University of Zululand

Characterisation of Production Systems and Phenotypic Traits of Indigenous Chickens in Communal Areas of KwaZulu-Natal

By

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DEDICATION

To Mrs. Vilakazi, the late Mr. Vilakazi and all my siblings

DECLARATION

I declare that the information submitted in this dissertation is my own work. It is submitted for the degree of Master of Science in the University of Zululand and it has not previously been submitted by me to any other University.

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Signed at____________________ on the day of________________2018.

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ABSTRACT

Indigenous chicken genetic resources play a major role in rural communities. There is therefore a need for their sustainable use and conservation. Conservation requires knowledge of production systems, phenotypic and genetic characteristics. The aim of this study was to understand the production systems and phenotypic variation among indigenous chickens in some areas of KwaZulu-Natal. A survey was conducted in six districts of KwaZulu-Natal to characterise indigenous chicken production systems;, predict body weight from linear body measurements of indigenous chickens using principal component analysis, and identify the morphological variation among indigenous chicken populations. Small flock sizes ranging from 2 to 80 indigenous chickens were observed in households. The majority of farmers started rearing a few indigenous chickens sourced from related stock through inheritance, gifts and buying. Indigenous chickens were reared as a source of meat, eggs and income. Most farmers (72%), were not aware of the importance of conserving indigenous chickens. The most common constraints raised by farmers were diseases, predators and theft. The most commonly practised production systems were extensive and semi-intensive. Poor management in terms of feeding, watering and health was reported in all surveyed areas. Principal component analysis of linear body measurements extracted two principal components with a total variance of 63.94%. Principal component one, related to body size, had the largest share of breast circumference, body length and shank circumference. Principal component two, related to body shape, had high loadings on toe length, shank length and back length. The use of principal components was more appropriate than the use of original correlated variables in predicting the weight of indigenous chickens. Variation in morphological traits was observed; 10 plumage colours were realised from different locations, and variation was also observed in skin colour, eye colour, shank colour and comb type. Variation in phenotypes may reflect variation in the genome of the indigenous chickens. Discriminant analysis identified body weight as the most discriminating variable in differentiating indigenous chickens. Two major clusters were formed: the first by Newcastle, Port Shepstone and Cedara; the second by Pietermaritzburg and Ladysmith. Empangeni and Jozini individually joined the two clusters. Although Jozini showed itself to be more distant to the others, 51.1% of indigenous chickens were correctly assigned to their population. It was concluded that with the existing variation improvement in size and aesthetic characteristics of the indigenous chickens can be achieved through selection according to the needs of the farmers. Farmers require assistance on husbandry and management of indigenous chickens.

Key words: Indigenous chicken genetic resource, production systems, morphological variation.

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CHAPTER 1: INTRODUCTION

1.1 General introduction

Indigenous chickens are scavenging chickens kept in extensive conditions, more especially in rural areas Aklilu *et al.* (2013)**.** They have important characteristics that are usually not found in exotic chicken breeds, including the ability to adapt to change in climate and to fight predators, and resistance to diseases. Indigenous chickens play a vital role in human livelihoods and contribute significantly to food security of rural communities. They are mostly kept for meat and egg production (McAinsh *et al.*, 2004). These chickens also serve as a source of income for farmers in rural areas (Muchadeyi *et al.*, 2005; Muchadeyi *et al.*, 2007). However, they have been reported to be among the animal genetic resources at risk of becoming endangered (Mtileni *et al.*, 2012). Therefore, action towards their conservation is imperative and their characterisation can help formulate informed strategies for their conservation.

Characterisation involves obtaining all the information which contributes to reliable prediction of genetic performance of an animal genetic resource in a particular environment and provides the basis for distinguishing between animal genetic resources for assessing available diversity (Rege and Okeyo, 2006). Characterisation includes knowledge on production systems to which the breed is adapted in order to obtain better knowledge of the breed, its present potential uses for food and agriculture in defined environments. Characterisation also includes phenotypic attributes (physical features, performance means and variances, and special traits), and historical development of the breed (crossbreeding, selection and connectedness with other breeds) (Rege and Okeyo, 2006; Tixier-Boichard *et al.*, 2009). Characterisation of livestock breeds is the first approach to sustainable use of animal genetic resource (Lanari *et al.*, 2003). The first step of the characterisation process requires knowledge of the variation of morphological traits (Yakubu *et al.*, 2009). It has been speculated that the insufficiency of information about the genetic diversity and resources present in the indigenous farm animals in developing countries has led to their underutilisation, replacement and dilution through crossbreeding.

Mtileni *et al.* (2009) have characterised production systems in Limpopo, the Eastern Cape andin the Northern Cape and the findings showed that indigenous chickens were reared in an extensive or in a semi-intensive system under subsistence farming. The authors reported that in the subsistence farming systems chickens are left to scavenge to meet their nutritional needs. The study revealed that even though there are some challenges, indigenous chickens in South Africa contribute significantly to the livelihood of rural communities.

Other researchers conducted studies on morphological variation using discriminant analysis to identify morphological traits that have the most discriminating power in discriminating indigenous chicken genotypes and populations (Ajayi *et al.*, 2012; Al-Atiyat, 2009; Getu *et al.*, 2015). Egena *et al.* (2014b) and Udeh and Ogbu (2011) employed principal component analysis to identify the relationship between body weight and different linear body measurements of indigenous chickens. A positive relationship between body weight and most of the body measurements was reported by Udeh and Ogbu (2011) , the authors recorded highly significant positive correlation for breast circumference and shank lengths for different strains of chickens. However, the studies were conducted in Nigeria. In KwaZulu-Natal, Mngonyama (2012) reported on the breed of indigenous chickens kept in uMnambithi-Ladysmith and Impendle municipalities in KwaZulu-Natal. There is, therefore, scanty information on characterisation of morphological traits of indigenous chickens and their production systems in some communal areas of KwaZulu-Natal.

The aim of this study was to characterise the production systems and the morphological traits of the indigenous chickens in different areas of KwaZulu-Natal.

1.2 Objectives of the study:

i. To characterise indigenous chicken production systems in communal areas of KwaZulu-Natal.
ii. To predict body weight from linear body measurements of indigenous chickens using principal component analysis.
iii. To identify variation caused by morphological traits among the indigenous chickens in different locations using discriminant analysis.

1.3 Outline of the dissertation

1.3.1 Chapter one presents the introduction, the objectives and the outline of the dissertation.

1.3.2 Chapter two presents the literature review which covers the history and origin of indigenous chickens, types of indigenous chickens, importance of indigenous chickens, indigenous chicken diversity, phenotypic characterisation of indigenous chickens, indigenous chicken production systems and conservation of Animal Genetic Resources.

1.3.3 Chapter three presents the results from a survey conducted to identify indigenous chicken production systems in communal areas of KwaZulu-Natal. The survey covered management practices used by farmers in rearing indigenous chickens and constraints encountered by farmers when rearing indigenous chickens.

1.3.4 Chapter four presents the relationship between indigenous chicken body measurements and also presents the effects of age and location on linear body measurements. It also demonstrates the regression formulas that were obtained to predict body weight of indigenous chickens from linear body measurements and principal components.

1.3.5 Chapter five presents morphological variation among indigenous chickens using discriminant analysis.

1.3.6 Chapter 6 discusses the results of the whole study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Understanding of origin, subsequent history and evolution of Animal Genetic Resources diversity is essential for the design of sustainable conservation and utilisation strategies (Rege and Gibson, 2003). Livestock diversity originates from wild ancestors and was shaped through processes of mutation, genetic drift and human and natural selection (Rege and Gibson, 2003). Indigenous chickens form part of a group of animals that were domesticated years ago. They were first domesticated in the centre of origin known as the Indus Valley Region about 5000 years ago, and in South East Asia and East China about 7500 to 8000 years ago (Rischkowsky and Pilling, 2007). The indigenous chicken known as *Gallus Domesticus* is said to have descended from the Red Jungle Fowl known as *Gallus gallus* (Getu, 2014).

Indigenous chickens have undergone evolution. Their history started with the evolution of the genus *Gallus*, followed by the emergence of the domestic fowl from its ancestors (progenitors), and, finally, the appearance of a large number of the current breeds. There are various species which have been considered as ancestors of domestic fowls. These species are *Gallus gallus* (Red jungle fowl), *Gallus latayettei* (Ceylon jungle fowl), *Gallus sonerrati* (Grey jungle fowl) and *Gallus varius* (green jungle fowl) and were all found in South Asian regions (Getu, 2014; Mogesse, 2007b).

The Red jungle fowl is one of the oldest domesticated chickens and it became most popular in areas of Europe during the 19th century where it was used in regional rituals and for cock fighting (Hassaballah *et al.*, 2015; Mwacharo *et al.*, 2013). However, as poultry industries became developed as commercial industries in the 20th century, poultry became utilised for meat and eggs. The Red jungle fowl has been accepted by geneticists as the ancestor of indigenous chickens because of the similarities which were observed during studies on morphological characteristics (comb types and feathers) which showed similarities between the Red jungle fowl and indigenous chickens (Dessie *et al.*, 2011).

The Red jungle fowl (*Gallus gallus*) is prevalent in Himalayas, Northern India, Southern China and Southeast Asia where centres of domestication exist. Indigenous chickens were introduced from Asia to Africa for different reasons; as source of protein, because of low husbandry requirements, and for being easily available for sacrifice at sociocultural functions. The initial causes for adoption of indigenous chickens by African communities could have been sociocultural and recreational. The fourth to third millennia BC have been advanced as the period for the arrival of indigenous chickens in Africa (Mwacharo *et al.*, 2013). In North Africa, indigenous chickens were present in Egypt from the second millennium BC. In Sub-Saharan Africa the earliest widely accepted evidence of Indigenous chickens dates to the mid-first millennium AD (Mwacharo *et al.*, 2013). In East, South and West Africa indigenous chickens appeared in the late first millennium AD. The domestication of these indigenous chickens was introduced by the traders on route to India, and European Settlers in the early 15th and 16th centuries (Petrus, 2011).

2.2 South African conserved indigenous chickens

Potchefstroom Koekoek chicken, Lebowa-Venda chicken, Ovambo chicken and Naked Neck chicken are regarded as native to South Africa and adapted to harsh conditions in rural areas. The Potchefstroom Koekoek is a South African chicken breed which was developed in the 1950s by Professor Chris Marais at the Potchefstroom Agricultural College (Grobbelaar *et al.*, 2010).

The word Koekoek refers to its colour pattern which is a sex-linked gene that is useful for colour sexing. The chicken can be easily identified as a hen or cock by looking at its colour, as cocks have light grey bars while hens are darker (Van Marle-Koster and Nel, 2000). The Potchefstroom Koekoek is well adapted to South African climate. It can produce eggs and meat consistently without consuming excessive amounts of feed. This characteristic makes it a popular breed among rural farmers in South Africa and other countries (Mngonyama, 2012). It is classified as a heavy breed, with an average body weight varying from 3 to 4 kg for cocks and 2.5 to 3.5 kg for hens. They reach sexual maturity at 130 days.

The Lebowa-Venda breed was first described by a veterinarian, Dr Naas Coetzee who noticed these chickens in the Venda area of Limpopo Province (Mogesse, 2007a). Lebowa-Venda is a multicoloured chicken with basic colours similar to those of the indigenous cattle and goats in the area, which is white, black and brown (Van Marle-Koster and Nel, 2000). It has the single comb but rose-comb and five-toed feet may also be observed. The Lebowa-Venda is characterised by low egg production but they are broody and have a very good mothering ability (Mngonyama, 2012; Mogesse, 2007a). The Lebowa-Venda chicken is fairly large compared to other indigenous chicken types and also lays fairly large tinted eggs. These chickens reach sexual maturity at 143 days with an average body weight of 2.1 kg in cocks and 1.4kg in hens at 20 weeks old (Mogesse, 2007a).

The Ovambo chicken originated in the northern part of Namibia and Ovamboland (Grobbelaar *et al.*, 2010). It is dark-coloured and small in size, characteristics which enable it to camouflage itself and protect chicks from predators. It is very aggressive and agile (Mngonyama, 2012). It has been known to catch and eat mice and young rats. This type of chicken can fly and roost in the tops of trees to avoid predators. Sexual maturity is reached at 20 weeks, and at this age cock usually weigh 2.16 kg and hens approximately 1.5 kg.

South African Naked Neck chickens are thought to have originated in Malaysia and are now found mainly in rural areas. They have a variety of colour patterns (Grobbelaar *et al.*, 2010).They are characterised as dual-purpose breeds adaptive to hot climates and they reach sexual maturity at 155 days with an average weight of 1.95kg for cocks and 1.4kg for hens (Mngonyama, 2012). There are two types of Naked Necks; the one that is a purebred with a completely naked neck, and the other one, which is not pure bred, which has a tassel on the front part of the neck. Sometimes frizzled, they are thermo-resistant and are resistant to some diseases (Mngonyama, 2012).

A study conducted in the Northern KwaZulu-Natal District by Mngonyama (2012) showed that communal farmers kept the Ovambo, Potchefstroom Koekoek and Naked Neck chickens. The Ovambo breed was the most popular, and the least popular was the Naked Neck. The Naked Neck tend to thrive in heat prone areas because the fewer feathers enable the chicken to tolerate more heat (Tarwireyi and Fanadzo, 2013). There is a lack of information on the type of indigenous chickens found in other areas of KwaZulu-Natal, hence this study was conducted in order to understand the morphological characteristics of indigenous populations in six districts of kwaZulu-Natal.

2.3 Importance of indigenous chickens

The use of indigenous chickens varies from region to region and from community to community within a region (Dessie *et al.*, 2011; Padhi, 2016). Indigenous chickens contribute significantly to rural communities; they ameliorate poverty in poor households. They can convert any available feed resources around the house to highly nutritious products. They are responsible for food security as they provide animal protein in the form of meat and eggs (Wethli, 2003). They also act as a source of income because they are mostly sold for emergent cash needs. They also play a role in providing special meals in traditional ceremonies such as weddings and funerals (Mapiye *et al.*, 2008; Mtileni *et al.*, 2012). They are also used as gifts when welcoming high status visitors and as a token of appreciation when a service has been rendered. In rural areas the relationship with the in-laws is usually strengthened using indigenous chickens. Special clothes (skirts and hats) and pillows for healers for everyday use are also made from chicken feathers.

Indigenous chickens have a high reproduction rate per unit time, and are efficient in transforming feed protein and energy into human food. They require very low capital, labour and space, which allows chicken production to be practised even by landless individuals (Mngonyama, 2012; Muchadeyi *et al.*, 2004). Indigenous chickens' production empowers women with some skills of animal husbandry and in some cases entrepreneurship skills as rearing the chickens is a tasked carried out by women. In addition, indigenous chickens are used by some communal farmers for pest control by placing a movable chicken house in their kraals(McAinsh *et al.*, 2004; Mtileni *et al.*, 2009).

2.4 Phenotypic characterisation of indigenous chickens

Phenotypic characterisation is a process of identifying distinct breed populations and describing their external and production characteristics in a given environment under given management including social and economic factors such as market orientation, niche marketing opportunities and gender issues (Food and Organization, 2012). Phenotypic and genetic characterisation are used to measure and describe genetic diversity as a basis for understanding and utilising animal genetic resources sustainable. Animal genetic resources can be characterised primarily or in an advanced form (Food and Organization, 2012). Primary characterisation refers to activities that can be carried out on a single visit to the field such as s measurement of animal morphological features, interviews with livestock owners, observation, and measurement of aspects of the production environment, and mapping of the geographical distribution (Food and Organization, 2012). Advanced characterisation is used to describe the activities that require repeated visits, and activities such as measurement of productive capacities such as growth rate, and adaptive capacities which include resistance and tolerance to diseases in production environments. Characterisation includes breeds' phenotypic characteristics including physical features, appearance and economic traits (growth, reproduction and range of variation in these traits). In general, the focus is on productive and adaptive attributes of the breed (Food and Organization, 2012).

Images of adult females and males in their production environment also form part of characterisation. Phenotypic characterisation also includes information on the origin and development of the animal and the biotic and abiotic surroundings of an animal. Responses of breeds to diseases and parasite challenges, severe climate and poor feed quality also form part of phenotypic characterisation.

Adequate phenotypic characterisation of animal genetic resources is essential for the appropriate design of a breeding programme. The first step towards phenotypic characterisation of animal genetic resources requires knowledge of the morphological trait variation (Yakubu *et al.*, 2010a; Yakubu *et al.*, 2010b). Livestock animals vary in their morphological structure; they can also be differentiated by differences in size and shape.

Physical or morphological characteristics can be useful in the classification of populations, breeds and species (Rege and Okeyo, 2006). Indigenous chickens have different characteristics which include different colours, shapes and sizes. They are not as efficient at putting on weight as exotic breeds and do not lay all year round, even when fed with expensive high protein feed (Mngonyama, 2012). They can be selectively bred for certain colours which make them suitable for specific traditional purposes. They are hardy, adapt well to rural environments, can adjust to fluctuations in feed availability and can survive without inputs.

Indigenous chickens have the ability to adapt to diverse temperatures and to scavenge for food. They consume materials including grass seeds, household scraps and insects (Mogesse, 2007a).

They have small body sizes, with mature body weight that ranges between 1.3 and 1.9 kg for males and between 1.0 and 1.4 kg for females (Mngonyama, 2012). Smaller body size reduces feed requirements and increases feed efficiency. This characteristic is necessary for survival in the extensive system because of the limited availability of feed. Indigenous chickens are alert; some have long shanks which they use to run away from predators. If necessary, they even fight with predators to safeguard their chicks (Besbes, 2009).

The presence of melanin pigments is responsible for most of the colours of the feathers. Plumage colour and comb type have been found to have significant economic value (Dana *et al.*, 2011). In some countries, specific choices for plumage colours have been observed, thus affecting market preferences in different geographic regions. The results from the study conducted by Dana *et al.* (2011) indicated that plumage colour followed by comb type affect market preference of chickens and are second in importance to live weight. In Northern Ethiopia plumage colour is regarded as most important, for both producers and sellers. Also, normal feathered and Naked Neck feather distribution are equally as important as plumage colour, followed by breed and comb type (Asgedom, 2007).

2.5 Indigenous chicken diversity

Diversity among farm animals within and among countries is of major interest to the scientific community because it is a significant resource for livestock development and for responding to changing needs and production requirements in the context of an increasing world population. Understanding of phenotypic diversity in animal genetic resources helps in their better management and conservation (Rege and Okeyo, 2006).

