CHARACTERIZATION OF INDIGENOUS CHICKEN IN RWANDA

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CHARACTERIZATION OF INDIGENOUS CHICKEN IN RWANDA

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DECLARATION

I declare that this dissertation contains my own work except where specifically acknowledged, and it has been passed through the anti - plagiarism system and found to be compliant and this is the approved final version of the Thesis.

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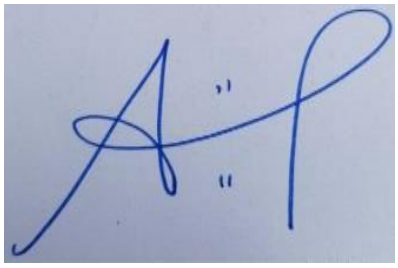

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ABSTRACT

Poultry development is one of the most important pathways to pro-poor livestock induced growth. It contributes to poverty alleviation, against malnutrition and disease in rural areas. The native chickens have been indicated by a traditional low input/low output farming system. Indigenous chicken in Rwanda have been characterized by farmers into four types (Inshenzi, Sekaganda/Inganda, Imirangi/Umujosi and Indayi) but the difference between them in terms of phenotypic and molecular features are not yet known. Objectives of this study were to contribute to genetic improvement of indigenous chickens in Rwanda through phenotypic and molecular characterization. The phenotypical and blood samples were collected from indigenous chickens domesticated at four agro-ecology zones in Rwanda and factorial experimental design was used where we examined management system, phenotypical and genotypic traits in terms of production. A selection was randomly where the villages closed to big cities and commercial harbors were not selected. We assessed phenotypical traits of 1080 indigenous chickens and we took morphometric measures and blood samples of 120 chickens from twelve districts. We found the 23 related genes from those morphometric measures (head, wattle and beak length) by using SNP markers and 22 nearest genes from blood samples by SNP markers based on the highest genetic potential in terms of indigenous chicken production. Then after, we observed four different genotypes which were characterized by low homozygosity of 0.140088 for Imirangi and 0.15327 for Inshenzi and low similarities of 0.022467 between Imirangi and Inshenzi from the genetic distance than two others (Inganda and Indayi). Among those four genotypes of IC in Rwanda; Imirangi and Inshenzi showed the highest genetic potential in term of production traits (egg and body weight) than Inganda and Indayi. Our findings will help to select indigenous chicken with high genetic potential in terms of production and provide new clues for further study in breeding program of indigenous chicken.

KEY WORDS

1. Indigenous chicken
2. Phenotype characterization
3. Single Nucleotide Polymorphism

LIST OF ABBREVIATIONS

1. AnGR: Animal Genetic Resources
2. AFLP : Amplified fragment length polymorphism
3. CAVM: College of Agriculture, Animal Science and Veterinary Medicine
4. FAO: Food Agriculture and Organization
5. IC: Indigenous Chicken
6. MINAGRI: Ministry of agriculture and Animal Resources
7. NISR: National Institute of Statistics Rwanda
8. SLU: Swedish University of Agriculture Sciences
9. SNP: Single Nucleotide Polymorphism
10. RAB: Rwanda Agriculture and Animal Resources Development Board
11. RAPD: Random Amplified Polymorphic DNA
12. RFLP : Restriction fragment length polymorphism
13. UNESCO: United Nations Educational, Science and Cultural Organization
14. UR: University of Rwanda

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CHAPTER ONE: INTRODUCTION

1.1. Background

Poultry development is one of the most important pathways to pro-poor livestock induced growth (Dolberg, 2016). It contributes to poverty alleviation, against malnutrition and disease in rural areas (Athar, 2019). Poultry domestication has important to the farmers in term of gaining a source of animal protein, income and gainful employment throughout the developing world (Bughio, 2018). Indigenous chickens have an ideal mothers and good sisters, excellent foragers and are well known to have developed adaptive features that contribute to survivability and reproduction under harsh climates (Duah et al, 2020). The poultry production is growing faster than smallholder livestock systems (Bughio, 2018).

Though the native chickens have several valuable characters that are not found in commercial production; it indicated by an appropriate traditional low input/low output farming system (Hailemichael et al, 2016). Local chickens have slow grower and poor layers of small-sized eggs and their management is predominantly free range- a typical feature of poultry rearing in East Africa and much of the developing world (DLS, 2015). Rwanda is characterized by the coexistence of 2 systems: rudimentary village poultry and industrial poultry at its infancy, the 2 systems facing scarcity of inputs to fully exploit their genetic potential (MINAGRI, 2012).

