There is a postulation that chickens were brought to South America by Polynesians, which were first settled in South America in late 1200 A.D. (Lawler, 2010; Stores *et al.* 2011). It was also believed that, the introduction of chickens to the East coast of South America, was brought by Portuguese or Spanish conquistadors around 1500 A.D. (Storey *et al.*, 2011). Other scholars indicated that; chickens were brought to America from Africa in the 16th Century as the results of Dutch and Portuguese slave trade (Caudill, 1975; Wasserman, 2008). Thomson *et al*. (2014) reported a controversies regarding the introduction of chickens to America from the evidences that indicates chickens were brought from the Polynesian Islands to Chile in 1350 A.D., and other evidence which suggesting chickens were brought by Spanish Conquistadors around 1500 A.D.

The present global genetic variation in chicken populations was influenced by the recent management practices and historic evolution process. Migration, gene flow, mutation, recombination, genetic drift, selection pressure, population size and breeding practices exercises by human are contributing factors to the existing population structure and genetic differentiation.

1.3 An overview of poultry production trend

The world's livestock sector is growing at an unprecedented rate and the driving force behind this enormous surge is a combination of population growth, rising incomes, increasing purchasing power, growth of intensive agriculture and urbanization. Poultry production is the most dynamic sector that signified the greatest growth of all meat sectors during the last decades (FAO, 2007; FAO, 2010). Currently, poultry production is characterized by faster growth in consumption and trading than any other major agricultural sectors in the world. FAO statistical reports described more than a 35% increase in poultry meat production from the year 2000 (66.9 mil. tons) to 2013 (106.8 mil. tons). Presently the total meat production is 308.3 million tons, where pork is the most widely consumed meat in the world (114.6 mil. tons), followed by poultry (106.8 mil. tons), beef (67.5 mil. tons), and mutton (13.7 mil. tons).

Table 1.2: Worldwide meat production (million tons/year) from various species

Specie	2000	2005	2007	2008	2009	2010	2011	2012	2013
Poultry	66.9	82.8	90.1	91.9	93.6	98.9	102.6	104.9	106.8
Pork	91.3	104	99.8	104	106.3	109.3	109.2	112.7	114.6
Beef	60	64.6	65.1	65.2	65	66.7	67.3	67.4	67.5
Ovine	11.4	13.1	14	12.9	12.9	13.7	13.4	13.4	13.7
World	233.9	269.7	274.4	279.4	283.6	294.2	298.1	304.1	308.3

Source: FAO (2011a; 2012a and 2013)

By the year 2050, the world population is projected to grow to 10 billion people. Most of the growth is expected to occur in poor developing countries, where income elasticity of demand for food continues to be high. The population increase, combined with moderately high-income growth, could result in more than a 70% increase in demand for food and other agricultural products (Wik *et al.*, 2008).

In developing countries, poultry meat consumption growth is much more pronounced than in developed countries (FAO, 2012a; FAO, 2013). The demand for meat in the developing world has been increasing annually due to growing populations, rising incomes and urbanization (de Haan *et al.*, 2001; Delego, 2003; Delgado *et al.*, 2008; Narrod *et al.*, 2008; Trostle and Seeley, 2013). The demand for livestock products is expected to double in sub-Saharan Africa and South Asia, from 200 kilocalories per person per day in year 2000 to some 400 kilocalories in the year 2050. The largest regional percentage increase in population will be Africa. The World Population Reference Bureau projected human population to double in Africa from 1.1 billion to about 2.3 billion by the year 2050 (PRB, 2013). Global Poultry Trend (2013ab) reported the expected increased for poultry demand in China, India, Thailand, Bangladesh and Africa as reflecting high population increases. However, in Eastern Asia an inadequate supply of pig meat observed starting in 2007, has resulted in a gradual shift in consumption from pork to poultry. In the Middle East the demand for poultry meat is more important where competition with pork is almost non-existing (FAO, 2010).