The process of domestication has played a role in the emergence of distribution of livestock diversity through various environmental factors such as temperature, humidity, type of vegetation and disease. In different parts of the world, diversity in human needs in the form of selection for different phenotypes mostly preferred for cultural purposes and economical patterns has also contributed to the diversity of various livestock species including chickens (Rege and Gibson, 2003). These preferences led to the manipulation of genes for domestic livestock. Variations in human population density, culture and farming systems are also believed to have contributed to diverse animal genetic resource evolution (Dessie *et al.*, 2011).

The exposure of animals to new environments as humans migrated to different parts of the world caused animals to be subjected to selection for adaptation to new environments.

The demand for high performing animals has resulted in the crossbreeding of indigenous breeds with those which are said to be high performing, thus resulting in a loss of diversity in indigenous animals (Rege and Gibson, 2003) . Even though indigenous breeds may not have high production they still have valuable contributions to make to rural communities. They perform better than exotic and crossbreeds in harsh environments because of their ability to survive with minimal health care (Mtileni *et al.*, 2012).

Diversity can be assessed phenotypically and genetically by use of molecular markers (Food and Organization, 2012; Silva *et al.*, 2009).'Phenotypic variation' refers to variation within and between distinct breeds based on their observable attributes. It also represents an important measure of adaptation of an organism to its environment because phenotypic characters interact with living and non-living factors of the environment. Indigenous chickens can be phenotypically diverse or varied, which is the variation of the physical traits or phenotypic characters of the organism such as differences in anatomical, physiological, biochemical and behavioural characteristics (Cuesta, 2008; Petrus, 2011).

Phenotypic diversity in indigenous chickens has been observed in morphological characteristics such as plumage colour pattern, skin colour, adult body size, body conformation, comb type and shank colour. Plumage colour is the major element of the phenotypic standard used to define and identify breeds. Multiple colours are commonly observed in indigenous chickens as an advantage by providing camouflage against predators. Large variations in plumage colour across regions have been observed by Ssewannyana *et al.* (2008); the authors attributed these to geographical isolation as well as periods of natural and artificial selection. There is also speculation that these variations could be due to limited exchange or transport of local chickens over long distances.

The common feather structure of the indigenous chicken populations has been found to be the normal feathered, with a few being frizzled and silky feathered (Mtileni *et al.*, 2012) Naked Neck has also been observed as a means of adaptation to hot climate. The Naked Neck gene is described as one of the major genes in indigenous chickens that has desirable effects on heat tolerance and adult fitness. There is a perception that reduced feather coverage enhances heat dissipation and prevents the effects of heat on chickens reared in hot climates. It is also assumed that reduced feathering saves on feather proteins, which may be used for egg or meat production (Melesse and Negesse, 2011). Studies have been conducted on phenotype characterisation of indigenous chickens in different countries, including Uganda, Ethiopia, Botswana and Nigeria. Researchers reported variation in plumage colour and feather distribution. The majority of chickens were normal feathered, followed by crested and naked neck. Variation in shank colour, comb type, skin colour, head shape, beak colour, earlobe colour and wattle colour were reported (Rotimi *et al.*, 2016; Ssewannyana *et al.*, 2008).

Genetic diversity within animal species refers to the variety of genetic variation evolved during domestication and is displayed by the existence of structural variation among genomes of individuals, strains and population (Mtileni *et al.*, 2012).Molecular markers can provide criteria to assess genetic diversity between and within populations and can also be used to study relationship between populations and provide information on the history of populations (Hassen *et al.*, 2009; Mtileni *et al.*, 2010).The genetic diversity within and between different chicken populations in the Limpopo and Northern Cape regions in South Africa has been evaluated using microsatellites and mitochondrial systems (Hassen *et al.*, 2009; Mtileni *et al.*, 2010; Mwacharo *et al.*, 2013) Mitochondrial DNA sequencing has been used for studying the evolution of closely related species and the maternal origin of chickens (Razafindraibe *et al.*, 2008). Findings from a study done by Mtileni *et al.* (2011) using microsatellite markers revealed that South African indigenous chicken populations added diversity to purebred commercial lines and African chickens.According to Mtileni *et al.* (2011) the use of microsatellites shows that South African chickens could be a product of multiple domestication events, leading to a high level of genetic diversity. South African chickens could be unique lineages from the purebred lines (Muchadeyi *et al.*, 2008).

Genetic diversity provides information for future advances in the improvement of responses to human and animal production needs (Mtileni *et al.*, 2012). Ya-Bo *et al.* (2006) conducted a study in Southern China to evaluate genetic variation and genetic distances between twelve populations of Chinese indigenous chicken breeds using microsatellites markers. Higher levels of genetic diversity were obtained than the reports of European chicken populations. It was speculated that the variation could be due to difference in location, sample sizes, experimental chickens, and the source of the microsatellites used. Indigenous chicken populations representing seven different areas of North West Ethiopia were studied using microsatellite markers to determine genetic variation (Hassen *et al.*, 2009). The study included three local lines of South African chickens and two commercial lines for comparison. Long genetic distances from Ethiopian chickens were observed in commercial chickens rather than the South African indigenous chickens. The study proved that Ethiopian chickens are still not highly diluted with commercial breeds. Some studies have made an attempt to address the origin of African village chickens through the analysis of the Mitochondrial DNA D-loop sequence. Muchadeyi *et al.* (2008) observed two distinct haplogroups in Zimbabwe village chickens which they assumed came from South East Asia and the Indian subcontinent. Razafindraibe *et al.* (2008) observed two haplogroups in a Madagascar village and assumed that one was from Indonesia and the other of African Continental origin.

2.6 Indigenous chicken production systems

Production systems can be categorised into extensive (scavenging), semi-intensive and intensive, depending on the objectives of the producer, type of inputs used, and number and type of chickens kept (Mogesse, 2007b). Indigenous chickens in Southern African countries are usually owned by individual households and are maintained under an extensive system which is characterised by lower quality housing, lower feeding and health care inputs, and sometimes the unavailability of inputs (Mtileni *et al.*, 2012).

Indigenous chickens obtain their daily feed by scavenging. Chickens under this system are managed based on available local information and are left to scavenge for feeds during the day and confined at night. They scavenge for food waste, green grass, leafy vegetables and any scattered grains. They are also supplemented by household waste, maize, millet, sorghum and ripe pawpaw seeds. Supplements provided vary, depending on season and availability (Kingori *et al.*, 2010). The supplements can either be broadcasted on the ground or placed in feeders once or twice a day. Chickens of different age groups live and scavenge together (Mogesse, 2007a) . If drinking water is provided, tins or broken clay pot pieces are normally used (Kingori *et al.*, 2010).

Housing under the extensive production system is not developed and where it does exist, it is mainly to protect indigenous chickens from predators and extreme weather. Simple structures such as half drums without air inlets are used to provide shelter to indigenous chickens at night (Mtileni *et al.*, 2012). Where shelter is not provided, trees may be used as the option. The extensive production system is characterised by low capital inputs, which results in low chick output, egg and meat production per chicken. The replacement stock originate from hatching own chicks or are purchased from the neighbours or given as gifts. Live chickens are sold during times of need for cash or when farmers and their families are sick. Eggs are also sold when hatching is not required. Local traders purchase live chickens and eggs from farmers and transport them for sale to urban markets, while eggs are also sold within households or through the local supermarkets.

Indigenous chickens in this production system are mostly managed by women and children, as they dominate most of the activities (feeding, watering and selling) relating to chickens. There are various constraints associated with this production system, namely, diseases, predators and harsh environments. When indigenous chickens scavenge they come into contact with wild animals which leaves them exposed to various diseases which may be hard to prevent or cure because in this type of production system there are no formal health measures. Farmers rear indigenous chickens using their indigenous knowledge, and they have little information on controlling diseases as they mostly use ethno-veterinary practices when curing chickens (Mtileni *et al.*, 2012).

In the semi- intensive production system, chickens are fed balanced feed, either produced by large feed companies or by the local feed mill. In this system, flock size varies between 50 and 500 chickens on average (Besbes, 2009). The use of specialised breeds is more common than the indigenous breeds. This type of production system is practised in small households where families are financially more stable than the households who practise the extensive production system (Kingori *et al.*, 2010). The semi-intensive production system is composed of moderate management levels. Chickens reared under this system are mainly crosses between indigenous and exotic breeds. They are let out in the mornings to scavenge (for food waste, green grass, leafy vegetables and any scattered grains) and are confined in shelters at night. They get supplementation from grains, oil seed cakes and food waste, plus commercial feeds occasionally. Water and veterinary care is provided even though it is not enough. In young chicks mortality can be 40% and above (Kingori *et al.*, 2010).

The intensive system, which usually consist of specialised breeds, constitutes less than 30 % of the total poultry population in Africa. It is most common in urban areas, where there are markets for eggs and chicken meat (Abdelqader *et al.*, 2007). Producers in this production system aim at using the recommended standard practices, such as breed of choice, depending on production objectives, appropriate housing, feeding, health, and disease control programmes. Various types of chickens can be found in this production system. Flock sizes in this production system are normally in their thousands. The stocks of chickens contributing to the global production of meat and eggs are designed and managed by a few primary breeders in response to market demands. The intensive production system is a high input - high output system. It is market oriented and the main objective of production is to make profit. Chickens used are specialised improved breeds to achieve optimum genetic potential. Specialised breeds require quality management and controlled environmental conditions (Aini, 1990). The majority of the farmers in rural communities cannot meet the intensive farming standard management practice requirements due to limited physical and capital resources and also because of poor technical knowledge.

2.7 Conservation of Animal Genetic Resources

The Food and Agricultural Organization (FAO, 2007) of the United Nations has proposed an integrated programme for the global management of genetic resources on an international level. The communication and information system (Domestic Animal Diversity Information System) have been developed by FAO with the purpose to assist countries by providing extensive searchable database and guidelines for better characterisation, utilisation and conservation of animal genetic resources. The conservation of animal genetic resources (AnGRs) includes strategies, plans, policies, and actions undertaken to ensure the maintenance of current and future diversity of farm animal genetic resources (Mavule, 2012a; Rege and Gibson, 2003).

The Organization's Global Databank for Animal Genetic Resources (FAO, 2007) has reported that breeds with the ability to survive harsh environments, tolerance to disease, and which also utilise low value feeds, should be conserved for beneficial purposes in future. Animals that are genetically adapted to their environments could be a source of the genes needed to improve the health and performance of commercial breeds (Rege and Okeyo, 2006). However, identification and adequate documentation of the AnGRs is required for informed conservation plans. Inclusion of the communities in the conservation plan is also recommended (Kohler-Rollefson, 2000).

Indigenous chickens are among the breeds with an ability to survive harsh environments. However they are considered to be the most endangered and under- conserved (Hoffmann, 2009; Mtileni *et al.*, 2012). In Africa 60% of avian species are of unknown risk status; this lack of data is a serious constraint to effective prioritisation and planning of breed conservation measures. ‘About 30 %’ or ‘31% of avian species have been classified as being at risk. Among avian species chickens have the highest number of breeds at risk around the world. Extinct breeds have mainly been reported among chickens (FAO.2009). In South Africa, frizzled, naked neck, dwarf and silky genes have been reported to be at risk. These genetic resources should be conserved for their features, and traits of scientific and economical interest (Mtileni *et al.*, 2012).

Characterisation, conservation and use of indigenous animal resources under low levels of inputs are usually more productive then the exotic breeds. The conservation of indigenous chicken genetic resources is necessary in light of the rapid loss of indigenous breeds through commercial dilution and breed replacement. All kinds of domestic species and species with potential for domestication are considered to be important for conservation. Indigenous chicken populations with economic potential, scientific use and cultural interest should be incorporated into conservation efforts (Mtileni *et al.*, 2012).

Indigenous animal genetic resources can be conserved by *in situ* conservation, also known as on-farm conservation, which is the conservation of live animals within their production system in the area where the breed developed its characteristics and where the breed is now normally found together with husbandry activities that are undertaken to ensure the continued contribution of animals to sustainable food and agricultural production. (Gandini *et al.*, 2004; Hall and Bradley, 1995; Rege and Gibson, 2003)

In the Veneto region of Italy the regional government of Veneto in collaboration with the University of Padova implemented an *in situ* poultry conservation programme known as Conservation and Valorization of local poultry genetic resources of the Veneto region (Co.Va.). The programme was initiated in 2000 and included four different poultry species (chicken, duck, turkey and helmeted guinea fowl) and four conservation nuclei flocks located in different areas of the region. Six local Chicken breeds (Robusta Maculata, Robusta Lionata, Ermellinata di Rovigo, Pepoi, Padovana and Polverara) are conserved as part of the project in different areas of the Veneto Region. Duck breeds were Germana Veneta, and Mignon, while the turkey breeds were Bronzato Comune, and Ermellinato di Rovigo. The guinea fowl breed was the Caomsciata (De Marchi *et al.*, 2006).

The importance of conservation has long been recognised in South Africa (Mtileni *et al.*, 2012; Mtileni *et al.*, 2011). An indigenous chicken conservation programme known as the Fowls for Africa Project was initiated by the Animal Production Institute of the Agricultural Research Council in 1994. Under this programme four native chicken breeds are kept at the Agricultural Research council at Irene as conservation flocks of indigenous populations (Mtileni *et al.*, 2011; Van Marle-Koster and Nel, 2000).The breeds that form part of the conservation flocks include Venda chicken, Ovambo chicken, Naked Neck and Potchefstroom Koekoek.

Ex situ is another form of conservation. It involves conservation of animals in a situation removed from their habitat; it can be the storage of genetic resources that will be later used by farmers and includes cryogenic preservation (Gandini *et al.*, 2004; Rege and Gibson, 2003).

CHAPTER 3: CHARACTERISATION OF INDIGENOUS CHICKEN PRODUCTION SYSTEMS IN COMMUNAL AREAS OF KWAZULU-NATAL

3.1 Abstract

Indigenous chicken production systems in communal areas of KwaZulu-Natal were characterised in order to identify their management practices and the constraints associated with production. A survey was conducted using questionnaires administered to 120 farmers in rural areas of KwaZulu-Natal. The commonly practised production systems were semi-intensive and extensive. All the farmers had poorly constructed houses which were not efficient at preventing indigenous chickens from attack by predators. Some of the farmers did not have any form of housing so the chickens found shelter in trees. In Jozini and Empangeni 5% and 65 % of indigenous chickens, respectively, spent some time in trees. Poor management in terms of feeding, watering and health was reported in all surveyed areas. Farmers used ethno-veterinary practices for curing and prevention of diseases. There was no formal market for selling indigenous chickens. The most common constraints raised by farmers were diseases, predators and theft. It was concluded that improving management practices can help mitigate the constraints mentioned and prevent the loss of indigenous chickens. The use of indigenous chickens as a source of meat and eggs was highly ranked by farmers, followed by a source of income when the need arises, with an index of 0.69 and 0.18, respectively. The majority of farmers started rearing a few indigenous chickens sourced from related stocks through inheritance, gift or buying. Flock sizes ranging from 2 to 80 indigenous chickens were observed. The study revealed that 72 % of farmers were not aware of the importance of conserving indigenous chicken genetic resources. It was concluded that farmers require professional assistance on how to manage indigenous chickens to enhance production.

Keywords: Production systems, Indigenous chickens, Management practices, Production

3.2 Introduction

Knowledge of the production environment enables the understanding of production and the adaptation potential of livestock (Food and Organization, 2012). In a low output environment, it may be difficult to measure traits for adaptation. However, these can be characterised by describing the production environment in which livestock have been maintained over time. Rischkowsky and Pilling (2007) have indicated that comprehensive understanding (description) of the production environment is essential to make use of performance data and understand special adaptation of breeds and population. Knowledge of the production environment helps to identify potential development opportunities which in turn provide an informed strategy of genetic improvement and conservation programmes for livestock.

Indigenous chickens are mostly valued because of their vital role in human livelihood (culturally, socially and economically) and their significant contribution to human food security, as they are used as a source of protein in the form of meat and eggs (Muchadeyi *et al.*, 2007). Indigenous chickens are mostly reared under extensive and semi-intensive production systems in rural areas because of their low input requirements which conform to the socio-economic conditions of rural families (Abdelqader *et al.*, 2007). In these production systems householders use their local knowledge of feeding, breeding and health management practices. Indigenous chickens reared in these production systems usually have good adaptability which enables them to scavenge for feed and search for water. However, this exposes them to predators and diseases, which affects their producing capacity (McAinsh *et al.*, 2004; Muchadeyi *et al.*, 2007) . Indigenous chickens are characterised by slow growth, late maturity and low production performance (Habte *et al.*, 2013). Their low productivity limits their potential to uplift the living standards of rural farmers (Okeno *et al.*, 2012).

Understanding the characteristics of production systems can aid in making recommendations for improvement of production management practices of farmers and associated factors which are essential in developing improvement strategies (Mtileni *et al.*, 2009; Okeno *et al.*, 2012). Development and promotion of indigenous chicken production can ensure food security and income provision for rural people (Mngonyama, 2012). The study conducted by Mngonyama (2012),in Impendle and Ladysmith in KwaZulu-Natal revealed indigenous chickens to have a contribution to make to food security, school fees and human social welfare. Muchadeyi *et al.*

(2007) have characterised indigenous chicken production systems in Zimbabwe, revealing that indigenous chickens played a major role in food security and income provision. However, poor management practices and various constraints were identified which limit production.Mtileni *et al.* (2009) also did a study in Alfred-Nzo District in the Eastern Cape, Vhembe and Mopane District in Limpopo, and Kgalagadi District in the Northern Cape. Okeno *et al.* (2012) also did a study in Kenya and Moreda *et al.* (2014) studied production systems in the south west and southern parts of Ethiopia. These researchers reported that chickens were raised in an extensive system and to a lesser extent in a semi-intensive system under a mixed farming system. The most common supplementary feeds reported by Mtileni *et al.* (2009) were chicken waste, whole grain and crushed grain. They also reported as reported poor housing, and lack of housing for indigenous chickens. Newcastle disease and poor health management practices were found to be major causes of chicken loss (Al-Qamashoui *et al.*, 2014; Okeno *et al.*, 2012). There is a lack of information on the systems of production, including the constraints thereof, implemented by rural farmers when rearing indigenous chickens in KwaZulu-Natal. The objective of the study was to characterise indigenous chicken production systems in KwaZulu-Natal.