Rwanda is small country with a highly demographic population create the competition to livestock feeding due to shortage of land (Mahoro, 2017). The flock size and productivity were too low provided approximately 10% of meat and about 19% of eggs consumed in Rwanda (NISR, 2014). The balance was provided for imports from neighboring countries especially Uganda. Nevertheless, indigenous poultry meat and eggs were preferred by the consumers and dominate the market (Duah et al, 2018). Studies have shown that 70% of the consumers in Kigali preferred the local chicken products and there was a shortfall in supply against demand (GOP, 2019-20).

Nevertheless, the characteristically white-shelled eggs from indigenous and local birds sell at higher retail prices (120RwF) than eggs from commercial (90RwF) and these challenges are encapsulated in the price of chicken, which is relatively high at RWF 2,300/kg for meat and RWF 4,000-6,000/whole bird (NIANG, 2012). The priority of rural poultry farmer was to keep the birds that lay eggs with an optimum size as well as birds that grow to optimum body weight with the quality of the offering that satisfies special morphological features of the

chicken demanded by the receiver similar to indigenous birds (Dessie et al, 2012). But they cannot reach those profits because; poultry farmers still face many challenges. As they continue to rely on the importation of exotic breeds for creating genetic improvement in their farms (FAO, 2019). This scheme has not for some time been offering any long-term breeding strategy during crossbreeding with large framed exotic poultry breeds. These endeavours have proven to be unsustainable due to overdependence on external genetic material (Alemayehu et al, 2018).

Genetic improvement through selection is a long-term, tedious and costly undertaking. However, application of marker-assisted selection (MAS) considerably reduce the duration and cost of genetic improvement. In chicken, the candidate genes for MAS for egg production and feed efficiency are known; but not effectively utilized to enhance the participation of resource poor household.

Indigenous chicken was played the crucial role for rural economy and its up- gradation with respect to performance by using exotic breeds was shortly intervened to genetic improvement, thus increasing poultry products (Alemayehu, 2017). Africa species or breeds are endangered in time of not well differentiated and conserve; they may be lost even (Kunnasranta et al, 2016). Particular, for avian breeds are at an extinction risk of 30 % (Semik and Krawczyk, 2011). Species that have less genetic variation are at a greater risk (Laikre, 2010).

Indigenous chicken had distinct physical variations for both qualitative and quantitative traits; under intensive management conditions require could favor by developing a good breeding program for village conditions (Khawaja et al, 2013). The aim of this study was to identify the characteristics of indigenous chickens and preferred traits from poultry farmers to explore their full genetic potentiality.

1.2. Problem statement

Indigenous chickens contribute to high level of the consumed poultry products in developing countries like Rwanda and it serves as an investment and source of security for households from their use as sources of proteins and income. Though still there is an appropriate low input and output in local farming system. Indigenous chicken in Rwanda have been characterized by the farmers into four types (Inshenzi, Sekaganda, Imirangi and Indayi) but the difference between them in terms of phenotypic and genetic features are not yet known. This study was aimed to characterize indigenous chickens in Rwanda.

1.3. Justification of the study

Characterization will allow selection and breeding of indigenous chickens for their genetic improvement.

1. 4. Objectives

1.4.1. Overall objective

To contribute to genetic improvement of indigenous chickens in Rwanda through phenotypic and genetic characterization.

1.4.2. Specific objectives

1. To determine management system of indigenous chicken in Rwanda.
2. To characterize phenotypically indigenous chicken in Rwanda.
3. To determine the level of genetic diversity of indigenous chickens in Rwanda.

1.5. Hypothesis

The management systems of indigenous chickens, their phenotypic and genetic diversity in terms of production aren't enough compare to their full genetic potential.

1.6. Expected output

1. Management system of indigenous chicken in Rwanda identified.
2. Indigenous chicken in Rwanda were phenotypically identified.
3. Level of genetic diversity among indigenous chickens in Rwanda was determined.

CHAPTER TWO: LITERATURE REVIEW

2.1. Origin and domestication of chickens

The domestic chicken (*Gallus gallus*,) is likely originated from the wild Indian and Southeast Asian red jungle fowl. Development of the fowl kept can be partitioned into three phases. First phase began with the evolution of the genus *Gallus*, proceeded by the emergence of the domestic fowl from its progenitors and thirdly was in a large number of the current breeds, varieties, strains and lines. Kept of fowl in the region of the Indus valley is believed to have occurred by 2000 BC (Zeuner, 1963) but more recent archaeological founds proved that keeping of fowl appeared in China 6000 BC (West & Zhou, 1989).

The source of poultry industry was the most appeared in the 19th century for not meat purpose but used for the game of cock fighting and in religious rituals (Singh, 2000). The poultry products have been used during the 20th century when its commercial industry was developed (Crawford, 1990).

2.2. Chicken management systems

The different chicken's terminologies are used. Indigenous is the living naturally in an area; not introduced, Native is belonging by birth to a specific area; country and Local are native inhabitant (Oxford Dictionary, 1990). Hence, the word "indigenous" was mainly designed for the characterization of chickens. Poultry production is pointed into traditional, small and large-scale orientated sectors, with related to the purpose of the producer, inputs used, and the size and categories of birds kept. The chickens are kept in small flocks with different ages under a traditional scavenging system (FAO, 2019).

This tradition raising system was characterized by low input and output, the highest mortality caused by diseases, nutritional deficiencies and predation (Asresie and Mitiku, 2015).

2.3. Reproductive performance of indigenous chickens

Production of indigenous chicken and their potentials were lower compared to exotic birds (Alemayehu, 2017). Overall mean of eggs laid per clutch was 6.6 eggs and 14.7eggs for local chickens at Southern and Western Province in Rwanda and showed a mean of 1.4kg of body weight (Hirwa et al, 2019). According to Yadessa et al (2017) who was reported that, the overall mean of egg production per year of the local birds was an average 54.5eggs under traditional production conditions in Mezhenger, Sheka and Benchi -Maji zones of south western Ethiopia .According to Zereu and Lijalem (2016); the native Ethiopian chickens

should attain a live weight of 1.25 kg in slaughter ranges 8.6, 9.4 and 8.9 Months at village management condition.

2.4. Opportunities and challenges of chicken production

Indigenous chickens were the major sources of protein and income for small-scale farmers (Athar, 2019). Chickens have highly rate of prolificacy with a short duration and their transport was not difficulty compared to others livestock. Furthermore, they are good scavengers as well as foragers, disease tolerance; possess good maternal qualities, leanness meat and people like their multi-colored plumage (Jesuyon and Salako, 2013). However, low skills of modern raising, insufficient of feeds and appearance of diseases are the challenges of chicken production (Tadesse et al, 2017).

Newcastle disease is a highly contagious disease of chickens in local area and others like Gumboro disease, Marek disease (MD), and Fowl typhoid, Cholera, Mycoplasmosis and Coccidiosis are the major diseases that were the highest level in commercial poultry in the most African countries. Furthermore, others limitations were come from institutional and socio-economic in production of smallholder (Alemayehu et al, 2018).

2.5. Characterization and conservation of chicken genetic resources

Characterization of local animal genetic resources is the most important in making available the required information for the use and conservation of animal genetic resources (Osei-Amponsah et al, 2013). When used the foreign germplasms; could cause the genetic dilution from Animal Genetic Resources and it directly contributed to the productivity changes and deeply decreased available support for conservation duties (Weigend et al, 2013). Africa species or breeds are endangered and may be lost even in time of not well differentiated and conserve (Rege & Lipner, 1992).

Particular more, the 30 % of avian breeds are at risk of extinction ((Semik and Krawczyk, 2011). Global markets and exchange motions of human beings have an effect to chickens genetic makeup (Thiyagasundaram, 2013). The loss of genetic resources data for local chicken's farms in not developed countries has led to their underutilizations, replacement and dilution through cross-breeding. Now, breeding strategies for commercial poultry focus on specialized production lines, derived by intense selection from a few breeds and very large populations with a great genetic uniformity of traits under selection (Notter, 1999).

Native breeds have genes and alleles pertinent to survive to harsh conditions (Dahloum L et al, 2016). Characterization has a specific to genetic identity and the environment to which species or breed populations are adapted (Rege, 1992). Furthermore, it intervenes to the performance levels (meat, growth, reproduction, egg) and the genetic distinctiveness of the animal (FAO, 2011). Therefore, characterization, utilization and conservation of these indigenous genetic resources are of paramount importance.

2.6. Methods for measuring genetic diversity

Genetic diversity from the animals can affect by the factors including natural and artificial selection, mutation, migration, genetic drift and non-random mating (Markos, 2017). During animal breeding, man has mainly influenced the presence of genetic differences between breeds and populations by isolating and selecting them for favorable traits. Therefore, to keep information of the genetic differences between individuals, populations and breeds are required (Weigend et al, 2013).

Quantitative measurement of genetic diversity within and among populations is a crucial to decision making in genetic conservation and utilization plans. The phenotypic characters and molecular markers were the commonest ways to quantify these genetic diversities (Pym, 2013).

2.6.1. Phenotypic markers

Morphological polymorphisms are used to find out the relationship between breeds (Qureshi, 2018). Phenotypic markers are cheap and easy to apply regarding to environment in accordance with the nature of the qualitative and quantitative traits to be viewed. The prevalence characteristic of broodiness among the indigenous chicken females has correlated to their poor egg producing capacity. Thus, despite their slow growth and small size, they are costlier and expensive than other chicken (Negassa et al, 2014).

Diversity of the birds described mostly on phenotypes including adult body weight, egg weight, reproduction performance and immune responses to various diseases (Brown et al, 2017). Often, three factors; historical, phenotypic and genetic were considered during characterization of indigenous chicken.