3.3 Materials and Methods

3.3.1 Study site

The study was conducted in 6 communal areas in 6 districts of KwaZulu-Natal, namely, Empangeni in UThungulu District located at 28.6192°S, 31.5370°E, Jozini in UMkhanyakude District, located at 27.2719°S, 32.537°E, Port Shepstone in UGu District, located at 30.6218°S, 30.2513°E, Pietermaritzburg and Cedara in UMgungundlovu District, located at 29.5101° S, 30.3436°E, Ladysmith in UThukela District, located at 28.6783°S, 29.6035°E, and Newcastle in Amajuba District, located at 27.8036°S, 30.0665°E.

3.3.2 Farmer selection procedures and data collection

Data was collected from selected households which were identified by the extension officers from the Department of Agriculture and Rural Development in the different municipalities. A snowball sampling procedure was used to identify other indigenous chicken owners within the area. Data was collected from 120 households, with 20 households identified in each area.

Indigenous chicken farmers were interviewed individually at their homesteads using questionnaires. The questionnaires were focused on finding out the management practices, flock sizes, housing availability, feeding systems, health measures, and main uses of indigenous chickens in these communal areas of KwaZulu-Natal. Data about the constraints faced by farmers such as disease outbreaks and predators was also collected.

3.3.3 Statistical analysis

SPSS 2010 was used to analyse data and descriptive statistics were used to calculate frequencies of household characteristics and management practices. Reasons for rearing indigenous chickens were ranked by calculating indices (Index =sum of (3 for rank 1+2 for rank 2+1 for rank 3) given for each reason divided by the sum of (3 for rank 1+2 for rank 2+1 for rank rank 3) for all reasons.

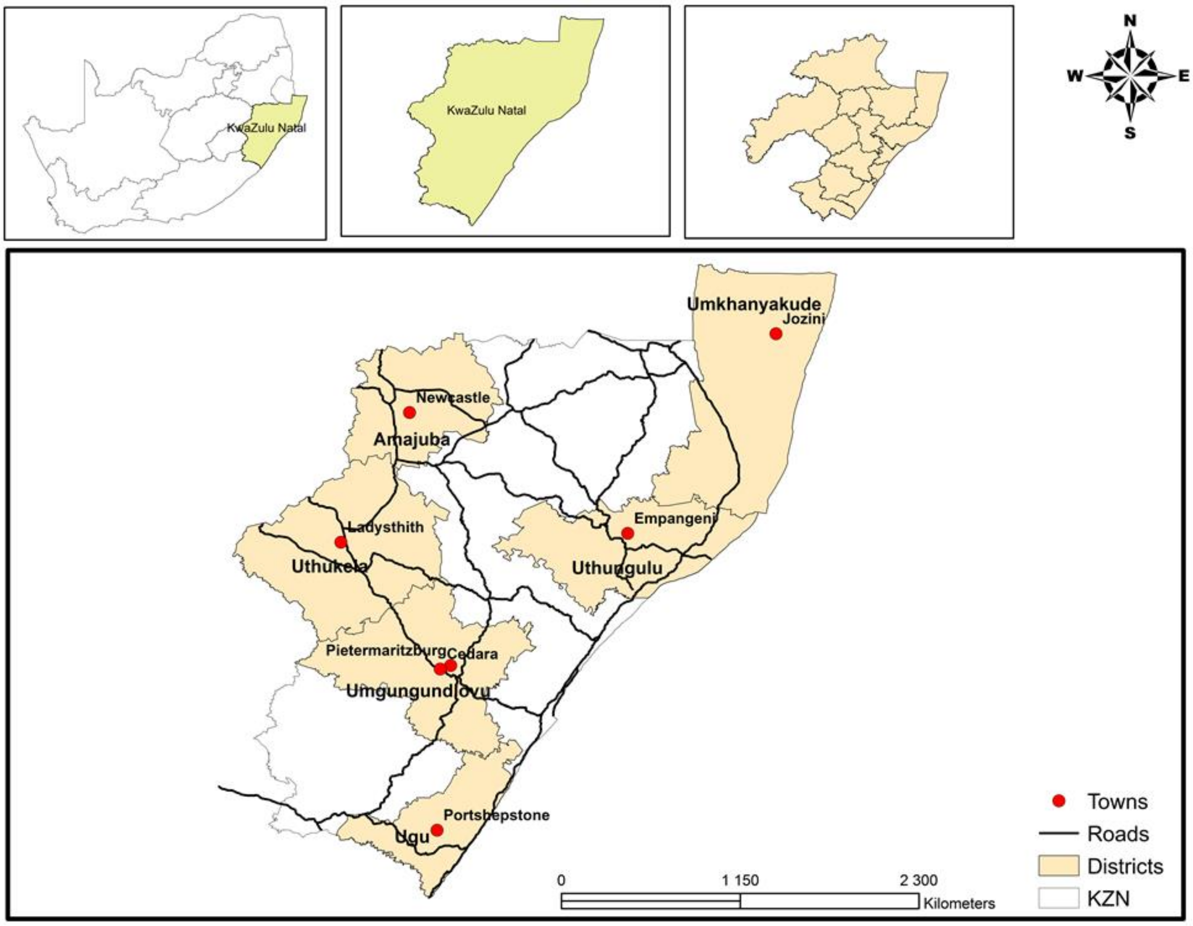


Figure 3. 1 Map illustrating areas where data on production systems of indigenous chickens was collected.

3.4 Results

3.4.1 Household characteristics

Table 3.1 presents the household characteristics and biographical information (demographics) of the farmers. The majority of respondents in all the areas were females (55% to 95%). The largest proportion (65%) of farmers who participated were those between the ages of 40 and 59 years. The majority of households had between 1 and 4 members; other households had between 5 and 10 members. Most (60%) of the farmers who participated in the study had no basic education while others had gone through primary (50%) and high school (40%) education. Flock sizes ranged from 2 to 80 indigenous chickens per household.

Table 3. 1 Household characteristics, gender, age group and educational level for participants rearing indigenous chickens in selected areas of KwaZulu-Natal

	Gender (%)		**Age group (%)**			**Household size (%)**		**Educational level (%)**			**Flock size**
Area	Male	Female	20-40yrs	40-59yrs	60-80yrs	1-4	5-10	None	primary	High school	
Empangeni	25	75	20	65	15	70	30	55	25	20	2- 30
Jozini	45	55	20	60	20	95	5	60	30	10	10-80
Port Shepstone	5	95	25	35	40	80	20	30	50	20	5-58
Pietermaritzburg	10	90	10	55	35	85	15	35	25	40	7-40
Newcastle	20	80	30	45	25	80	20	40	30	30	3-30
Ladysmith	25	75	10	40	50	70	30	50	30	20	6-35

3.4.2 Farmers' perceptions of the importance of indigenous genetic resources

Table 3.2 presents farmers' perceptions on the importance of indigenous chicken genetic resources. Farmers were interviewed to see if they had knowledge about conservation of Animal Genetic Resources (AnGR). A total of 74.2% of farmers had no knowledge, 12.5% had minimal knowledge and only 13.3% knew about conservation of AnGR. They were further interviewed about the importance of AnGR and of indigenous chickens. A total of 15% percent felt they were not important, 60% stated they were very important because of specific use such as home consumption and income generation.

Table 3. 2 Farmers' perceptions of the conservation of indigenous chickens

Awareness about conservation	No of farmers	Percentage
Not aware	89	74.2
Less aware	15	12.5
Fully aware	16	13.3
Value for AnGR		
Not important	18	15
Important	30	25
Very important	72	60
Value for indigenous chickens (IC)		
Not important	18	15
Important	30	25
Very important	72	60

Table 3.3 shows priorities on the use of indigenous chickens given by the farmers. Meat and egg production was highly ranked by farmers, followed by source of income, with the least being for traditional purposes.

Table 3. 3 Priorities for keeping indigenous chickens by households in northern KwaZulu-Natal

Reasons	Rank 1	Rank 2	Rank 3	Index
Meat and eggs	120	0	0	0.690979
Income	0	46	0	0.176583
Traditional purposes	0	29	11	0.132438

3.4.3 Indigenous chicken production systems in KwaZulu-Natal

The results presented in table 3.4 show that indigenous chickens were reared under semi-intensive production systems in all the areas except for Jozini where the majority of farmers (65%) reported that they reared the chickens under the extensive system. In the semi- intensive system, the indigenous chickens were allowed to scavenge during the day but were confined at night in pens constructed from any locally available material. Indigenous chickens in the extensive system were left to scavenge for feed during the day and spent the night in trees. Indigenous chickens in all the areas were provided with supplement feed, with household waste being the major supplement provided by farmers. Water was provided in all the areas. Only 20% at Jozini and 5% of the farmers at Empangeni reported that they did not provide any water for the chickens but rather the indigenous chickens find water from puddles and dew as they scavenge for feed. Farmers reported that they use plastic dishes to provide water for the chickens.

Table 3. 4 Types of production system for indigenous chickens in different communal areas of KwaZulu-Natal

	System of Production (%)		**Housing (%)**		**Supplement Feed (%)**		**Provision of water (%)**	
Area	Extensive	Semi-intensive	Pen	Tree	Yes	No	Yes	No
Empangeni	5.0	95	95	5.0	100	-	95	5.0
Jozini	65	35	35	65	100	-	80	20
Port Shepstone	-	100	100	-	100	-	100	-
Pietermaritzburg	-	100	100	-	100	-	100	-
Newcastle	-	100	100	-	100	-	100	-
Ladysmith	-	100	100	-	100	-	100	-

Table 3.5 shows the supplements given to indigenous chickens. About 60% of farmers provided them with maize grain, 30.8% gave household waste as feed supplements and 9.2 % gave crushed yellow maize as the form of supplements. About 70% of farmers grew crops. The majority of the farmers (90.8%) grew maize and 70% of the farmers used the crops as a supplement feed for the indigenous chickens.

Table 3. 5 Supplements given to indigenous chickens in a form of feed in rural areas of KwaZulu-Natal

Type of supplements	No of farmers(Frequency)	Percentage
Maize grain	72	60
Household waste	37	30.8
Crushed yellow maize	11	9.2
Growing of crops		
Yes	84	70
No	36	30
Type of crops		
Maize	109	90.8
Sunflower	11	9.2
No crops		
Feed for (IC) from crops		
Yes	84	70
No	36	30
Access to veterinary service		
Yes	40	33.3
No	80	66.7
Access to extension service		
Yes	30	25
No	90	75

The most common challenges mentioned by farmers were theft, diseases and predators (Table 3.6). Theft was highly ranked by farmers, with an index of 0.74, followed by diseases (0.24), and, lastly, predators (0.02). Plans reported by the farmers to prevent these challenges are presented in Table 3.7. Pen construction was highly ranked as the plan to prevent theft and predators, followed by the use of vaccines and ethno-veterinary procedures to prevent diseases.

Table 3. 6 Challenges encountered when rearing indigenous chickens

Reasons	Rank 1	Rank 2	Rank 3	Index
Theft	120	0	0	0.74
Diseases	0	45	29	0.24
Predators	0	0	10	0.025

Table 3. 7 Plans to prevent indigenous chicken challenges

Plan	Rank 1	Rank 2	Rank 3	Index
Pen	120	0	0	0.80
Vaccines	0	30	13	0.16
Ethno-veterinary procedure	0	0	17	0.04

Newcastle disease was perceived by the farmers to be the most prevalent disease affecting indigenous chickens, followed by sores on eyes and respiratory diseases (Table 3.8).

Table 3. 8 Ranking of the diseases encountered when rearing indigenous chickens in areas of KwaZulu-Natal

Challenge	Rank 1	Rank 2	Rank 3	Index
Newcastle	112	3	5	0.75
Sores on eyes	0	45	20	0.25
Respiratory diseases	0	0	26	0.02

Farmers were interviewed about sale of their indigenous chickens. Most (92.5%) of the farmers sold their indigenous chickens. The majority (81.0%) of farmers reported selling only when a need arose, while some (19.0%) sold their indigenous chickens to reduce numbers. Other (13.5%) of farmers sold only cocks as they grow old or if there are too many cocks in a flock and 86.5 % reported selling either male or female chickens at any point in time. Some farmers (48.6%) gave chickens as gifts.

Table 3. 9 The Sale of indigenous chickens by the rural farmers of KwaZulu-Natal

Aspects of Marketing	Frequency	Percentage
Selling of indigenous chicken		
Yes	111	92.5
No	9	7.5
Reason for selling		
Need arises	90	81.0
Increase in number	21	19.0
Type of (IC) sold		
Old cocks	15	13.5
All types (hen, cock, chicks)	96	86.5
Price range for selling (R)		
Gift	54	48.6
50-59	30	27.0
60-100	27	24.3
Future plans for producing (IC)		
Selling	92	76.7
Home consumption	28	23.3

3.5 Discussion

Knowledge of the management practices and constraints associated with indigenous chicken production systems gives a clear understanding of what can be done to improve indigenous chicken production and develop indigenous chicken breeding programmes. In the present study the majority of the respondents were females in all the surveyed areas, indicating that most of females are more responsible than males for the rearing of indigenous chickens. Although the women took the lead in rearing the chickens, the youth was reported to play a role, especially during school holidays. Women were also found to be the decision makers on production of indigenous chickens. These findings are in line with McAinsh *et al.* (2004) in Zimbabwe who reported major roles in indigenous chicken production being played by women and children. Males participated more in constructing chicken houses. Similarly, Mogesse (2007a), in Northwest Ethiopia, reported that it was mainly females who were responsible for the rearing of indigenous chickens even in male headed households while males were responsible for crop cultivation and other off-farm activities.

The study revealed that other members of the household participated in rearing indigenous chickens. These findings are comparable to the findings of Mngonyama (2012) who did a survey in the highveld areas of KwaZulu-Natal. The researcher reported that about 6 members participated in indigenous chicken production per household, thus reducing labour requirements. Mngonyama (2012) reported the participation of household members aged between 16 years and 65+yrs, which is in agreement with the age composition in this study.

The flock sizes at Ladysmith and Pietermaritzburg are similar to the results of the work done by Mngonyama (2012) in other areas of KwaZulu-Natal (Empendle and Ladysmith). The author reported flock sizes of 5 to 20 per household. Flock sizes ranging from 12 to 24 have been reported in other developing countries (Okeno *et al.*, 2012). Flock sizes ranging between 10 and 20 were observed in Empangeni and Newcastle, and similar findings were reported by Mtileni *et al.* (2012) in the Eastern Cape. The flock sizes ranging from 5 to 60 in Port Shepstone were similar to those found in the Centane District in the Eastern Cape by Mwale and Masika (2009) . Small flock sizes (fewer than 5) were observed to be the result of poorly constructed houses which give access to predators and thieves. Shortage of feed was also reported as a cause of small flock sizes. This is in line with the findings of Mammo *et al.* (2008) in Jamma District, South Wollo, Ethiopia who reported small flock sizes due to poor feed resources, disease problems, shortage of labour, and problems with neighbours.

Most of the farmers in this survey depended on farming of indigenous chickens for various reasons in their livelihoods. The results obtained were similar to findings of Mtileni *et al.* (2009) and Mapiye *et al.* (2008) who reported that indigenous chickens play significant roles such as a protein source, for manure and for cultural ceremonies. Indigenous chickens were also used as a source of income, similar to the observation by McAinsh *et al.* (2004) in Zimbabwe. Those authors reported that the income obtained from the sale of indigenous chickens was used for school fees, groceries and other sudden expenses.

Extensive and semi-intensive production systems were systems commonly used by farmers in KwaZulu-Natal. Similarly (Dana *et al.*, 2010b) and found that the majority of indigenous chickens were reared under extensive systems in rural areas. At night the indigenous chickens were confined in houses poorly constructed of local material. This is similar to the report by Moreda *et al.* (2014) that poultry houses in the South West and Southern parts of Ethiopia were constructed from local materials such as wood and wire and that some of the indigenous chickens found places to put up in trees and bamboo. The existence of indigenous chicken houses, even if poorly constructed, indicates that farmers are aware of the importance of shelter and also the importance, per se, of their indigenous chickens (Kugonza *et al.,* 2004; Moreda *et al.*, 2014).

The shelter of the chickens was rarely cleaned. Although some farmers reported cleaning them once a week and others monthly, some farmers reported not cleaning them at all. McAinsh *et al.* (2004) stated that indigenous chicken houses in Zimbabwe were only cleaned once a week, thus causing the occurrence of various diseases which result in the mortality of indigenous chickens.In the present study Indigenous chicken houses had small roosting facilities that could not provide protection against predators. According to Mtileni *et al.* (2009) proper housing makes management easier and can assist farmers in rearing indigenous chickens to market age in a short period of time.

Shortage of feed and poor quality of feed are considered to be limiting factors for livestock production. Indigenous chickens mostly rely on scavenging feed, although supplementary feeding was provided. Indigenous chickens of different age groups were fed together. Household waste was provided as an unlimited supplement in addition to the scavengable feed resource. Farmers reported that through scavenging, their chickens are able to meet requirements for proteins, vitamins and minerals. Other feeds such as maize grains would be seasonally provided; some farmers would buy crushed yellow maize for their indigenous chickens. Farmers' perception of crushed yellow maize is that it enables indigenous chickens to grow fast and produce more eggs. The same system was reported by McAinsh *et al.* (2004) for the chickens in Zimbabwe.Moreda et al 2014 found that indigenous chickens in Ethiopia obtained feed from scavegimg but all farmers provided supplementary feeding.

Even though indigenous chickens can meet their nutritional requirements through scavenging, there can be various challenges associated with scavenging, such as changes in climatic condition which can affect production of the grains consumed by indigenous chickens (Kingori *et al.*, 2010). Increase in human population causes competition for feed and grains, which could have an effect on indigenous chicken production in the future. According to Mtileni *et al.* (2012) low performance of indigenous chickens in terms of their production can be largely attributed to the poor feed resource base. The use of alternative feed resources, such as termites, maggots and worms to increase the scavenging feed resource base has been suggested by other researchers (Mtileni *et al.*, 2012). Termites have the ability to survive in dry conditions; they consume wood and other plant matters such as leaves and animal dung.

The provision of water reported in this study agrees with the report of McAinsh *et al.* (2004). This has been the trend also with other surveys conducted by Moreda *et al.* (2014) and Mwale and Masika (2009) where water was provided using plastic dishes and tyres once a day, not ad libitum. Insufficient water may be the cause of late maturity of the indigenous chickens in the rural areas, that was reported by farmers, if the chickens do not get up to 500ml of water per day in a hot climate (McAinsh *et al.*, 2004). Insufficient provision of water causes slow growth rate because low water intake results in low feed intake which has a negative impact on growth.