2.6.2. Molecular markers

During the last two decades; several DNA markers such as RAPD, AFLP, RFLP and microsatellites have been found and applied in genetic diversity analysis (Weigend et al,

2013). In this current period, they have found another modern molecular marker type called Single Nucleotide Polymorphism (SNP). The difference from others methods; DNA-based methods are not influenced by external factors and show accurate data about genetic diversity. This holds particularly true for DNA-profiling methods based on the polymerase Chain Reaction. It was powerful tool for examining diversity within and among individuals, families and populations and it plays a crucial role on locus specificity, abundance and random distribution over the genome and their co-dominant inheritance (Semik and Krawczyk, 2011).

The markers evolution has formed new ways for the selection and genetic improvement of livestock. Practically, DNA based polymorphisms are being applied for marker-assisted selection strategies, parentage testing, species identification and population genetic studies (Naqvi, 2007). They contributed to genetic linkage maps and can led to an identify loci that influence the rate of improvement in production traits (Zhang et al, 2015). Molecular are used to predict the total genetic merit of livestock to redesign animal breeding and management programs (Nigussie, 2011).

2.6.3. Single Nucleotide Polymorphism

It is a new and very promising molecular marker system that gives occasion to found the genetic diversity in animals kept by carry out the mode and extent of variation in specific positions in the genome (Zhang et al, 2015). SNPs may occur in the coding but mainly non-coding and intergenic regions of the genome. In the chicken genome, SNP has been a frequency of 1 SNP per 225 bp and is five time over in humans (Orsini et al, 2011).

2.7. Statistical analysis of gene diversity and genetic distance

Applying of molecular markers linked to strength statistical ways during genetic characterization may lead to access new approaches to decide how the conservation take place and rational management of AnGR (Hanotte & Jianlin, 2005). Genetic distances are metrics that have been made to condense allele frequency differences among populations and indigenous chickens between Northern-western and Central-Northern area in Rwanda was the lowest genetic distance of 0.029 and their highest was 0.125 between Eastern and Southern-Western area and between exotic chickens was 0.231 (Habimana et al, 2019).

However, they would use the standard genetic distances (*D*S) of Nei (1972; 1978), the chord distance (*D*A) of Nei et al (1983) and estimate of genetic structure (FST), in which its values can range from 0 to 1 (Pym, 2013).

CHAPTER THREE: MATERIAL AND METHODS

3.1. Study area

Our study area was located in four agro-ecological zones; each zone corresponded to Province and was partitioned into three Districts based on random selection of an area that was away to the big market and cities. We took the twelve Districts from those four zones:

a) Eastern zone: Bugesera, Rwamagana and Nyagatare District.
b) Western zone: Rubavu, Ngororero and Nyamasheke District.
c) Northern zone: Rulindo, Musanze and Gakenke District.
d) Southern zone: Kamonyi, Nyamagabe and Nyanza District.

3.3. Experimental animals

3.2. Experimental animals

Healthy indigenous chickens, maintained in those four agro-ecological zones were randomly selected for study. In different local farms including all breeding males and females which were proportional to the flock size and reached a sexual maturity to best represent the diversity among farms

3.3. Experimental design and treatments

Factorial design (3x3 factorial experiments) was used. Where three factors include their management system (production system, feeding practices, housing and maintenance and vaccination), their phenotypically traits (head, wattle and beak length) and genetically characters from their genomic were contributed in IC production. The 90 IC was filled on questionnaires for each individual and a total 10 blood samples of IC from each district study was used.

The 1,080 indigenous chickens was used for phenotypes characterization, among them 120 IC was used for morphometric parameters and blood samples for molecular characterization. A selection was randomly where the villages closed to big cities and commercial harbors were not selected.

3.4. Sample size determination

The total number of indigenous chickens in the twelve survey Districts was 1,080 and using a simplified process of determining the sample size for a finite population (Krejcie and Morgan, 1970). Based on this method, sample size for each District was determined as follow:

$$N = \sum_{i=1}^{n=12} (2n)\ (3c)(3v)(5IC)$$

Where N: Sample size

i: Number of selected District; n: Number of selected Sectors per District

c: Number of selected Cells per Sector; v: Number of selected Villages per Cell

IC: Number of indigenous chickens selected per Village

3.5. Phenotypic characterization

A field survey was done and 1,080 questionnaires were administered to indigenous chicken household farmers and qualitative and quantitative traits were recorded from 120 indigenous chickens following the recommended descriptors for chicken genetic resources (FAO, 2011).

3.5.1. Qualitative morphological traits

They were visual recorded (1. Head shape 2. Comb form 3. Structure of comb 4. Eye color 5. Ear lobe shape 6. Ear lobe color 7. Beak color 8. Plumage patterns 9. Feather structure and 10. Shank color).

3.5.2. Quantitative morphological traits

They were metrical recorded by using measuring tapes (calibrated in centimetres) and a spring balance (a 5-kg measuring scale) to measure the respective quantitative traits of sampled chickens (1. Head length 2. Beak length 3. Wattle length 4. Neck length 5. Wing length 6. Wing span 7. Body length 8. Tarsus length 9. Tarsus diameter 10. Shank length 11. Shank diameter and 12. Body weight).

3.6. Genetic characterization

During this research, the 120 blood samples of IC was sampling from twelve Districts. Two milliliter of blood were collected from pectoral vein into tube (EDTA 0.5 M). The tubes were kept in a portable, insulated cool boxes with dry transported to the laboratory work in Rwanda Agriculture and Animal Resources Development Board at Rubirizi Station, where they kept at −80 °C until where DNA amplification took place.

3.6.1. Deoxyribonucleic acid (DNA) extraction

DNA was extracted from blood samples using Promega genomic DNA extraction kit following the protocol of the ReliaPrep^{TM} Blood gDNA Miniprep System. Nano drop was used for DNA quantification.

3.6.2. Single Nucleotide Polymorphisms (SNP) identification

After DNA quantification; those samples were directly sent to MacrogenInc at Biosciences eastern and central Africa-International Livestock Research Institute (BecA-ILRI) Hub located in Nairobi, Kenya for sequencing by using Hiseq2500 Annotation genes. The sequence reads were trimmed using Sickle at threshold length of 80-100 and Q of 20. The

obtained quality reads were assembled together to get contigs and those were put into protein evolution by blasting. The SNPs were called using SAMtools v1.3.1 (Li et al, 2009).

Resultant SNPs were subjected to the following filtering criteria using Plink v1.07 software (Purcell et al, 2007); minimum SNP quality of 20, 5% missing SNP genotypes and Hardy–Weinberg equilibrium ($P < 10^{-6}$), call frequency > 95%, heterozygosity > 0.4 and minor allele frequency > 0.05).

3.7. Data Analysis

The qualitative parameters were analyzed by physical observation, using descriptive statistics and statistical package for social science (SPSS). Those two later were used for the quantitative variables. The genotypic frequency and P-values were estimated and calculated. The following model was fitted for association of each genotype (SNPs).

$Yij = Xb + Za + Zc + e$

Where, Y = represented the dependent variable (Growth performance and egg traits; b = vector of fixed effects of sex and hatch number; a = vector of random direct genetic effects;

c = vector of random common environmental effects; e = vector of residual effects; and X, Za and Zc are incidence matrices relating records to fixed, direct genetic and common environmental effects, respectively (Gilmour et al, 2006).

CHAPTER FOUR: RESULTS INTERPRETATION

4.1. Management system of indigenous chickens

4.1.1. Chicken production system

Chicken production system was the highest significance ($p < 0.001$) in Rwanda (Table 1). Scavenging only was the most dominant in all chicken production system with 43.2% followed by scavenging + seasonal supplementation, semi-scavenging and intensive system with 35.3%, 13.8% and 7.6% respectively. Eastern Province was the most observed in scavenging only of indigenous chickens kept with 54.7%.

Table 1: Chicken production system

Chicken production system	Provinces					
	North	South	East	West	overall	P values
Chicken production system (%)						
Scavenging only	36.5	40.8	54.7	40.2	43.2	0.000
Scavenging + Seasonal supplementation	39.6	31.7	33.5	36.8	35.3	
Semi scavenging	16.9	19.6	4.7	14.6	13.8	
Intensive system	6.9	7.9	7.2	8.4	7.6	

4.1.2. Flock productivity

Flock productivity in Rwanda is shown in Table 2. Sexual maturity for cocks, sexual maturity for hen, egg laying cycles per year, eggs given for incubation, chicks hatched per cycle, number of weaned chicks and chicks' mortality rate were the highest significant ($p < 0.001$). Sexual maturity for cocks was the most observed with 6.5months. Northern and Western Provinces were the most prominent in cock's sexual maturity (6.7months). Sexual maturity for hen was the most observed with 6.7 months. Western Province was the highest delayed in hen's sexual maturity (7.1months).

Egg laying cycles per year was the most dominant with 3.0cycles. Northern Province was the highest level in egg laying cycles per year (3.4cycles). The overall mean of egg laying per cycle of IC was not significant different ($p > 0.05$) and it was 17.7eggs. Local chickens at

Northern Province produced many eggs per cycle than others (18.9eggs). Overall mean of eggs produced per year was significant different ($p < 0.05$) and it was 47.9eggs. Indigenous chickens at Northern Province produced many eggs per year than others (58.7eggs). There was not significant different ($p > 0.05$) in all eggs given for incubation types. Naturally incubation was the highest level (99.7%) compared to artificially incubation (0.3%). Naturally incubation was the most dominant at Western and Southern Provinces (100%). Eggs given for incubation were accounted for 8.8 eggs. Northern Province was the most observed in eggs given for incubation (9.3 eggs).