Even though there was no formal market, the indigenous chickens were sold to neighbours when the need arose. McAinsh *et al.* (2004) reported that the income obtained was used for school fees, groceries, clothes and sudden expenses. Similar findings were obtained in this study. Other farmers reported using indigenous chickens as their source of protein (meat and eggs) because they can be slaughtered easily and consumed instantly without requiring any storage facilities compared to other animals. The same was reported by Mwale and Masika (2009) and Okeno *et al.* (2012) in the Centane district in the Eastern Cape, and in Kenya.

Farmers reported that mortality of indigenous chickens occurred from various causes such as diseases and predators. Mtileni *et al.* (2012) in studies conducted in Limpopo, Northern Cape, and the Eastern Cape Province indicated that Newcastle disease was reported as the major constraint. Similar results were reported by Mwale and Masika (2009). The prevalence of diseases was observed in all the districts, probably because of poor health management and poor health services (veterinary services). This is in agreement with the results reported in Eastern Uganda by Kugonza *et al.* (2004) and Moreda *et al.* (2014) in the Dawo and Seden

Sodo districts in the South West Showa Zone of the South West part of Ethiopia, and Mehale Ameba and Mahurena Aklile districts in the Gurage Zone of Southern Ethiopia who reported mortality of indigenous chickens from the prevalence of Newcastle disease and coughing. Introduction of new stock to existing stock, flock contacts while scavenging, and exchange of indigenous chickens in the neighborhood were also noted as causes of diseases. All these contribute to the limited development of a health programme in indigenous chicken production. This is in agreement with the reports of Mtileni *et al.* (2012) and Kugonza *et al.* (2004) that farmers have little knowledge about controlling such diseases. These findings are similar to the findings of Moreda *et al.* (2014) who reported that biosecurity in extensive production systems for indigenous chickens is very poor and very risky since scavenging chickens live together with other livestock species and people.

According to Mtileni *et al.* (2012) the wealth status of the household is assumed to have an effect on flock management, feed availability and disease control strategies. Wealth, age and access to production resources are usually related (Aklilu *et al.*, 2008). There is an assumption that youth-headed households are often poor and have little access to the resources required to control diseases compared to households headed by adults (Aklilu *et al.*, 2008; Mtileni *et al.*, 2012). According to Mtileni *et al.* (2012) Newcastle disease is likely to occur in chickens from youth-headed households because of lack of finances to buy vaccines to prevent the disease.

The predators of indigenous chickens reported by farmers were dogs, wild cats, rats, eagles and snakes. These were reported to be the most common predators in all the districts. These findings are similar to those of Mtileni *et al.* (2012) who reported eagles, snakes and wild cats as major predators. According to Kusina *et al.* (2001) predators increase during the dry season when vegetation declines and predators search for food near homesteads. During the rainy season vegetation protects indigenous chickens from flying predators such as eagles. Construction of indigenous chicken houses can help protect indigenous chickens (Kugonza *et al.*, 2004). Mngonyama (2012) has also suggested hunting, trapping or poisoning of predators such as rats as a way of reducing the number of mortalities. Mtileni *et al.* (2012) also reported hostile environments during the early days of chicks and poor housing to be the major causes of mortalities. Lack of extension and veterinary services was also identified as a constraint to indigenous chicken production, as was also found by Mwale and Masika (2009).

3.6 Conclusion

Indigenous chickens play a vital role in the livelihoods of rural communities. They are reared in an extensive production system which is associated with constraints that limit their productivity because of poor management standards. There is a need to address the issue of the constraints (diseases, predators and theft) identified in this survey by improving feeding, provision of water ad libitum, construction of houses, and improvement of health management including provision of vaccines that can enhance the productivity of indigenous chickens. The constraints regarding health management could be prevented by consulting extension and veterinary services. People in rural areas need to be educated about the importance of indigenous chickens.

CHAPTER 4: MORPHOLOGICAL STRUCTURE OF INDIGENOUS CHICKENS IN KWAZULU-NATAL BASED ON PRINCIPAL COMPONENT ANALYSIS OF BODY MEASUREMENTS

4.1 Abstract

The study was conducted to predict body weight from linear body measurements of indigenous chickens using principal component analysis. Body measurements were taken from 350 chickens: body weight (BW), shank length (ShL), body length (BoL), back length (BaL), shank circumference (ShC), breast circumference (BrC), neck length (NL) and toe length (TL) . The body weights were measured using a 5kg weighing scale. Phenotypic correlations among body weight and linear body measurements were positive and highly significant ($r = 0.21$-0.71; $P<0.01$). Body weight and breast circumference had the highest correlation of 0.71. Lower correlation (0.21) was observed between body length and toe length. Principal component analysis with variance maximising orthogonal rotation was used to extract components. Two principal components were extracted with a total variance of 63.94%. Principal Component1 (PC1) had the largest share of breast circumference (0.84), body weight (0.83), and body length (0.76) and shank circumference (0.62). Principal component 2 (PC2) had high loadings on toe length, shank length, and back length at 0.85, 0.79 and 0.62 respectively. Principal components were found to be more appropriate in estimating body weight than using original linear body measurements. The principal components based on a linear regression model could be a preferable tool for selecting indigenous chickens. They can be useful in predicting body weight of indigenous chickens in the absence of weighing scales.

***Keywords*:** indigenous chicken, body measurements, principal component analysis, body weight

4.2 Introduction

Indigenous chickens are classified as non-descriptive types because of the lack of information (Food and Organization, 2012), but they play a vital role in human livelihoods in rural areas and therefore need to be characterised as a first step to conservation. Characterisation of domestic animals is the first approach to their sustainable use and their conservation. Phenotypic characteristics such as morphological trait measurements have been found useful in contrasting size and shape of animals and they could provide useful information on the suitability of animals for selection (Yakubu *et al.*, 2009).

Body weight is one of the important traits for indigenous chickens as it is mostly selected for by farmers for meat production. Knowledge on how it can be improved is of great importance. It is therefore important to know which body measurements can be used to predict body weight in the absence of weighing scales and also to know which morphological traits could be improved in order to increase body weight (Besbes, 2009). It is assumed that breast circumference alone can be used to predict body weight because of the high correlation that is normally observed (Assan, 2015).

Among the indigenous chicken traits, body weight and linear body measurements are commonly used for measuring growth in indigenous chickens (Udeh and Ogbu, 2011). Body weight is a trait of economic importance as the price of chicken largely depends on it. However, weighing scales are not always available in rural areas, but measuring tape is commonly used. Rural farmers use inaccurate guess-estimates of body weight. According to Kunene (2010) body weight can be predicted from body characteristics which can be easily measured. Using linear body measurements for predicting body weight can help indigenous chicken keepers to have a cheap, accurate, easy and rapid estimation of body weight (Gueye *et al.*, 1998). Linear body measurements together with body weight describe more completely an individual or population than weighing and grading methods (Mavule, 2012b). Several researchers have used body measurements in describing the morphological structure of different livestock species (de Componentes and en la Cuantificación, 2009; Ogah, 2011; Yakubu *et al.*, 2009).

Udeh and Ogbu, (2011) and Mendes (2009) used a multivariate technique known as principal component analysis. Principal component analysis is a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables known as principal components which are ordered so that the first few retain most of the variation present in the original variables (Udeh and Ogbu, 2011). Principal component analysis (PCA) has been employed by Ogah (2011) and Yakubu *et al.* (2009) to analyse data for growth in chickens and other domestic animals. Growth is complicated because it is controlled by genetic and non-genetic factors. Its traits are biologically related, so it should be explained by using the multivariate technique (Udeh and Ogbu, 2011). This technique has been used to identify the relationship between body weight and other morphological traits in indigenous chickens (Mendes, 2011) and also to assess body size and conformation of indigenous Nigerian turkeys and ducks (Ogah, 2011; Ogah *et al.*, 2009).

The same technique was used to examine the relationship among body measurements in three strains of broiler chickens with a view to identifying those components that define body conformation, which could be used as selection criteria for improving meatiness in broilers (Ogah, 2011). Yakubu *et al.* (2009) used PCA to describe the interdependency among the morphological traits of extensively managed indigenous chickens in Nigeria and to predict their body weight. Body weight is an important trait to people in rural areas of KwaZulu-Natal because they sell indigenous chickens when in need of money. They need cheap, accurate, easy and rapid estimation of body weight. The relationship between body weight and linear body measurements has not yet been sufficiently studied in indigenous chickens in KwaZulu-Natal. The study was carried out to predict body weight from linear body measurements of indigenous chickens using principal component analysis.

4.3 Materials and Methods

4.3.1 Study site

The study was conducted in 6 communal areas located in 6 districts of KwaZulu-Natal, namely, Empangeni in UThungulu district, located at 28.6192°S, 31.5370°E, Jozini in UMkhanyakude district, located at 27.2719°S, 32.537°E, Port Shepstone in UGu district, located at 30.6218°S, 30.2513°E, Pietermaritzburg and Cedara in UMgungundlovu district, located at 29.5101° S, 30.3436°E, Ladysmith in UThukela district, located at 28.6783°S, 29.6035°E and Newcastle in Amajuba district, located at 27.8036°S, 30.0665°E.

4.3.2 Data collection

Data on morphological traits was collected from the selected households which were identified by the extension officers from different municipalities. A total number of 350 indigenous chickens at the age of 6 months (24 weeks) and above were randomly selected. The age was chosen by considering the slow maturation of indigenous chickens to reach their adult age. Interviewed farmers memorised the age of their indigenous chickens. Indigenous chickens were caught using hooks for measurement of the quantitative traits.

4.3.3 Measurement of Traits

Body weight (BW), shank length (ShL),Shank circumference (ShC), toe length (TL),body length (BoL), back length (BaL),neck length (NL) and breast circumference (BrC) were measured on each indigenous chicken. The methods of Ajayi *et al.* (2012) and Yakubu *et al.* (2009) were used as a point of anatomical reference. Body measurements were taken using a measuring tape calibrated in centimeters and body weight was measured using a 5kg weighing scale. The body length (BoL) was length taken between the tip of the rostrum maxillare (beak) and that of the cauda (tail, without feathers); shank length (ShL) was taken as the distance from the hock joint to the tarsometatarsus; breast circumference (BrC) was measured as the circumference of the breast around the deepest region of the breast; toe length (TL) was calculated by measurement of the longest toe; back length (BaL) was measured as the distance below the neck region to the cauda (tail without feathers); shank circumference (ShC) was measured as the diameter of the metatarsus just below the spur and neck length (NL) was measured as the distance below the head to the beginning of back length. All measurements were taken by the same individual to avoid between-individual variations.

4.3.4 Statistical analysis

Means, standard errors of body weight and linear body measurements were obtained using the statistical package for social science SPSS 20 (2010). Pearson coefficient of correlation among body weight and linear body measurements was estimated, and the principal factor analysis was obtained from the correlation matrix. Principal component analysis was applied to linear body measurements, and linear body measurements were combined and formed unrelated components. The interpretation of principal components was improved by varimax rotation. The appropriateness of the principal component analysis was tested using communalities. Bartlett's Test of Sphericity was conducted to determine the appropriateness of the common factor model in analysing body weight. Models for predicting body weight from (a) body measurements and (b) from principal components were obtained using the stepwise multiple regression procedure. Models with a higher coefficient of determination (R^2) were considered better than models with low (R^2).

$BW= a+B_iX_i+\ldots.B_kX_k$ (a)

$BW=a+B_iCP_i +B_kPC_k$ (b)

where BW is the body weight, a is the regression intercept, B_i is the *ith* partial regression coefficient of the *ith* linear body measurement, and X_i or the *ith* principal component (PC).

4.4 Results

4.4.1 Descriptive statistics of body measurements

Table 4.1 shows the descriptive statistics of body weight and linear body measurements of indigenous chickens of different age groups. Shank length in age groups from 6 to 24 months was similar but a difference was observed at the age 24+ months. Toe length and shank lengths were similar at 6 to 18months, with difference observed at 24 months. The body length difference was observed at 18 to above 24 months. The shortest back length was for chickens of 6 to 12 months, while at 12 to 18 months and 18 to 24 months back lengths were more or less similar. The largest back length was observed above 24 months. Short neck length was observed at 6 to 12 months, but difference observed at 18 to 24 months. Significant difference in body weight at all age groups was observed. Body weight increased as the age of indigenous chickens increased. An increase of 1.38kg to 1.97 kg was observed from 6 to 24 months.

Table 4. 1 Descriptive statistics of body weight (kg) and linear body measurements (cm) of indigenous chickens at different age groups

Traits	6-12 Months	12-18 Months	18-24 Months	≥24 Months	P<0,001
ShL	9.00 ± 0.21^{a}	8.81 ± 0.13^{a}	9.44 ± 0.15^{a}	10.29 ± 0.35^{b}	***
TL	5.82 ± 0.12^{a}	5.67 ± 0.09^{a}	6.07 ± 0.12^{ab}	6.49 ± 0.17^{b}	***
ShC	4.47 ± 0.08^{a}	4.57 ± 0.07^{a}	4.73 ± 0.07^{ab}	5.00 ± 0.14^{b}	***
BoL	39.42 ± 0.58^{a}	41.15 ± 0.42^{ab}	42.25 ± 0.51^{b}	45.76 ± 0.79^{c}	***
BaL	23.75 ± 0.35^{a}	25.37 ± 0.35^{b}	26.04 ± 0.33^{bc}	27.36 ± 0.52^{c}	***
NL	11.53 ± 0.25^{a}	11.99 ± 0.19^{b}	12.34 ± 0.19^{bc}	13.17 ± 0.49^{b}	***
BW	1.38 ± 0.05^{a}	1.75 ± 0.04^{b}	1.97 ± 0.04^{c}	2.31 ± 0.12^{d}	***
BrC	30.19 ± 0.48^{a}	32.46 ± 0.32^{b}	33.32 ± 0.31^{b}	35.79 ± 0.65^{c}	***

Means in the same row bearing different superscripts are highly significantly*** ($p<0.001$) different. Shank length (ShL),Toe length (TL),Shank circumference (Shc), Body length (BoL), Back length (BaL), Neck length (NL), Body weight (BW) and Breast circumference (BrC).

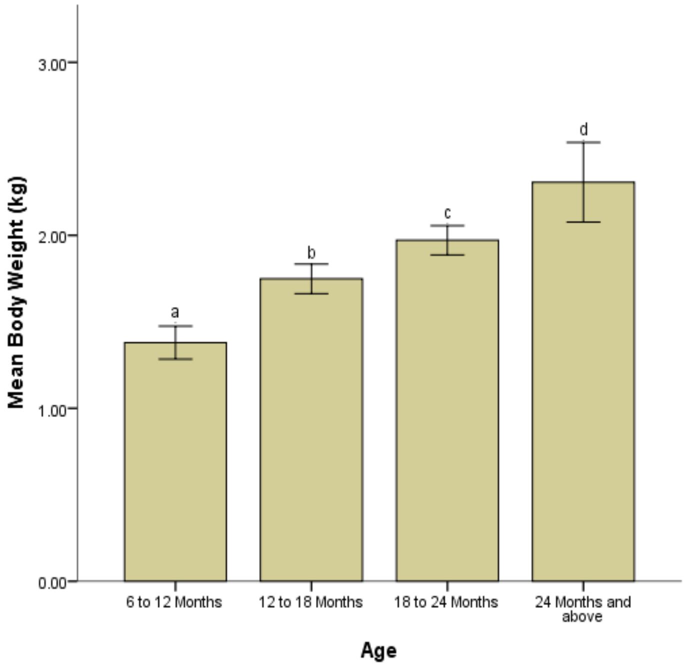


Figure 4.1Body weight of indigenous chickens at different age groups

Standard errors of the means are represented by error bars. Significance difference ($p<0.001$) is represented by different letters on the bars.

4.4.2 Correlation of body weight and body measurements

Correlation of body weight and linear body measurements of indigenous chickens is presented in Table 4.2. The correlation coefficient ranged from r=0.21 to r=0.71. Highly significant ($p<0.01$) correlation was recorded for body weight and breast circumference(r=0.705), body weight and body length (r=0.61) and body weight and shank circumference (r=0.60). The lowest correlation was observed between body length and shank circumference (r=0.21).

Table 4. 2 Correlation coefficients of body weights and linear body measurements of indigenous chickens in communal areas of KwaZulu-Natal

Traits	Shank Length	Toe Length	Shank Circumference	Body Length	Back Length	Neck Length	Body Weight	Breast Circumference
Shank Length	1							
Toe Length	0.54**							
Shank Circumference	0.43**	0.39**						
Body Length	0.42**	0.21**	0.42**					
Back Length	0.52**	0.39**	0.33**	0.44**				
Neck Length	0.43**	0.36**	0.46**	0.49**	0.38**			
Body Weight	0.48**	0.39**	0.60**	0.61**	0.52**	0.49**		
Breast Circumference	0.32**	0.23**	0.47**	0.49**	0.32**	0.39**	0.71**	1

**. Correlation is significant at p<0.01 level (2-tailed)

Eigen values, percentage of total variance along with the rotated component matrix and communalities of body measurements of indigenous chickens are presented in Table 4.3. Communalities represent the estimate of variance in each variable represented by components. The percentage of total variance is used to determine the accountability of total component on what is represented by body measurements. The Eigen values represent the amount of variance out of the total variance explained by each of the components. The communality ranged from 0.49 to 0.79. Two principal components were extracted, with Eigen values of 4.08 and 1.03 for principal component 1 and principal component 2 respectively.

Principal component 1 accounted for 51.05% of total variance and principal component 2 accounted for 12.89 %. The combination of these two principal components accounted for 63.94%. Principal component 1 had high loadings on breast circumference, body weight, body length and shank circumference at 0.84, 0.83, 0.76 and 0.62 respectively, meaning that PC1 was related to body size. Principal component 2 had high loadings on toe length, shank length, and back length at 0.85, 0.79 and 0.62 respectively, meaning that PC2 was related to body shape. A diagrammatic presentation is shown in Figure 4.2. The scatter plot indicates that PC2 had high loading of shank length (0.791) and toe length (0.851) which increase as the values of PC2 increase but shank lengths and toe lengths lie within the lower values of PC1, which indicates that PC1 had high loading values of breast circumference (0.84), body weight (0.83) and body length (0.76).