The chicks hatched per cycle were the most accounted for 7.6 chicks. Northern Province was high in chicks hatched per cycle (8.1 chicks). The greatest number of weaned chicks was 5.0 chicks. Northern Province was high observed of weaned chicks (5.9 chicks). The highest level of chicks' mortality was (34.0%). Eastern Province was the most observed in chicks' mortality rate (38.3%).

Table 2: Flock productivity

Flock productivity	Provinces				Overall mean	P values
	North	South	East	West		
Sexual maturity for cocks (months)	6.7	6.3	6.3	6.7	6.5	0.000
Sexual maturity for hens (months)	6.9	6.7	6.2	7.1	6.7	0.000
Egg laying cycles per year	3.4	3.0	2.8	2.9	3.0	0.000
Number of eggs per cycle	18.4	17.4	18.9	16.2	17.7	0.762
Number of eggs produced per year	58.7	45.4	43.6	43.1	47.9	0.009
Eggs given for incubation	9.3	8.3	9.1	8.7	8.8	0.000
Naturally incubation	99.6	100.0	99.2	100.0	99.7	0.313
Artificially incubation	0.4	0.0	0.8	0.0	0.3	
Chicks hatched per cycle	8.1	7.1	7.8	7.4	7.6	0.000
Number of weaned chicks	5.9	4.5	4.8	4.9	5.0	0.000
Chicks mortality rate	27.6	37.5	38.3	32.4	34.0	0.000

4.1.3. Available feed stuffs

Available feed stuffs and feeding management in four agro-ecological zones are presented in Table 3. The maize bran was the most dominant with 24% followed by maize grain,

commercial feeds, fish meal, others, rice bran, soybeans, sorghum, wheat and bone meal with 20.2%, 17.6%, 11.0%, 7.4%, 5.9%, 4.8%, 4.5%, 2.7% and 1.6% respectively. Eastern Province was the most dominant in maize bran (33.8%).

Table 3: Available feed stuffs

Available feed stuffs (%)	East	West	North	South	Total
Commercial feeds	9.0	23.3	25.4	13.1	17.6
Maize bran	33.8	20.9	29.9	16.8	24.3
Maize grain	24.8	14.9	17.4	23.9	20.2
Rice bran	5.4	0.3	0.0	15.8	5.9
Fish meal	10.4	14.9	9.0	9.1	11.0
Sorghum	3.6	1.0	3.0	9.8	4.5
Wheat	0.9	5.1	5.0	0.0	2.7
Soybeans	7.2	4.7	4.0	3.7	4.8
Bone meal	0.0	4.1	0.0	1.3	1.6
Other*	5.0	10.8	6.5	6.4	7.4

**Other include: Kitchen wastes, Vegetables, Flours from milling machines, sweet potatoes, sunflowers, Brewer residues, cassava, etc*

4.1.4. Available feed nutrients

Available feed nutrients in Rwanda are shown in (Table 4). Carbohydrate was the most abundant with 49.8 % followed by protein, minerals, and vitamin with 29.7%, 14.2% and 6.3% respectively. Eastern Province was the highest level in carbohydrate (54.3%) and proteins (30.8%).

Table 4: Available feed nutrients

Available feed nutrients (%)	East	West	North	South	Total
Carbohydrates	54.3	47.4	46.3	52.4	49.8
Protein	30.8	32.6	28.0	27.6	29.7
Minerals	5.9	12.7	19.6	16.4	14.2
Vitamin	9.0	7.2	6.1	3.5	6.3

4.1.5. Season of ingredients availability

Season of ingredients availability is presented in Table 5. The rainy season was the most abundant in ingredients with 40.6% followed by both season and dry season with 38.7% and 20.8%. Carbohydrates were the most observed at dry season with 39.8% followed by protein, minerals and vitamin with 30.1%, 29.2%, and 20.8% respectively. Vitamins were the most abundant in rain season with 40.6% followed by carbohydrates, proteins and minerals with 31.0%, 29.3% and 22.7% respectively. Minerals were the most dominant at both season with 48.1% followed by proteins, vitamins and carbohydrates with 40.6%, 38.7% and 29.2% respectively.

Table 5: Season of ingredients availability

Nutrients	Dry season (%)	Rainy season (%)	Both seasons (%)
Carbohydrates	39.8	31.0	29.2
Protein	30.1	29.3	40.6
Minerals	29.2	22.7	48.1
Vitamin	20.8	40.6	38.7

4.1.6. Feeding Practices

The feeding practices were significant different ($p < 0.05$) in four agro-ecological zones (Table 6). Scavenge with supplement was the most dominant with 51.9±0.9 followed by total scavenging and entirely on commercial diet with 42.8±3.33 and 7.1±0.4 respectively. Scavenge with supplement was the most observed at Northern Province with 56.3±3.1. There was not significant different ($p > 0.05$) from chicken farmers who did not make a feed mixing (94.9±0.55). A feed mixing was high practical at Western Province with 6.5±0.8.