Table 4. 3 Eigen values and percentage of total variance along with the rotated component matrix and communalities of body measurements for indigenous chickens

Variable	Component		Communality
	1	2	
Breast circumference	0.84	0.00	0.72
Body Weight	0.83	0.33	0.79
Body Length	0.76	0.21	0.62
Shank Circumference	0.62	0.38	0.53
Neck Length	0.56	0.42	0.49
Toe Length	0.00	0.85	0.73
Shank Length	0.29	0.79	0.71
Back Length	0.37	0.62	0.53
Eigenvalues	4.08	1.03	
% of total Variance	51.05	12.89	
Cumulative %	51.05	63.94	

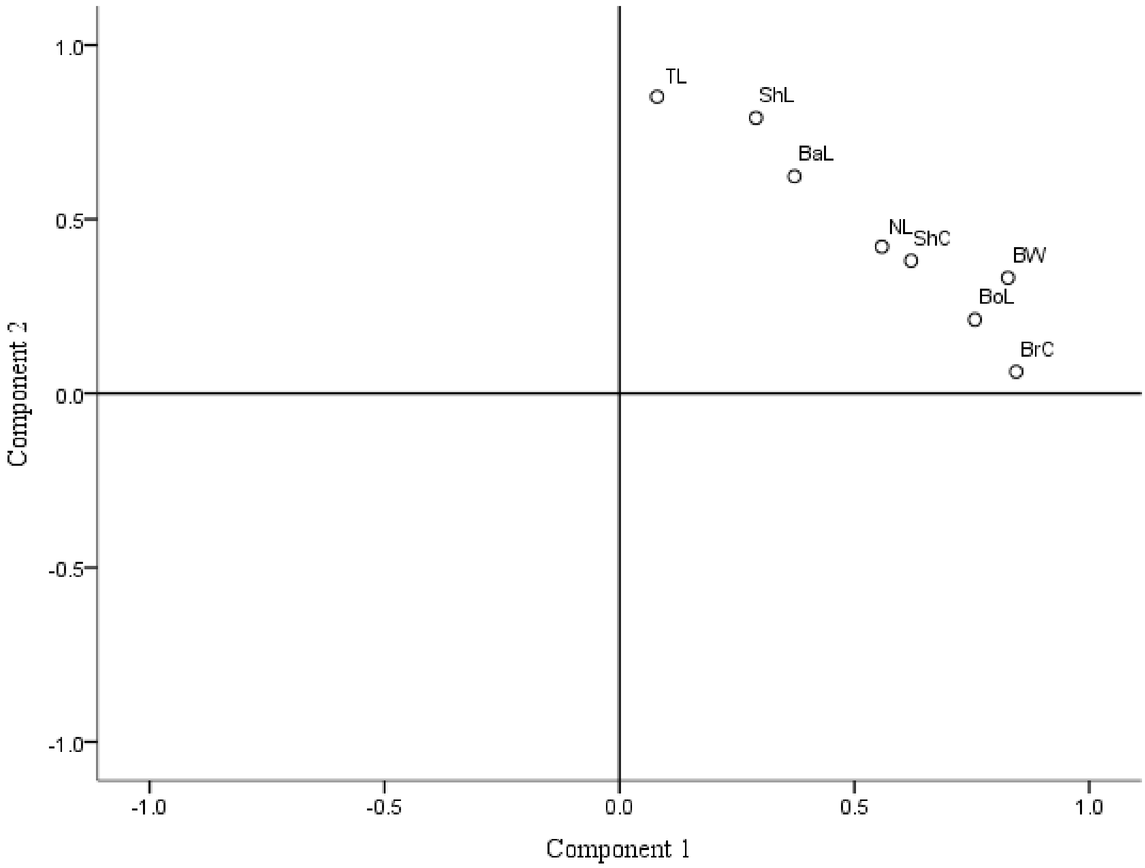


Figure 4. 1 Principal components of the factors and associations of body measurements after Varimax transformation.

Breast circumference (BrC), body weight (BW), body length (BoL), shank circumference (ShC),neck length (NL), back length (BaL), Shank length (ShL), toe length (TL).

4.4.3 Prediction of body weight from linear body measurements and independent principal component scores

Table 4.4 presents the interdependent original body dimensions and their independent component factor scores which were used to predict body weight of indigenous chickens. The results of the stepwise multiple regression analysis revealed that breast circumference alone accounted for 49.7% of the variation in body weight. The inclusion of back length in the model increased the proportion of the explained variance to 59.3%. The accuracy of the model was further improved to R^2=65.3% due to the inclusion of shank circumference. When the shank circumference and body length was included in the model R^2= 67.9% was obtained. Further inclusion of the toe length resulted in R^2=68.5%. The use of principal component 1 as a single predictor explained R^2= 68.4% of the total variability in body weight. The combination of principal component 1(PC1) and principal component 2 (PC2) gave a considerable improvement in the amount of variance R^2=79.4%. The best prediction equation after inclusion of component scores was found to be BW=0461PC1+0.I85PC2+1.824.

Table 4. 4 Stepwise multiple regression of body weight on original body measurements and factor score in indigenous chickens

Model	**Predictors**	**Models**	**R^2 (%)**	**SE**
Original body measurements as predictors				
1	BrC	BW=0.10BrC-1.46	49.7	0.40
2	BrC,BaL	BW=0.085BrC+0.049BaL-2.222	59.3	0.36
3	BrC,BaL,ShC	BW=0.069BrC+ 0.041BaL+0.207ShC-2.434	65.3	0.33
4	BrC,Bal,ShC,BoL	BW=0.060BrC+0.032BaL+0.180ShC+0.021BoL-2.683	67.9	0.32
5	BrC,Bal,ShC,BoL,TL	0.060BrC+0.028BaL+0.161ShC+0.022BoL+0.043TL-2.760	68.5	0.32
Principal components as predictors				
1	PC1	BW=0.461PC1+1.824	68.4	0.31
2	PC2	BW=0.461PC1+0.185PC2+1.824	79.4	0.25

4.5 Discussion

The results obtained in body weight and linear body measurements of indigenous chickens were similar to the results of Egena *et al.* (2014b) in Nigeria where the average body weight of 1.69kg was obtained (which is almost equal to 1.7kg) obtained at the age of 12 to 18 months. Shank lengths were lower than those reported by Egena *et al.* (2014b). The difference could be due to environmental factors, genetic makeup differences and feed availability in areas where indigenous chickens are reared.

The highest correlation coefficient between body weight and morphological traits was observed between BrC and BW (r=0.705). This result is in line with the results of Egena *et al.* (2014) where the authors suggested that breast circumference could be used as a reliable predictor trait of body weight for most livestock species (Milla *et al.*, 2012; Moela, 2014; Raji *et al.*, 2009; Semakula *et al.*, 2011). The results suggest that body weight of indigenous chickens can be predicted using linear body measurements. It has been reported that the increase in any linear body measurement leads to an increase in body weight (Egena *et al.*, 2014a).Toe length, followed by shank length, had a lower correlation, which is also similar to the findings of Egena *et al.* (2014b) . High positive correlations between traits suggest that selection for a trait may lead to a correlated response in the other trait (Rolf *et al.*, 2010) ;Greiner, 2001; Yakubu *et al.*, 2009) Positive correlations of traits suggest that traits are under the same gene action (Pleiotropy). This can help manipulate the improvement of indigenous livestock species (Greiner, 2001; Rolf, 2015).

The communalities obtained are similar to the findings of Egena *et al.* (2014b), Udeh and Ogbu (2011), and Yakubu *et al.* (2009). The relevance of principal component as a multivariate statistical tool was evident in the reduction of the large number of explanatory variables into components that gave a better description of body size and shape (Yakubu *et al.*, 2009). Eight linear body measurements have been reduced to two components. PC1 has largely been associated with size and PC2 associated with body shape (Mavule, 2012b; Yakubu *et al.*, 2009). These principal components could be useful in evaluating animals for breeding and selection purposes (Ajayi *et al.*, 2012), and they can be used as selection criteria for improving body weight of indigenous chickens (Egena *et al.*, 2014b). PC1 had high loadings of body length (BoL), breast circumference (BrC) and shank circumference (ShC). Shank length (ShL), toe length (TL) and back length (BaL) were more associated with PC2. This is similar to the findings of Ajayi *et al.* (2012) and Egena *et al.* (2014b). The lowest contribution of shank length to PC1 indicates its weakness in explaining the total variation in body measurements of indigenous chickens.

PC1 has been observed to account for large variation in different chicken genotypes. This has been the tendency in studies that used principal component factor analysis, as reported by Mendes (2009) in chickens and Shahin and Hassan (2000) in rabbits (Ajayi *et al.*, 2012).The high association observed between body weight and breast circumference might be attributed to a large deposit of bones and muscles in the breast region of indigenous chickens (Ajayi *et al.*, 2012).

The results obtained in the present study are like the finding of Egena *et al.* (2014b) where the variability R^2=60.2% was obtained after all the body measurements (body length, breast girth, shank thickness, wing length and shank length) were included in the model. In the present study, R^2=68.5% was obtained with the inclusion of breast circumference, back length, shank circumference, body length and toe length. The slight difference in R^2 percentages obtained in these studies could be due to wing length and shank length being included in the study of Egena *et al.* (2014b) and back length and toe length being included in the present study. However, in both studies, the use of principal component scores gave a better and more reliable assessment of body weight than the use of correlated variables. This is in line with the findings of other researchers (Yakubu *et al.*, 2009).

4.6 Conclusion

The high correlation coefficient observed between body weight and morphological traits indicates that breast circumference can be used as a reliable predictor of body weight. The principal component technique revealed the relationships between body measurements. Two principal components represented size and shape of indigenous chickens. Higher communalities obtained show the contribution made by the variable in determining the size or the shape of indigenous chickens. The use of principal components was more appropriate than the use of interrelated linear body measurements for predicting body weight of chickens. This is an indication that principal components could be useful in the selection and breeding of indigenous chickens.

CHAPTER 5: MORPHOLOGICAL DIFFERENTIATION OF SIX INDIGENOUS CHICKEN POPULATIONS IN KWAZULU-NATAL USING CANONICAL DISCRIMINANT ANALYSIS

5.1 Abstract

The study was conducted to evaluate morphological variation among indigenous chickens indifferent communal areas in KwaZulu-Natal. Variation in their morphological traits is mostly as a result of local adaptation and ecological character displacement. There is a lack of information about the phenotypic characteristics and variation among indigenous chickens in KwaZulu-Natal. Data was collected from 350 indigenous chickens obtained from different households; 6 qualitative traits were observed and 8 quantitative morphological traits were measured. A total of 10 plumage colours was observed in all the locations (red, white, black, wheaten, grey, golden laced, barred, blue breasted red, crele, and buff columbian). Golden laced was the most common plumage colour in all the locations. Pink, white and yellow were the observed skin colours. Yellow skin colour was the most predominant, ranging from 42.9% to 76.7% of chickens among the populations. Orange and brown eye colours were observed; orange was the most common (65% to 87%). Comb types observed were single, pea and rose, with single comb type being the most common in all the populations (54% to 100%). Shank colours observed were yellow, white, green, black and grey, with yellow shank colour being the most common. Linear body measurements indicated that indigenous chickens from Jozini and Newcastle had higher body measurements for breast circumference (BrC), neck length (NL) and back length (BaL) while indigenous chickens from Empangeni measured the least for breast circumference (BrC), body weight (BW) and back length (BaL). Variation in body size was observed in different locations. The average body weight ranged between 1.67kg and 2.15kg. Body weight was identified as the most discriminating variable, represented by its high F-value =13.082, with Wilks Lambda =0.81. The greatest Mahalanobis distance (53.23) was obtained between Empangeni and Jozini. Larger distances were also obtained between Jozini and other locations, reflecting morphological diversities. Indigenous chickens in Port Shepstone and Newcastle were similar (3.579). Two main clusters were formed, the first in Newcastle, Port Shepstone and Cedara, and the second in Pietermaritzburg and Ladysmith. Empangeni and Jozini individually joined the two clusters although Jozini showed itself to be more distant from other flocks. A total of 51.1 % of indigenous chickens were correctly assigned to their populations. This study revealed the existence of phenotypic diversity between indigenous chickens in KwaZulu-Natal. This diversity could be exploited for the improvement

of the production and aesthetic traits of indigenous chickens through selection and breeding between populations.

Keywords: indigenous chickens, morphological variation, discriminant analysis

5.2 Introduction

The term “indigenous chicken” refers to an unimproved multipurpose type of chicken that is mostly reared under extensive and free range systems. They are considered to be gene reservoirs for adaptive traits in different conditions (Al-Atiyat, 2009; Ogah, 2013). They have the ability to adapt to different climates and to fight predators, and are resistant to diseases (Al-Atiyat, 2009). However, indigenous chickens are said to perform poorly compared to exotic breeds. This belief has resulted in the crossbreeding of indigenous breeds with those which are said to be highly productive in order to meet the demand for high performance. This has led to a loss of diversity in indigenous animals. Although they lack high productivity, they still make valuable contributions to rural communities. It is therefore important that they be conserved for future use.

Indigenous chickens are known to vary in terms of their phenotype (their morphological identity) (Aklilu *et al.*, 2013; Ogah, 2013). Phenotypic characterisation of these local chickens is a prerequisite for devising long-term management programmes. Understanding the extent of variation in morphological traits is called primary characterisation (Food and Organization, 2012). Phenotype is the observable and measurable nature of animals caused by environmental and genetic factors. Phenotypic variation is caused both by environmental and genotypic components (Besbes, 2009; Getu *et al.*, 2015). This variation may be the result of local adaptation and ecological character displacement (Ogah, 2013). Genetic variability reflects variation among animals in the population due to genetic differences in the population (Mavule, 2012b). Knowledge on phenotypic and genetic variation can aid in the sustainable use and conservation of livestock (Mtileni *et al.*, 2012; Ogah, 2013).

The use of the technique of multivariate discriminant analysis was recommended by the FAO in 2012 for phenotypic characterisation of indigenous chickens. This technique has been found to be more useful than univariate techniques as it considers all variables simultaneously when differentiating populations (Food and Organization, 2012; Getu *et al.*, 2015), it does not limit the number of variables (traits) to be monitored, and confirms the discriminating capacity. Al-Atiyat (2009) conducted a study using performance traits to discriminate indigenous chickens from other genotypes in Jordan. The researcher was able to differentiate indigenous chickens from other genotypes using morphometric traits. Yakubu (2011) employed canonical discriminant analysis to identify the most discriminating variable in the sexes of ducks using body weight and linear body measurements.

Studies on morphological variation have been conducted in areas of KwaZulu-Natal but they were based on small ruminants (Kunene, 2010; Mavule, 2012b). The studies were conducted to obtain information contributing to the conservation of Zulu sheep. There is limited information on indigenous chicken differentiation (classification) in different areas of KwaZulu-Natal. The objective of the study was to identify morphological variation among indigenous chickens in different communal areas in KwaZulu-Natal using discriminant analysis.

5.3 Materials and Methods

5.3.1 Data collection

Quantitative data was collected as described in Chapter 4. Measurements collected from 350 indigenous chickens included body weight (BW), back length (BaL), body length (BoL),breast circumference (BrC), neck length (NL), toe length (TL), shank length (SL) and shank circumference (SC). The following observed qualitative traits were also recorded: plumage colour, skin colour, shank colour, comb type, earlobe colour and eye colour.

5.3.2 Statistical analysis

The Statistical Package for Social Sciences version 20 (SPSS 2010) was used to analyse quantitative data. The univariate analysis of variance of the General Linear Model was used to compute the mean comparison for morphological characteristics for different populations. Tukey's method was used for pairwise comparisons of the mean. Crosstabs of the descriptive statistics was used to calculate frequencies for all the quantitative traits. Canonical discriminant analysis, which is a multivariate technique, was used for body weight and seven linear body measurements. The standardised discriminant function was used to screen the most discriminating traits among areas. The significance of the discriminant function was tested using Wilks Lambda. Bartlett's V transformation of Lambda was used to compute the significance of Lambda. Variables of Wilks Lambda between 0 and 1 were accepted. Unstandardised discriminant procedure was used to identify areas, and means were computed for each variable per area. Clusters that grouped indigenous chickens were therefore obtained using means, by the SPSS hierarchical cluster analysis.

5.4 Results

The frequencies of the qualitative traits observed among the indigenous chickens are presented in Table 5.1. A total of 10 plumage colour types was identified in the 6 areas of study. Each location in the 6 districts had different predominant plumage colours. Barred plumage colour was the abundant plumage in Cedara (65.2%), wheaten, golden laced and black plumage were the most predominant in Jozini (21.4%). In Ladysmith the most common plumages were crele and golden laced (19.6%). Black and golden laced were abundant at 20% in Empangeni. In Newcastle the golden laced was predominant (27.4%), in Pietermaritzburg crele was predominant (27.3%), and in Port Shepstone the most common was the golden laced at 30.4%. Other colours which were observed were blue breasted red, buff columbian, grey, red and white, as shown in Figure 5.1. Golden laced seemed to be the predominant plumage in all the locations except Cedara and Pietermaritzburg.

Three skin colours (white, pink and yellow) were observed. Most indigenous chickens in the different locations had yellow skin colour. The range of the frequency for this colour was 10% to 76.7%, followed by white skin colour (6.5 to 45.0%), except for the indigenous chicken population at Empangeni. The percentage of chickens with yellow skin colour observed in the different areas ranged from 42.9% to 76.7%. White skin colour ranged from 6.5% to 45% and pink skin ranged from 4.1% to 45%. Two eye colours were observed; orange and brown. Orange was common (average % of 96.3) in all the locations. Four earlobe colours were observed; red, black, red and white, red, and yellow. In all the locations red was the most common earlobe colour, ranging between 65% and 87%; brown was the least (0.6% to 2.4%). Three comb types were observed (single, pea and rose). The single comb (54%-100%) was the most common in all the locations, followed by the rose comb (2.4% -39.7%); the pea comb (2.6%-11.9%) was the least common. The shank colours observed were black, green, grey, white and yellow. Yellow was the most common in all the locations, followed by green, white. Black and grey were the least shank colours observed.

a) Barred b) Buff Columbian c) Golden laced

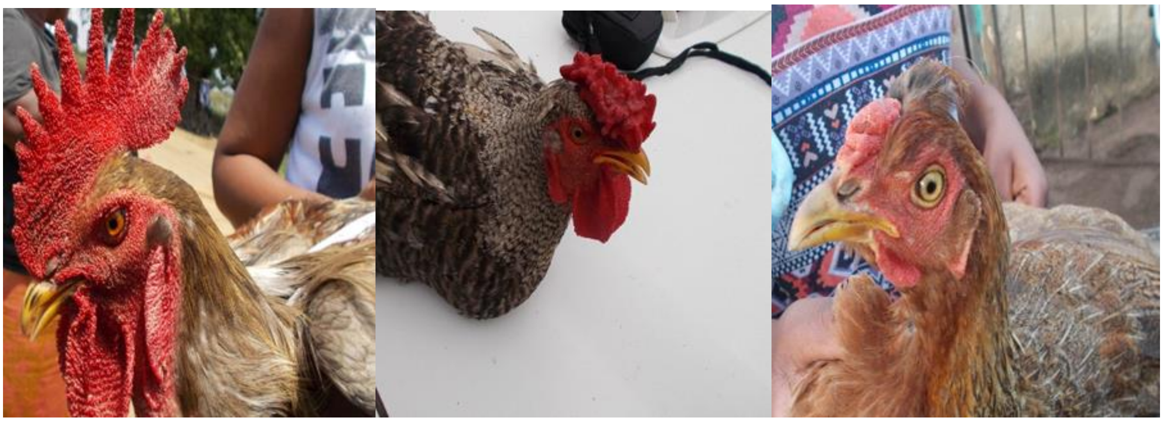
d) Black e) White f) Wheaten

g) Crele h) Grey j) Blue crested red

k) Red.

Figure 5. 1 Different plumage colours for indigenous chickens in areas of KwaZulu-Natal



a) Single b) Rose c) Pea

Figure 5. 2 Different type of combs for indigenous chickens in areas of KwaZulu-Natal

a) White b) Yellow c) Grey

d) Green e) Black

Figure 5. 3 Different shank colours for indigenous chickens in areas of KwaZulu-Natal.

Table 5. 1 Frequencies for qualitative traits of indigenous chicken populations in selected communal areas of KwaZulu-Natal

Traits	Type	Cedara	Jozini	Ladysmith	Empangeni	Newcastle	Pietermaritzburg	Port Shepstone	Total
Plumage colour	Barred	65.2	4.8	14.1	5.0	9.6	15.9	10.7	14.6
	Black	30.4	21.4	7.6	20.0	1.4	0.0	5.4	8.9
	Blue breasted red	0.0	0.0	4.3	10.0	5.5	2.3	3.6	3.7
	Blue laced	0.0	9.5	2.2	10.0	0.0	0.0	5.4	3.1
	Buff Colombian	0.0	11.9	9.8	5.0	26.0	6.8	12.5	12.6
	Crele	0.0	0.0	19.6	0.0	15.1	27.3	12.5	13.7
	Golden laced	0.0	21.4	19.6	20.0	27.4	13.6	30.4	21.1
	Red	0.0	2.4	3.3	15.0	5.5	0.0	3.6	3.7
	Wheaten	0.0	21.4	12.0	10.0	6.8	27.3	8.9	12.6
	White	4.3	7.1	7.6	5.0	2.7	6.8	7.1	6.0
Skin colour	Pink	17.4	33.3	29.3	45.0	4.1	6.8	14.3	19.4
	White	26.1	23.8	6.5	45.0	19.2	22.7	21.4	19.1
	Yellow	56.5	42.9	64.1	10.0	76.7	70.5	64.3	61.4
Shank colour	Black	0.0	9.5	2.2	5.0	0.0	0.0	1.8	2.3
	Green	13.0	28.6	7.6	20.0	19.2	27.3	5.4	15.7
	Grey	0.0	7.1	9.8	5.0	5.5	0.0	1.8	5.1
	White	4.3	9.5	23.9	15.0	5.5	6.8	17.9	13.4
	Yellow	82.6	45.2	56.5	55.0	69.9	65.9	73.2	63.4
Comb type	Double	0.0	11.9	0.0	0.0	0.0	0.0	7.1	2.6
	No	0.0	4.8	2.2	5.0	5.5	9.1	5.4	4.6
	Rose	0.0	2.4	21.7	5.0	39.7	36.4	7.1	20.3
	Single	100.0	81.0	76.1	90.0	54.8	54.5	80.4	72.6
Ear Lobe colour	Black	0.0	2.4	0.0	0.0	1.4	0.0	0.0	0.6
	No	0.0	4.8	0.0	5.0	0.0	0.0	0.0	0.9
	Red	87.0	76.2	83.7	65.0	89.0	86.4	73.2	81.7
	Red, white	13.0	14.3	6.5	30.0	4.1	9.1	12.5	10.0
	Red, yellow	0.0	2.4	9.8		5.5	4.5	14.3	6.9
Eye colour	Brown	0.0	16.7	0.0	5.0	4.1	2.3	1.8	3.7
	Orange	100.0	83.3	100.0	95.0	95.9	97.7	98.2	96.3

Table 5.2 presents the means of linear body measurements and body weights in the selected locations. Indigenous chickens in Jozini and Newcastle had higher body measurements while indigenous chickens in Empangeni measured the least for many traits. Variation in body size in different locations was observed, with the average body weight ranging between 1.67kg and 2.15kg. Diversity was found in some morphological traits such as body length, back length, shank circumference and toe length. Indigenous chickens at Jozini had longer body length (28.405±0.54) compared to other areas and it was similar to that of the populations in Pietermaritzburg, whereas Port Shepstone, Newcastle, Empangeni and Cedara had the least

body length and were statistically ($P>0.05$) similar. Jozini had the longest back length (43.94±0.97), similar to Ladysmith, Newcastle and Port Shepstone, whereas Empangeni had the shortest (38.61±1.12), but this was comparable to Cedara and Pietermaritzburg. Indigenous chickens from Jozini had large shank circumference (5.23±0.13). In Pietermaritzburg the chickens had the smallest shank circumference (4.03±0.08); and was similar to those in Cedara. Indigenous chickens from Empangeni had longest toe length (7.03±0.29) and had similar to toe length to the population in Jozini, whereas Port Shepstone had the shortest (5.19±0.09), similar to the toe length of chickens in Cedara.

Table 5. 2 Means and standard errors of different body measurements for indigenous chickens in different areas of KwaZulu-Natal

	Traits							
Areas	**BrC**	**NL**	**BW**	**BoL**	**BaL**	**ShC**	**T L**	**ShL**
Cedara	33.50±0.82[a]	10.78±0.33[a]	1.79±0.81[ab]	24.26±0.56[ab]	39.87±1.81[ab]	4.17±0.15[ab]	5.33±0.25[ab]	8.69±.32[a]
Jozini	33.92±0.62[a]	13.99±0.38[a]	2.15±0.11[b]	28.41±0.54[c]	43.94±0.97[c]	5.23±0.13[d]	6.46±0.21[de]	9.95±0.29[b]
Ladysmith	31.99±0.39[a]	12.03±0.18[a]	1.79±0.05[ab]	25.75±0.33[ab]	42.02±0.48[abc]	4.59±0.06[bc]	6.12±0.09[cd]	9.87±0.20[b]
Empangeni	31.40±0.81[a]	12.19±0.73[a]	1.72±0.10[a]	24.71±1.03[ab]	38.61±1.12[a]	4.82±0.16[cd]	7.03±0.29[e]	9.02±0.38[ab]
Newcastle	33.36±0.43[a]	12.11±0.28[a]	1.87±0.064[ab]	24.95±0.42[a]	42.60 ±0.58[bc]	4.75±0.09[c]	6.02±0.14[bcd]	8.96±0.18[ab]
Pietermaritzburg	32.00±0.58[a]	12.23±0.22[a]	1.67±0.07[a]	26.41±0.57[bc]	40.32±0.54[ab]	4.03±0.08[a]	5.58±0.13[abc]	9.11±0.21[ab]
Port Shepstone	33.02±0.57[a]	11.61±0.33[a]	1.74±0.80[a]	23.96±0.49[a]	41.536±0.64[abc]	4.82±0.09[cd]	5.19±0.09[a]	8.32±0.16[a]

Column means with different superscript are significantly $p<0.001$ different. Shank length (ShL), Toe length (TL), Shank circumference (ShC), Body length (BoL),Back length (BaL), Neck length (NL), Body weight (BW), Breast circumference (BrC).

Variation was observed in morphological traits. The data matrix was thus further subjected to canonical discriminant analysis for *post hoc* analysis. All eight variables were selected by stepwise discriminant procedure. These are presented in Table 5.3. All the selected variables were found to be significant in discriminating indigenous chickens.

Table 5. 3 Morphological traits that discriminate indigenous chickens from different locations in KwaZulu-Natal

	Tests of Equality of Group Means			
Function	Wilks' Lambda	F to enter	Sig. value	Tolerance
ShL	.927	4.498	.000	1.000
TL	.932	4.141	.000	1.000
ShC	.954	2.749	.013	1.000
BoL	.929	4.331	.000	1.000
BaL	.924	4.712	.000	1.000
NL	.968	1.891	.082	1.000
BW	.813	13.082	.000	1.000
BrC	.882	7.637	.000	1.000

Shank length (ShL), Toe length (TL), Shank circumference (ShC), Body length (BoL),Back length (BaL), Neck length(NL), Body weight (BW), Breast circumference (BrC).

The Mahalanobis distance matrix of indigenous chickens from different areas is presented in Table 5.4. All pairwise distances were highly significant (p<0.000). The greatest distance was between Empangeni and Jozini (53.23) while the shortest distance was between Port Shepstone and Newcastle (3.58). Jozini had the furthest distance to all other locations. The phenogram (Figure5.4) shows two main clusters: the first cluster formed by Newcastle, Port Shepstone and Cedara, the second cluster formed by Pietermaritzburg and Ladysmith. The second cluster was not far distant from the first cluster. Empangeni and Jozini individually joined the two clusters, although Jozini was far separated from the others.

Table 5. 4 Mahalanobis distance between the indigenous chicken populations of KwaZulu-Natal using morphological traits

	Proximity Matrix						
Case	**Absolute Squared Euclidean Distance**						
	Cedara	Jozini	Ladysmith	Empangeni	Newcastle	Pietermaritzburg	Port Shepstone
Cedara	.000						
Jozini	48.26	.000					
Ladysmith	12.88	18.90	.000				
Empangeni	11.58	53.23	14.73	.000			
Newcastle	10.61	19.07	3.74	20.92	.000		
Pietermaritzburg	9.42	26.99	4.57	8.91	10.00	.000	
Port Shepstone	4.35	36.55	7.97	15.92	3.58	10.28	.000

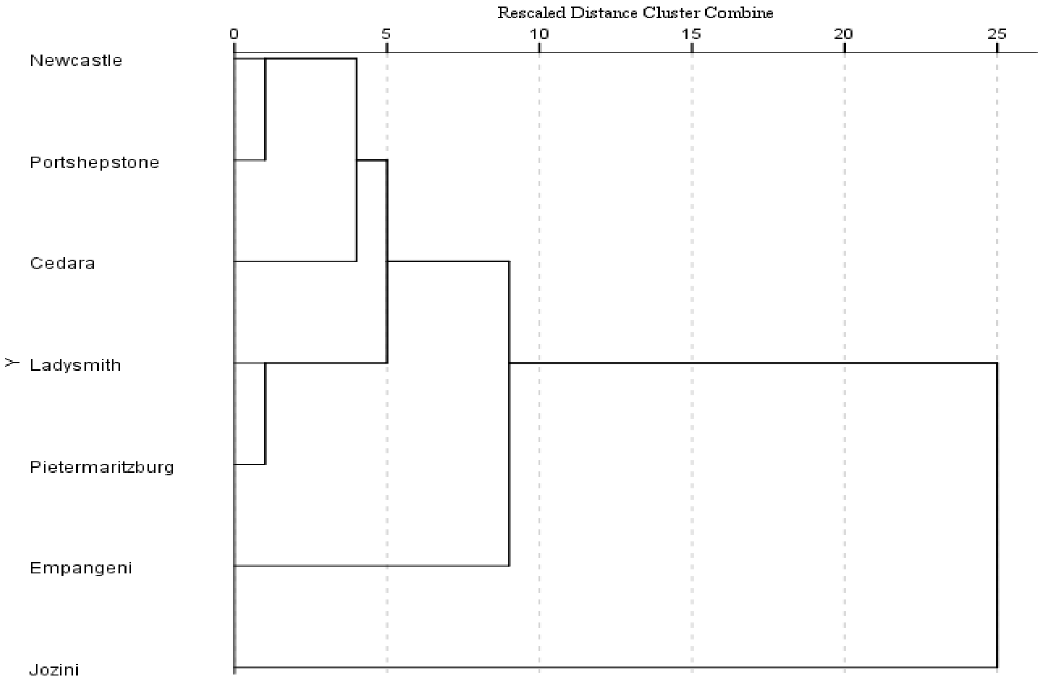


Figure 5. 4 Phenogram showing the relationship between indigenous chicken populations

Discriminant function analysis was able to correctly classify 51.1% of the indigenous chickens into their original populations. The results are presented in Table 5.5. Cedara had the highest percentage of correct classification (78.3%) whereas Newcastle had the lowest percentage of correct assignment (21.9%). A total of 27.4% of indigenous chickens were correctly classified for Port Shepstone but only 13.7% for Ladysmith and Jozini.

Table 5. 5 Predicted group membership using discriminant analysis on indigenous chickens from different communal areas of KwaZulu-Natal

Area	Empangeni	Jozini	Port Shepstone	Pietermaritzburg	Cedara	Newcastle	Ladysmith	Total
Empangeni	75.0	5.0	0.0	5.0	5.0	5.0	5.0	100.0
Jozini	4.8	42.9	14.3	9.5	4.8	4.8	19.0	100.0
Port Shepstone	1.8	5.4	62.5	10.7	5.4	5.4	8.9	100.0
Pietermaritzburg	0.0	0.0	9.1	75.0	2.3	0.0	13.6	100.0
Cedara	8.7	0.0	0.0	4.3	78.3	4.3	4.3	100.0
Newcastle	2.7	13.7	27.4	11.0	9.6	21.9	13.7	100.0
Ladysmith	6.5	7.6	13.0	8.7	10.9	5.4	47.8	100.0

5.5 Discussion

Phenotypes express genetic characteristics modified by environmental conditions. Researchers have reported that variance in genotypes and environment can affect phenotypic variance (Mavule, 2012b; Yakubu *et al.*, 2010a). Diversity in indigenous chickens has mostly been reported on with regard to immune responses to various diseases and reproduction performance (Mogesse, 2007a). Phenotypic diversity can be expected in different traits because of diverse agro-climates, socioeconomics and cultural considerations (Al-Atiyat, 2009; Mogesse, 2007a).

Variation in plumage colours has been a typical feature for characterising indigenous chickens in other parts of Africa (Dana *et al.*, 2010a). In the present study variation in plumage colour was observed. Such variation has been reported to be the result of artificial and natural selections (Duguma, 2006; Mogesse, 2007a). Variation in plumage colour is a form of adaptation to the living environment, such as camouflage against predators, and a breeding strategy (Dana *et al.*, 2010a). (Dana *et al.*, 2010a). The trichome pigment is related to indigenous chicken feather colours and is considered to be indicative of genetic differences among certain plumage colours (Dana *et al.*, 2010a). Some of the plumage colours obtained in the present study are in agreement with the findings of studies conducted in Ethiopia where red, white, greyish, black , and a mixture of colours referred to as wheaten in this study were observed. Different plumage colours are usually obtained as a result of pigmentation differences which are attributable to melanin (Dana *et al.*, 2010a).

Variation observed in skin colour occurs as the result of the presence or absence of carotenoid pigments where yellow indicates the presence of carotenoids and white the absence. The presence of carotenoids normally depends on the type of feed given to indigenous chickens. Indigenous chickens that are provided with yellow maize usually possess a high level of carotenoids. According to Dana *et al.* (2010a) yellow skin colour is associated with the adaptive fitness of an indigenous chicken, which reflects the health and nutritional status and the foraging efficiency of the indigenous chicken. Genetically, indigenous chickens with yellow skin colour are homozygous for the recessive allele which inhibits the expression of the beta-carotene dioxygenase 2 enzyme. White skin carries the dominant allele (Aklilu *et al.*, 2013) .

Current findings on eye colours are similar to results obtained by Aklilu *et al.* (2013) in indigenous chickens from Ethiopia. These authors reported orange eye colour as predominant and brown as the least. The variation observed in eye colour depends on the carotenoid pigments and blood supply to eye structures (Aklilu *et al.*, 2013). Red earlobes were found to be common in all the locations (65% to 89%), followed by white (6.5% to 30%), with black and red/yellow appearing to a lesser degree. Other researchers in Ethiopia have reported red earlobes as dominant in indigenous chickens (Melesse and Negesse, 2011). The proportion of white earlobes reported in the present study is lower than the findings of Duguma (2006) in western and eastern parts of Ethiopia and those reported by Egahi *et al.* (2010) in Nigeria. Similar proportions of red and white earlobes were reported by Ssewannyana *et al.* (2008), according to whom earlobe colour is a breed -specific trait.

Comb type occurs as the result of the interaction of genes but its size is associated with gonadal development and light intensity (Tabassum *et al.*, 2015). Three comb types were observed in the present study (single, rose and pea). Indigenous chickens with single comb type have been reported by several researchers (Aklilu *et al.*, 2013; McAinsh *et al.*, 2004; Mogesse, 2007a). The high percentage of single comb type is in agreement with the findings of Liyanage *et al.* (2015) in Sri Lanka but different to the findings of Dana *et al.* (2010a) in Ethiopia where a higher percentage of pea comb type was reported. Variation in comb types may be attributed to differences in the allele frequency responsible for comb type and interaction of the genes responsible for its expression (Liyanage *et al.*, 2015). The single comb type is most common in tropical regions. Incidentally, single comb helps to reduce body heat by about 40% (Liyanage *et al.*, 2015).

The large number of chickens with yellow shank colour observed is in agreement with the findings of Dana *et al.* (2010a). The frequency result of white shank colour (23.9%) is similar to the 28% and 29.1% reported by Dana *et al.* (2010a) and Melesse and Negesse (2011), respectively. The absence of melanin pigments due to the carotenoid pigment in the epidermis results in the yellow colour of the shanks, whereas their presence results in the black colour of the shanks. Green occurs as a result of the combination of black and yellow pigments (Guni and Katule, 2013) In the absence of both yellow and black pigments white is most likely to be observed. Some researchers have reported white shank colour as a result of shortage in scavengable feed resources (Dana *et al.*, 2010a; Melesse and Negesse, 2011).