There was not significant different ($p > 0.05$) in proportion group of mixed ingredients Carbohydrates were the highest in proportion with 73.6±1.23 followed by protein, minerals and vitamins with 21.7±0.77, 3.8±0.68 and 0.9±0.47 respectively. Northern Province was in high proportion of carbohydrates (76.3±1.55). There was the highest significant ($p < 0.001$) in feed provision mode. Feeds put in the troughs were the most observed with 66.3±5.03

followed by feeds scattered on the ground and both methods with 33.2±4.72 and 0.5±0.28 respectively. Feeds put in the troughs were the highest level at Northern Province (81.0%). There was the highest significant ($p < 0.001$) in feeds providing frequency. Feeds provide for a twice a day was the most practicable with 47.8±4.88 followed by once a day and available all the time with 31.0±4.68 and 21.1±39.08 respectively. Western Province was the most observed in feeds providing for a twice a day (55.3±4.33).

Table 6: Feeding Practices

Feeding Practices (%)	Provinces				Overall	P values
	North	South	East	West		
Total Scavenging	36.4±3.6	38.0±2.7	54.2±6.58	42.0±0.46	42.8±3.33	0.001
Scavenge with supplement	56.3±3.1	54.1±2	38.5±5.8	51.9±0.9	50.1±11.8	
Entirely on commercial diet	7.3±0.1	7.9±0.4	7.3±0.1	6.1±1	7.1±0.4	
Position on feed mixing (%)						
Yes	4.6±0.28	5.7±0.34	3.7±0.7	6.5±0.80	5.1±0.53	0.331
No	95.4±0.28	94.3±0.34	96.3±0.80	93.5±0.80	94.9±0.55	
Proportion of group of ingredients mixed (%)						
Carbohydrates/energy	76.3±1.55	74.7±0.63	69.1±2.60	73.3±0.17	73.6±1.23	0.640
Proteins	22.3±0.34	19.8±1.09	23.7±1.15	22.6±0.51	21.7±0.77	0.851
Minerals	1.1±1.55	4.6±0.46	4.7±0.51	4.0±0.11	3.8±0.68	0.513
Vitamin	0.2±0.40	0.9±0.00	2.6±0.98	0.0±0.51	0.9±0.47	0.153
Mode of feed provision (%)						
Feeds put in the troughs	81.0±8.48	55.7±.6.11	58.7±4.38	68.3±1.15	66.3±5.03	
Feeds scattered on the ground	19.0±8.19	42.3±5.25	41.3±4.57	31.7±0.86	33.2±4.72	0.000
Both methods	0.0±0.28	2.0±0.86	0.0±0.28	0.0±0.28	0.5±	
Frequency of providing feeds (%)						
Once a day	37.6±3.81	35.7±7.36	25.2±3.34	23.7±4.21	31.0±4.68	
Twice a day	54.7±3.98	43.5±4.81	36.7±6.40	55.3±4.33	47.8±4.88	0.000
Available all the time	7.7±59.85	20.8±0.17	38.1±96.3	21.1±0.00	21.1±39.08	

4.1.7. Provision of water

The great number of IC farmers in Rwanda was high significant different ($p < 0.05$) in water provision to their chickens with 91.3% (Table 7). The chicken farmers at Eastern Province were the highest level in water providing (94.5%). There was the highest significant ($p < 0.001$) in equipment used. Part of a jerry cans were the most prominent with 51.1% followed by sauce pan, other (specify)*, drinker and broken Pots with 27.2%, 9.5%, 6.9% and 5.3% respectively. Part of jerry cans was the most used at Western Province (61.3%).

There was the highest significant ($p < 0.001$) in watering frequency. Water providing in all the time was the most practicable with 74.8±5.13 followed by once a day, twice a day and sometimes with 16.3±4.05, 7.9±0.34 and 0.9±0.42. Water providing in all the time to local chickens was high observed at Eastern Province (86.8 %).