The average body weight ranged from 1.67 kg to 2.15 kg, similar to the findings of 1.4kg to 2.1kg reported by Ssewannyana *et al.* (2008) in Uganda, and Melesse and Negesse (2011) in the southern region of Ethiopia respectively. A weight of 1.69kg was observed in the highlands of Ethiopia and a 2.05kg average weight in the north west of Ethiopia (Aklilu *et al.*, 2013). However, indigenous chickens in Jarso and Horro districts in Ethiopia had lower weights (1.29 and 1.12 kg) (Aklilu *et al.*, 2013). Variation in phenotype may reflect variation in genes. These results revealed variation in indigenous chickens' qualitative traits. This suggests the availability of genetic improvement through selection of indigenous chicken resources. The shank length range of 8.32cm to 9.95cm was within the range of Melesse and Negesse (2011). Shank length is regarded as a good indicator of skeletal development, which relates to the amount of meat a chicken can carry (Ingram *et al.*, 2000).

Variation in morphological traits has been estimated by some researchers using multivariate discriminant analysis. Discriminant analysis can be defined as a body of procedures that maximises differences between groups which at first seem intermingled with each other (Yakubu, 2011). Shank length, toe length, shank circumference, body length, back length, neck length, body weight and breast circumference were identified as being more powerful in discriminating indigenous chicken populations. This suggests that these body measurements can better differentiate indigenous chicken populations without having to measure all the body measurements of an indigenous chicken. Body weight was identified as the most discriminating variable. These findings are similar to the results obtained by Ogah (2013) where body weight and body width were identified as the most discriminating variables. Shank length as the discriminating variable is in line with the findings of Getu *et al.* (2015).

The low differentiation obtained between Newcastle and Ladysmith populations and Pietermaritzburg and Ladysmith using Mahalanobis distance did not give enough statistical support to separate their indigenous chickens as different breeds. The results could indicate that these indigenous chickens are not different breeds even though morphological variations were observed. The classification result of indigenous chickens to their location was 51.1%, which confirmed low differentiation among populations. A reasonable reflection of the overall genetic performance can be obtained if phenotypic observations are based on a large enough sample size and morphological traits measured show significant difference among populations (Mavule, 2012b). The results obtained in this study could be due to the gene flow of indigenous chickens in close proximity to each other (Ladysmith and Newcastle).

The large distances obtained between Jozini and all other locations (Empangeni, Pietermaritzburg, Port Shepstone, Newcastle and Cedara) shows morphological diversity. This could be associated with environmental conditions inferring the considerable genetic variability. Maintaining genetic variability is crucial in order to continue improving the ability to adapt to changes in climate and diseases while improving the livelihoods of indigenous chicken farmers. The genetic variation observed could be very important to indigenous chicken farmers as a resource to be drawn upon to select indigenous chickens and develop new breeds. Genetically diverse populations provide a greater range of options for the future, whether associated with environmental changes, emerging diseases threats, new knowledge of human nutritional requirements or fluctuation in market conditions and changing societal needs (Rege and Gibson, 2003).

5.6 Conclusion

The findings show variation in morphological traits in indigenous chicken populations. These variations enable indigenous chickens to survive in different environmental conditions. The variations obtained can be used for improvement of indigenous chickens in different areas depending on traits preferred by farmers because there are specific choices for plumage and skin colours that affect preferences of different markets around the world. Variation in body weight observed in different locations can be used to improve body size by exchanging or selecting cocks from areas with indigenous chickens with large body weights such as Jozini. Most populations were predominantly characterised by yellow skin colour, a trait that reflects the adaptive fitness of indigenous chickens in extensive environments.

CHAPTER 6: GENERAL DISCUSSION

The objectives of the study were to characterise indigenous chicken production systems in communal areas of KwaZulu-Natal, predict body weight from linear body measurements of indigenous chickens using principal component analysis, and identify variation caused by morphological traits among the indigenous chickens in different locations using discriminant analysis.

Farmers in surveyed areas raise indigenous chickens for home consumption and emergent cash needs. They are not very much concerned with the number of chickens produced. Rather, food security was an important reason for keeping the chickens. The most commonly practised production systems in the surveyed areas were the semi-intensive and extensive production systems. Indigenous chickens are reared under poor management conditions. None of the farmers had proper designated housing for the indigenous chickens. They had poorly constructed houses which were not efficient in protecting indigenous chickens from predators and theft. Women play the major role in rearing indigenous chickens using their local knowledge while men only take part in construction of houses using any local available material. The results obtained from the survey indicate that there is a gap in terms of management of indigenous chickens and there is less concern among the farmers in terms of the survival of indigenous chickens for future purposes.

Formal training on production and management of indigenous chickens should be provided to women, as it would help them improve their knowledge and also improve household and community living standards. The use of indigenous chickens as a source of meat and eggs was highly ranked by farmers, followed by their function as a source of income. However, there is an absence of formal markets for indigenous chickens. This suggests a necessity to explore the possibilities of organised marketing so that farmers can make more income from the indigenous chickens they rear.

Farmers reported the use of ethno-veterinary practices for curing and preventing of diseases. More research needs to be done on ethno-veterinary practices used by farmers to check their effectiveness on chickens. In order to ensure a high rate of indigenous chicken survival, and the prevention and elimination of diseases, veterinary officers should enforce strict adherence to vaccination programmes to mitigate diseases such as Newcastle disease. There should also be training on all aspects of indigenous chicken husbandry for rural farmers.

Body weight is the trait of most economic importance in rural areas as indigenous chickens are priced based on it. Body weight was predicted from different linear measurements. Breast circumference had a high correlation with body weight, which suggests that breast circumference can be used to predict body weight in the absence of weighing scales in rural areas. The results suggest that body weight of indigenous chickens can be predicted using linear body measurements because the increase in any linear body measurement leads to an increase in body weight.

Estimating the weight can help farmers give indigenous chickens appropriate prices if they decide to put their chickens on a market because body weight is the trait of most economic importance in rural areas. The strong relationship existing between body weight and body measurements may be useful as a selection criterion, since positive correlations of traits suggest that the traits are under the same gene action (Pleiotropy). This, therefore, provides a basis for the genetic manipulation and improvement of indigenous stock. Principal component analysis was used to determine the variability of individual traits and how each trait contributes towards the morphostructural variance of indigenous chicken to understand the type of traits that can best be improved through selection. The measurements associated with principal component 1 (BoL, BrC and ShC) were highly associated with body shape, while measurements associated with Principal Component 2 (Shank length (ShL), toe length (TL) and (BaL) were highly associated with body size. These extracted parameteres could be used in breeding and selection programmes to obtain well-structured indigenous chicken bodies using fewer measurements.

The study revealed variations in indigenous chickens' qualitative traits. This suggests the availability of the potential for selection of preferred qualitative traits of indigenous chicken resources for breeding. The fact that neck length, shank circumference, toe length, shank length, back length and body length are powerful in discriminating indigenous chicken populations indicate that these body measurements can better differentiate indigenous chicken populations. The longer Mahalanobis distances obtained between the different areas demonstrate morphological diversity. This may be associated with environmental conditions or it could indicate genetic variation caused by adaptation in these areas. Maintaining this genetic variability is crucial to continue improving the ability to adapt to current conditions. Moreover, the phenotypic variation in combination with genetic information could form a powerful tool for the promotion of effective conservation and utilisation of indigenous chicken genetic resources**.** .

6.1 Conclusion and Recommendations.

The study shows that farmers use indigenous chickens for consumption and as a source of income if there is an emergent need and yet they rely on that income for their needs. Farmers need to be assisted on how they can produce indigenous chickens commercially to ensure a continual source of income. The semi-intensive system is the most common production system in surveyed communal areas, with poorly constructed shelter (pens) from any local material. Farmers need to provide proper shelter for their indigenous chickens to prevent theft and predation. Indigenous chickens obtain feed by scavenging, and they are sometimes given supplements, but farmers need to ensure that indigenous chickens get sufficient feed by providing indigenous chickens with extra supplements. They could even grow maize for their chickens. Newcastle disease is the major challenge in indigenous chicken production systems. Provision of health services to rural farmers and technical training through veterinary boards is necessary. More intervention from different agricultural departments and extension services are needed to help farmers mitigate challenges associated with production systems. Body weight is an important trait for rural farmers because it is highly associated with body size. The prediction equation obtained will help rural farmers estimate accurate body weight using linear body measurements without going to the expense of buying scales. Under farm conditions breast circumference and body weight can be combined in a multiple regression equation to predict the body weight of indigenous chickens accurately. Indigenous chicken populations vary in some of their morphological traits. Variations observed in morphological traits in different locations can be used to improve indigenous chickens through exchange of indigenous chickens with traits preferred by farmers in different locations. This can be useful for selection.

REFERENCES

Abdelqader, A., C. Wollny, and M. Gauly. 2007. Characterization of local chicken production systems and their potential under different levels of management practice in Jordan. *Tropical Animal Health and Production* 39: 155-164.

Aini, I. 1990. Indigenous chicken production in South-east Asia. World's Poultry Science Journal 46: 51-57.

Ajayi, O. O., M. A. Adeleke, M. T. Sanni, A. Yakubu, S. O. Peters, I. G. Imumorin, M. O. Ozoje, C. O. N. Ikeobi, and O. A. Adebambo. 2012. Application of principal component and discriminant analyses to morpho-structural indices of indigenous and exotic chickens raised under intensive management system. Tropical Animal Health and Production 44: 1247-1254.

Aklilu, E., K. Kebede, T. Dessie, and B. AK. 2013. Phenotypic Characterization of Indigenous Chicken Population in Ethiopia. International Journal of Morphology 1: 24-32.

Aklilu, H., H. Udo, C. Almekinders, and A. Van der Zijpp. 2008. How resource poor households value and access poultry: Village poultry keeping in Tigray, Ethiopia. Agricultural Systems 96: 175-183.

Al-Atiyat, R. 2009. Diversity of chicken populations in Jordan determined using discriminate analysis of performance traits. International Journal of Agriculture and Biology 11: 374-380.

Al-Qamashoui, B., O. Mahgoub, I. Kadim, and E. Schlecht. 2014. Towards conservation of Omani local chicken: phenotypic characteristics, management practices and performance traits. Asian-Australiasian Journal of Animal Sciences 27: 767.

Asgedom, A. H. 2007. Village poultry in Ethiopia: socio-technical analysis and learning with farmers http://edepot.wur.nl/31478, WUR Wageningen UR.

Assan, N. 2015. Methodology and factors influencing the association of body weight, performance parameters with linear body measurements assessment in poultry. Scientific Journal of Pure and Applied Sciences 4: 200-210.

Besbes, B. 2009. Genotype evaluation and breeding of poultry for performance under sub-optimal village conditions. World's Poultry Science Journal 65: 260-271.

Cuesta, M. 2008. Pictorial guidance for phenotypic characterization of chickens and ducks, GCP/RAS/228/GER Working Paper.

Dana, N., T. Dessie, L. H. van der Waaij, and J. A. van Arendonk. 2010a. Morphological features of indigenous chicken populations of Ethiopia. Animal genetic resources 46: 11-23.

Dana, N., L. H. van der Waaij, T. Dessie, and J. A. van Arendonk. 2010b. Production objectives and trait preferences of village poultry producers of Ethiopia: implications for designing breeding schemes utilizing indigenous chicken genetic resources. Tropical Animal Health and Production 42: 1519-1529.

Dana, N., E. Vander Waaij, and J. A. van Arendonk. 2011. Genetic and phenotypic parameter estimates for body weights and egg production in Horro chicken of Ethiopia. Trop Anim Health Prod 43: 21-28.

de Componentes, A. d. A. F., and P. en la Cuantificación. 2009. Application of principal component factor analysis in quantifying size and morphological indices of domestic rabbits. International Journal of Morphology 27: 1013-1017.

De Marchi, M., C. Dalvit, C. Targhetta, and M. Cassandro. 2006. Assessing genetic diversity in indigenous Veneto chicken breeds using AFLP markers. Animal genetics 37: 101-105.

Dessie, T., T. Taye, N. Dana, W. Ayalew, and O. Hanotte. 2011. Current state of knowledge on phenotypic characteristics of indigenous chickens in the tropics. World's Poultry Science Journal 67: 507-516.

Duguma, R. 2006. Phenotypic characterization of some indigenous chicken ecotypes of Ethiopia. Red 19: 21-25.

Egahi, J., N. Dim, O. Momoh, and D. Gwaza. 2010. Variations in qualitative traits in the Nigerian local chicken. International Journal of Poultry Science 9: 978-979.

Egena, S., A. Ijaiya, and R. Kolawole. 2014a. An assessment of the relationship between body weight and body measurements of indigenous Nigeria chickens (Gallus gallus domesticus) using path coefficient analysis. Livestock Research for Rural Development 26.

Egena, S., A. Ijaiya, D. Ogah, and V. Aya. 2014b. Principal component analysis of body measurements in a population of indigenous Nigerian chickens raised under extensive management system. Slovak journal of Animal Science 47: 77-82.

Food, and A. Organization. 2012. Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines Rome, Italy.

Gandini, G., L. Ollivier, B. Danell, O. Distl, A. Georgoudis, E. Groeneveld, E. Martyniuk, J. Van Arendonk, and J. Woolliams. 2004. Criteria to assess the degree of endangerment of livestock breeds in Europe. Livestock Production Science 91: 173-182.

Getu, A. 2014. Review on Ethiopian poultry origin, domestication, classification and characterization of its production systems. Middle East journal of Scientific Research 22: 1025-1032.

Getu, A., K. Alemayehu, and Z. Wuletaw. 2015. Canonical Analysis for Assessment of Genetic Diversity of Three Indigenous Chicken Ecotypesin North Gondar Zone, Ethiopia. Iranian Journal of Applied Animal Science 4: 871-876.

Grobbelaar, J., B. Sutherland, and N. Molalakgotla. 2010. Egg production potentials of certain indigenous chicken breeds from South Africa. Animal Genetic Resources/Ressources génétiques animales/Recursos genéticos animales 46: 25-32.

Gueye, E., A. Ndiaye, and R. Branckaert. 1998. Prediction of body weight on the basis of body measurements in mature indigenous chickens in Senegal. Livestock Research for Rural Development 10: 1998.

Guni, F., and A. Katule. 2013. Characterization of local chickens in selected districts of the Southern Highlands of Tanzania: I. Qualitative characters. Livestock Research for Rural Development 25.

Habte, M., N. Ameha, and S. Demeke. 2013. Production performance of local and exotic breeds of chicken at rural household level in Nole Kabba Woreda, Western Wollega, Ethiopia. African Journal of Agricultural Research 8: 1014-1021.

Hall, S. J., and D. G. Bradley. 1995. Conserving livestock breed biodiversity. Trends in Ecology Evolution 10: 267-270.

Hassaballah, K., V. Zeuh, R. A. Lawal, O. Hanotte, and M. Sembene. 2015. Diversity and Origin of Indigenous Village Chickens (Gallus gallus) from Chad, Central Africa. Advances in Bioscience and Biotechnology 6: 592.

Hassen, H., F. Neser, A. De Kock, and E. van Marle-Köster. 2009. Study on the genetic diversity of native chickens in northwest Ethiopia using microsatellite markers. African Journal of Biotechnology 8.

Hoffmann, I. 2009. The global plan of action for animal genetic resources and the conservation of poultry genetic resources. World's Poultry Science Journal 65: 286-297.

Ingram, D., L. Hattens III, and B. McPherson. 2000. Effects of light restriction on broiler performance and specific body structure measurements. Journal of Applied Poultry Research 9: 501-504.

Kingori, A., A. Wachira, and J. Tuitoek. 2010. Indigenous chicken production in Kenya: A review. International Journal of Poultry Science 9: 309-316.

Kohler-Rollefson, I. 2000. Management of animal genetic diversity at community level. GTZ.

Kugonza, D. R., C. C. Kyarisiima, and A. Iisa. 2004. Indigenous chicken flocks of Eastern Uganda: I. Productivity, management and strategies for better performance.

Kunene, N. W. 2010. Characterisation of indigenous Zulu (Nguni) sheep for utilisation, improvement and conservation.

Kusina, J., N. Kusina, and J. Mhlanga. 2001. A survey on village chicken losses: causes and solutions as perceived by farmers. In: ACIAR PROCEEDINGS. p 148-155.

Lanari, M. R., H. Taddeo, E. Domingo, M. P. Centeno, and L. Gallo. 2003. Phenotypic differentiation of exterior traits in local Criollo goat population in Patagonia (Argentina). Archiv fur Tierzucht Dummerstorf 46: 347-356.

Liyanage, R., C. Dematawewa, and G. Silva. 2015. Comparative study on morphological and morphometric features of village chicken in Sri Lanka. Tropical Agricultural Research 26.

Mammo, M., T. Berhan, and D. Tadelle. 2008. Village chicken characteristics and their seasonal production situation in Jamma District, South Wollo, Ethiopia. Livestock Research for Rural Development 20.

Mapiye, C., M. Mwale, J. Mupangwa, M. Chimonyo, R. Foti, and M. Mutenje. 2008. A research review of village chicken production constraints and opportunities in Zimbabwe. Asian-Australiasian Journal of Animal Sciences 21: 1680-1688.

Mavule, B. S. 2012a. Phenotypic characterization of Zulu sheep: implications for conservation and improvement, University of Zululand.

Mavule, B. S. 2012b. Phenotypic characterization of Zulu sheep: implications for conservation and improvement http://hdl.handle.net/10530/1253, University of Zululand.

McAinsh, C. V., J. Kusina, J. Madsen, and O. Nyoni. 2004. Traditional chicken production in Zimbabwe. World's Poultry Science Journal 60: 233-246.

Melesse, A., and T. Negesse. 2011. Phenotypic and morphological characterization of indigenous chicken populations in southern region of Ethiopia. Animal Genetic Resources/Ressources génétiques animales/Recursos genéticos animales 49: 19-31.

Mendes, M. 2009. Multiple linear regression models based on principal component scores to predict slaughter weight of broiler. Archiv für Geflügelkunde 73: 139-144.

Mendes, M. 2011. Multivariate multiple regression analysis based on principal component scores to study relationships between some pre-and post-slaughter traits of broilers. Tarim Bilimleri Dergis-Journal of Agricultural Science 17: 77-83.

Milla, A. P., M. Mahagoub, and I. Bushara. 2012. Estimation of live body weight from heart girth, body length and condition score in Nilotic cattle–Southern Sudan. Journal of Animal Science Advances 2: 453-457.

Mngonyama, M. B. A. 2012. Morphometric Characteristics and Consumer Acceptability of Meat from Potchefstroom Koekoek, Black Australorp, Venda and Ovambo Chickens, University of KwaZulu-Natal, Pietermaritzburg.

Moela, A. K. 2014. Assessment of the relationship between body weight and body measurement in indigenous goats using path analysis, University of Limpopo, Turfloop Campus.

Mogesse, H. H. 2007a. Phenotypic and genetic characterization of indigenous chicken populations in Northwest Ethiopia, University of Free State.

Mogesse, H. H. 2007b. Phenotypic and genetic characterization of indigenous chicken populations in Northwest Ethiopia. Unpublished PhD Thesis, University of the Free State, Bloemfontein, South Africa.

Moreda, E., H. Singh, T. Sisaye, and A. M. Johansson. 2014. Phenotypic Characterization of Indigenous Chicken Population in South West and South Part of Ethiopia. British Journal of Poulry Science 3: 15-19.

Mtileni, B., F. Muchadeyi, A. Maiwashe, M. Chimonyo, and K. Dzama. 2012. Conservation and utilisation of indigenous chicken genetic resources in Southern Africa. World's Poultry Science Journal 68: 727-748.

Mtileni, B., F. Muchadeyi, A. Maiwashe, M. Chimonyo, E. Groeneveld, S. Weigend, and K. Dzama. 2011. Diversity and origin of South African chickens. Poultry Science 90: 2189-2194.

Mtileni, B., F. Muchadeyi, A. Maiwashe, P. Phitsane, T. Halimani, M. Chimonyo, and K. Dzama. 2009. Characterisation of production systems for indigenous chicken genetic resources of South Africa. Applied Animal Husbandry & Rural Development 2: 18-22.

Mtileni, B., F. Muchadeyi, S. Weigend, A. Maiwashe, E. Groeneveld, L. Groeneveld, M. Chimonyo, and K. Dzama. 2010. A comparison of genetic diversity between South African conserved and field chicken populations using microsatellite markers. South African Journal of Animal Science 40: 462-466.

Muchadeyi, F., H. Eding, H. Simianer, C. Wollny, E. Groeneveld, and S. Weigend. 2008. Mitochondrial DNA D-loop sequences suggest a Southeast Asian and Indian origin of Zimbabwean village chickens. Animal Genetics 39: 615-622.

Muchadeyi, F., S. Sibanda, N. Kusina, J. Kusina, and S. Makuza. 2004. The village chicken production system in Rushinga District of Zimbabwe. Livestock Research for Rural Development 16: 2004.

Muchadeyi, F., S. Sibanda, N. Kusina, J. Kusina, and S. Makuza. 2005. Village chicken flock dynamics and the contribution of chickens to household livelihoods in a smallholder farming area in Zimbabwe. Tropical Animal Health and Production 37: 333-344.

Muchadeyi, F., C. Wollny, H. Eding, S. Weigend, S. Makuza, and H. Simianer. 2007. Variation in village chicken production systems among agro-ecological zones of Zimbabwe. Tropical Animal Health and Production 39: 453-461.

Mwacharo, J., G. Bjørnstad, J. Han, and O. Hanotte. 2013. The history of African village chickens: an archaeological and molecular perspective. African Archaeological Review 30: 97-114.

Mwale, M., and P. Masika. 2009. Ethno-veterinary control of parasites, management and role of village chickens in rural households of Centane district in the Eastern Cape, South Africa. Tropical Animal Health and Production 41: 1685-1693.

Ogah, D. 2011. Assessing size and conformation of the body of Nigerian indigenous turkey. Slovak Journal of Animal Science 44: 21-27.

Ogah, D. 2013. Canonical discriminant analysis of morphometric traits in indigenous chicken genotypes. Trakia Journal of Sciences 2: 170-174.

Ogah, D., A. Alaga, and M. Momoh. 2009. Principal component factor analysis of the morphostructural traits of Muscovy duck. International Journal of Poultry Science 8: 1100-1103.

Okeno, T. O., A. K. Kahi, and K. J. Peters. 2012. Characterization of indigenous chicken production systems in Kenya. Tropical Animal Health and Production 44: 601-608.

Padhi, M. K. 2016. Importance of Indigenous Breeds of Chicken for Rural Economy and Their Improvements for Higher Production Performance. Scientifica 2016.

Petrus, N. P. 2011. Characterisation and production performance of indigenous chickens in northern Namibia regions.

Raji, A., J. Igwebuike, and M. Usman. 2009. Zoometrical body measurements and their relation with live weight in matured local Muscovy ducks in Borno State, Nigeria. ARPN Journal of Agricultural and Biological Science 4: 58-62.

Razafindraibe, H., V. A. Mobegi, S. C. Ommeh, G. Bjørnstad, O. Hanotte, and H. Jianlin. 2008. Mitochondrial DNA origin of indigenous malagasy chicken. Annals of the New York Academy of Sciences 1149: 77-79.

Rege, J., and J. Gibson. 2003. Animal genetic resources and economic development: issues in relation to economic valuation. Ecological Economics 45: 319-330.

Rege, J., and A. Okeyo. 2006. Improving our knowledge of tropical indigenous animal genetic resources.

Rischkowsky, B., and D. Pilling. 2007. The state of the world's animal genetic resources for food and agriculture. Food & Agriculture Org.

Rolf, M. M., J. F. Taylor, R. D. Schnabel, S. D. McKay, M. C. McClure, S. L. Northcutt, M. S. Kerley, and R. L. Weaber. 2010. Impact of reduced marker set estimation of genomic relationship matrices on genomic selection for feed efficiency in Angus cattle. BMC genetics 11: 24.

Rotimi, E., J. Egahi, and A. Adeoye. 2016. Phenotypic characterization of indigenous chicken population in Gwer-West, Benue State, Nigeria. World Scientific News 53: 343-353.

Semakula, J., P. Lusembo, D. Kugonza, D. Mutetikka, J. Ssennyonjo, and M. Mwesigwa. 2011. Estimation of live body weight using zoometrical measurements for improved marketing of indigenous chicken in the Lake Victoria basin of Uganda.

Shahin, K. A., and N. Hassan. 2000. Sources of shared variability among body shape characters at marketing age in New Zealand White and Egyptian rabbit breeds. In: Annales de zootechnie. p 435-445.

Silva, P., X. Guan, O. Ho-Shing, J. Jones, J. Xu, D. Hui, D. Notter, and E. Smith. 2009. Mitochondrial DNA-based analysis of genetic variation and relatedness among Sri Lankan indigenous chickens and the Ceylon junglefowl (Gallus lafayetti). Animal genetics 40: 1-9.

Ssewannyana, E., A. Ssali, T. Kasadha, M. Dhikusooka, P. Kasoma, J. Kalema, B. Kwatotyo, and L. Aziku. 2008. On-farm characterization of indigenous chickens in Uganda. Journal of Animal and Plant Sciences 1: 33-37.

Tabassum, F., M. Hoque, F. Islam, C. Ritchil, M. Faruque, and A. Bhuiyan. 2015. Phenotypic and Morphometric characterization of indigenous chickens at Jhenaigati upazila of Sherpur district in Bangladesh. SAARC Journal of Agriculture 12: 154-169.

Tarwireyi, L., and M. Fanadzo. 2013. Production of indigenous chickens for household food security in rural KwaZulu-Natal, South Africa: a situational analysis. African Journal of Agricultural support 8: 5832-5840.

Tixier-Boichard, M., A. Bordas, and X. Rognon. 2009. Characterisation and monitoring of poultry genetic resources. World's Poultry Science Journal 65: 272-285.

Udeh, I., and C. Ogbu. 2011. Principal component analysis of body measurements in three strains of Broiler chicken. Science World Journal 6: 11-14.

Van Marle-Koster, E., and L. Nel. 2000. Genetic characterization of native southern African chicken populations: evaluation and selection of polymorphic microsatellite markers. South African Journal of Animal Science 30: 1-6.

Wethli, E. 2003. The importance of rural village chicken production. Poultry Bulletin (South Africa).

Ya-Bo, Y., W. Jin-Yu, D. Mekki, T. Qing-Ping, L. Hui-Fang, G. Rong, G. Qing-Lian, Z. Wen-Qi, and C. Kuan-Wei. 2006. Evaluation of genetic diversity and genetic distance between twelve Chinese indigenous chicken breeds based on microsatellite markers. International Journal of Poultry. Science 5: 550-556.

Yakubu, A. 2011. Discriminant analysis of sexual dimorphism in morphological traits of African Muscovy ducks. Archivos de zootecnia 60: 1115-1123.

Yakubu, A., K. Idahor, H. Haruna, M. Wheto, and S. Amusan. 2010a. Multivariate analysis of phenotypic differentiation in Bunajiand Sokoto Gudalicattle. Acta Agriculturae Slovencia 96: 75.

Yakubu, A., D. Kuje, and M. Okpeku. 2009. Principal components as measures of size and shape in Nigerian indigenous chickens. Thai Journal of Agricultural Science 42: 167-176.

Yakubu, A., A. Salako, I. Imumorin, A. Ige, and M. Akinyemi. 2010b. Discriminant analysis of morphometric differentiation in the West African Dwarf and Red Sokoto goats. South African Journal of Animal Science 40: 381-387.

APPENDIX

University of Zululand

Characterisation of Production systems of Indigenous Chickens in communal areas of KwaZulu-Natal.

Questionnaire for survey in chapter three

Name of the enumerator ______________ Region _______________

Farmer's name ________________ Communal area _____________

Date of interview ______________________

SOCIO-ECONOMIC CHARACTERISTICS

1. Sex and age of the respondent

a. Male b. Female

2. Age----------------

3. Educational level of the respondent

a. Illiterate b. Read & write

4. General income in rands per month

a. < 500 b.500-1000 c. >1000

5. Which specific type of indigenous chickens do you keep?

a. Ovambo ☐ b.Venda, ☐ c. Potchefstroom koekoek ☐ d. Naked neck ☐ e. All ☐

6 What is your reason for rearing that type of indigenous chicken?

a. Early maturity ☐ b. Good mothering ability ☐ c. Produces high number of eggs ☐

SELLING OF INDIGENOUS CHICKENS

1. Do you sell your indigenous chickens?

Yes ☐ No ☐

2. If yes, what determines your selling of chickens?

a. Need arises ☐ b. Demand by customers ☐ c. Preference by customers ☐

3. Which chickens do you sell?

a. Chicks ☐ b. Cock ☐ c. Hen ☐ d. All ☐

4. Do you have a specific age when you sell your indigenous chickens? Yes ☐ No ☐

If yes, at what age----------------Why?---------------------------------

5. Do you have the specific weight when selling your indigenous chickens? Yes ☐ No ☐

If yes, at what weight? --------------Why? -------------------------------------

6. How much do you obtain from selling your indigenous chickens per month?

a. <500 ☐ b.500-1000 ☐ c. >1000 ☐

7. Do you keep records for your indigenous chickens? Yes ☐ No ☐

8. If yes, has their number from last year Increased ☐ or Decreased ☐

9. If it has decreased, what do you think are the causes for the decrease?

a. Exposure to predators ☐ b. Theft ☐ c. Diseases ☐

10. What plans do you have to prevent the decrease of your indigenous chickens?

----

11. What are your future plans for rearing indigenous chickens?

a. Selling them to Companies ☐ b. Use them for food processing ☐ c. Home ☐ consumption

12. Where do you source all your indigenous chickens?

a. From hatching eggs ☐ b. Inheritance ☐ c. Gift from neighbours ☐ d. Purchase ☐

13. How many chickens did you use as the initial stock?

----

14. Do you know anything about breeding? Yes ☐ No ☐

15. Do you know any effect of inbreeding? Yes ☐ No ☐

16. Do you have any system in place to avoid inbreeding? Yes ☐ No ☐

17. What system do you use?

----

18. Do you have an extension office in your area? Yes ☐ No ☐

19. Do you contact the extension officer(s) in your area to assist you in terms of management of your indigenous chickens? Yes ☐ No ☐

20. How often do you contact the extension officer?

a. Once a week ☐ b. Once a month ☐ c. Once a year ☐ d. Not at all ☐

21. Do you have a specific type of indigenous chicken that you prefer? Yes ☐ No ☐

22. How do you select the type of chicken you prefer? In terms of a. Colour ☐ b. Size ☐ c. Sex ☐

23. What is the reason for your preference?

----

24. How do you ensure that the type of indigenous chicken you raise is maintained?

25. Do you think it's important to keep indigenous chickens? Yes ☐ No ☐

26 If yes, why? --

27. Do you know anything about extinction of indigenous chickens? Yes ☐ No ☐

28.If yes, what do you think causes the extinction of indigenous chickens?

----

29. What do you think can be done to prevent the loss of these indigenous chickens?

----

30. Which other animals do you keep in your home?

a. Cattle ☐ b. Goats ☐ c. Chickens ☐ d. Sheep ☐

31. What has been your production trend for these animals for the past 3 years? Increase or decrease. Estimate

	2012	2013	2014
Cattle	______________	______________	______________
Goats	______________	______________	______________
Chickens	______________	______________	______________

32. Do you know anything about exotic chicken breeds? Yes ☐ No ☐

33. Have you tried rearing exotic chicken breeds? Yes ☐ No ☐

If yes, what differences have you noticed between rearing indigenous chickens and exotic breeds?

Characteristic	Indigenous chicken breeds	Exotic chicken breeds
Early growth (poor, fair, good)		
Adaptability to change in climate (poor, fair, good)		
resistance to diseases (poor, fair, good)		

34. What challenges have you come across when raising your indigenous chickens?

----

35. Which chicken type do you prefer - indigenous chicken or exotic chicken breed? Why?

----

36. Where do you source information on raising your indigenous chickens?

a.Newspapers ☐ b. Magazines ☐ c. Radio ☐ d. Extension officer(s) ☐ e. Local information ☐

PRODUCTION SYSTEMS

1. State the number of members who care for chickens (Based on sex age group)

Age group Male Female	Male	Female
a. Under 14 years		
b. between 15 and 30 years		
c. between 31 and 60 years		
d. above 61 years		

2. On average how many days per week do you and your family spend taking care of the chickens?

a. 1 day ☐ b. 2- 4 days ☐ c. 5-7 days ☐ d. None ☐

Housing

1. What type of management system do you practise for your indigenous chicken rearing?

a. Extensive ☐ b. Semi-intensive ☐ c. Intensive ☐ d. Backyard system ☐

2. Where do your indigenous chickens sleep at night?

a. In the kitchen ☐ b. A room inside the house ☐ c. In trees d. In the pen ☐

3. If they sleep in the house or pen, how frequently do you clean your indigenous chicken house? How many days in a week

a.Everyday ☐ b. Once in a week ☐ c. Once a month ☐ d. Not at all. ☐

Feeding and Watering

1. Do you grow grains? a Yes ☐ b. No ☐

2. If yes what type of crops a. Maize ☐ b. Sorghum ☐ c. Rice ☐ d. Legumes ☐

3. Do indigenous chickens obtain feed from your cropping? a.Yes ☐ b.No ☐

4. If yes, in what form do you present the feed to your indigenous chickens? ---------------------
Why?---------------------------

5. Do you give supplementary feed to your indigenous chickens? a. Yes ☐ b. No ☐

6 If yes, what type of feed supplements do you give to your indigenous chickens?

a. Proteins ☐ b. Concentrates ☐ c. Minerals ☐

7. How often do you feed your indigenous chickens?

a. Once a day ☐ b. Two times a day ☐ c. Three times a day ☐ d. Not at all ☐

8. If you give feed how do you feed your indigenous chickens?

a. Put feed in containers ☐ b. Throw on the ground ☐ c. Others ☐ specify---------

9. If you do not give feed, reasons for not giving supplementary feeding

a. Lack of awareness about feed ☐ b. Unavailable ☐ c. Time shortage ☐ d. Can't afford to buy ☐ e. Others ☐ specify---------------

10. Do you give water to your indigenous chickens? Yes ☐ No ☐

11. If you give water to your indigenous chickens, where do you get water?

a Bore hole ☐ b. Rain water ☐ c. River ☐ d. Tap water ☐ e. Other, ☐ specify----------

12. If you give water to the chickens, what type of container do you use to supply the water?

a. Metal drum ☐ b. Piece of clay pot, ☐ c. Plastic containers ☐ d. Other ☐

13. If you provide water for indigenous chickens, how frequently do you wash the container?

a. Once a day ☐ b.Twice a day ☐ c. Once a week ☐ d. Once a month ☐ e. Not at all ☐

Health and disease control

1. Do you experience serious disease outbreaks? Yes ☐ No ☐

2. Which diseases have you experienced in your flock?

a. Fowl pox ☐ b.Gumboro ☐ c.Newcastle ☐ d.Other ☐ specify……

3. What do you do when chickens fall sick?

a. Treat them yourself b. Call in the vet/ Doctor c. Kill them immediately

d. Consume them immediately e. Sell them immediately f. Other, specify----------------

4. Do you use any medication (vaccines) to prevent diseases in your indigenous chickens?

Yes ☐ No ☐

5. Do you have any other techniques that you use for disease prevention? Yes ☐ No ☐

6. If yes, which are those techniques?

MORPHOLOGICAL TRAITS FOR INDIGENOUS CHICKENS

Climate changes

1. In which year did you start raising your indigenous chickens?

----

2. Have you noticed any changes in climate from the year you started rearing your indigenous chickens and other livestock? Yes ☐ No ☐

If yes, which are those changes? …………………………

3. What do you think of Temperatures from the year you started raising your indigenous chickens until 2015?

a. Increased ☐ b. Decreased ☐ c. Stayed the same ☐

4. Does the climate change have any effect on the survival of your indigenous chickens and other livestock? ? Yes ☐ No ☐

5. Do all your livestock species adapt to changes in climate? Yes ☐ No ☐

6. What do you do to ensure that the type of indigenous chickens you raise adapt to the changes in climate? -------------------

7. Which traits do you look for when selecting your indigenous chickens?

----

8. Which traits do you think enable the survival of indigenous chickens in the production system you practise?

----

9. Which traits do you prefer? Why

----

10. Which traits have been preferred the most by the people you sell your indigenous chickens to?

----

11. Has the preference of the morphological traits changed? Yes ☐ No ☐

12. If it has changed, what do you think causes the preference changes?

----

13. Do you think that climate change has an effect on the morphological traits of indigenous chickens in your production system? Yes ☐ No ☐