Table 7: Provision of water

Provision of water	Provinces				Overall	P values
	North	South	East	West		
Do you provide water to your chickens? (%)						
Yes	92.7	87.7	94.5	90.2	91.3	0.029
No	7.3	12.3	5.5	9.8	8.7	
Equipment used (%)						
Drinker	5.3	5.9	7.3	8.9	6.9	0.000
Sauce pan	21.3	24.5	38.6	23.4	27.2	
Broken Pots	7.4	1.7	6.6	5.5	5.3	
Part of a jerry cans	57.8	45.1	40.9	61.3	51.1	
Other (specify)*	8.2	22.8	6.6	.9	9.5	
Watering frequency (%)						
Once a day	22.9±3.81	24.1±4.5	7.8±4.9	11.1±3.00	16.3±4.05	0.000
Twice a day	10.6±1.55	7.6±0.17	5.4±1.44	8.1±02	7.9±0.34	
All the time	65.7±5.25	65.8±5.19	86.8±6.92	80.3±3.17	74.8±5.13	
Sometimes	0.8±0.05	2.5±0.85	0.0±0.51	0.4±0.28	0.9±0.42	

*Other includes basin, plate, bucket, small cans, etc.

4.1.8. Major constraints on feeding management

The major constraints on feeding management in Rwanda are presented in Table 8. Expensive feeds was the most prominent with 68.5% followed by shortage of feeds, inaccessibility of feeds, lack of knowledge on feeding and other*****constraints with 18.4%, 6, 4.4 and 2.8% respectively. Expensive feeds were high observed at Northern Province (77.3%).

Table 8: Major constraints on feeding management

	East	West	North	South	Total
Expensive feeds	55	76.6	77.3	65.1	68.5
Shortage of feeds	29.5	9.5	8.8	25.1	18.4
Inaccessibility of feeds	5	9	3	7.2	6
lack of knowledge on feeding	8.5	3	5.9	0.4	4.4
Other*	2	2	4.9	2.2	2.8

**Other include: Poor quality of feeds, high cost of transport, Lack of feeding equipment, lack of feeding space, etc.*

4.1.9. Breeds and breeding management of chickens

Breeds and breeding management of chickens in Rwanda are shown in Table 9. Local breed was the most abundant with 71.2% followed by Kuroilers, Sasso, exotics, crossbred, other***** and layers with 54.1%, 35.8%, 19.1 %, 9.8%, 5.2% and 4.9% respectively. Management of local breed was the most practicable at Eastern Province (76.3%). Inshenzi was the most observed in all local chicken ecotype with 82.3% followed by Indayi, Umurangi and Inganda with 12.3%, 4.4% and 1% respectively. Inshenzi was high domesticated at Northern Province (91.0%).

Carrying out selection was the highest significant different ($p < 0.001$). The great number of chicken farmers was carrying out selection (65.0%). Majority of chicken farmers in Eastern Province was carrying out selection (74.1%). Keeping a breeding cock was the highest significant different ($p < 0.001$). Keeping a breeding cock of less than a year was the highest dominant with 76.0% followed by 1 to 3 years and more than 3years with 19.7% and 0.4% respectively. Keeping a breeding cock of less than a year was the most apparently in Eastern Province (86.5%).

Practical of crossbreeding was not significant different ($p > 0.05$). The majority of chicken farmers were not done a crossbreeding with 75.6% and Western Province was at the highest level (77.0%) while chicken farmers at Eastern Province were done a crossbreeding at highly level (25.5%). Practical of a crossbreeding was a benefit to chicken farmers and it was the highest significant different ($p < 0.001$). The majority of IC farmers were benefiting from practice a crossbreeding (71.3%). Local chicken farmers at Northern Province were benefiting from practice a crossbreeding (25.5%).

Chickens crossbreeding were not significant different ($p > 0.05$). Random mating of native chickens was the most dominant with 76.5% followed by organized mating and both with 23.2% and 0.3% respectively. Random mating was the highest dominant in Northern Province (87.1%).

Table 9: Breeds and breeding management of chickens

Breeds and breeding management of chickens	Provinces					
	North	South	East	West	Overall	
Chickens breed (%)						
local breed	69.9	68.9	76.3	69.6	71.2	
Exotics	22.4	20.3	14.2	19.3	19.1	
Kuroilers	40.9	58.5	60.0	51.4	54.1	
Sasso	47.7	35.4	28.2	37.8	35.8	
Layers	2.3	4.6	3.5	8.1	4.9	
Other*	9.1	1.5	8.2	2.7	5.2	
Crossbred	7.7	10.9	9.5	11.0	9.8	
Local chicken ecotypes (%)					Overall	
Inshenzi	91.0	83.3	73.3	83.9	82.3	
Indayi	5.6	10.8	16.2	15.7	12.3	
Umurangi/umujosi	3.0	2.5	10.5	0.0	4.4	
Inganda	0.4	3.3	0.0	0.4	1.0	
Carrying out selection (%)					Overall	P values
Yes	59.2	59.1	74.1	67.5	65.0	0.000

No	40.8	40.9	25.9	32.5	35.0	
Duration of keeping a breeding cock (%)						
Less than a year	83.3	75.2	86.5	60.2	76.0	0.000
1 to 3 years	12.7	22.6	12.9	29.8	19.7	
More than 3years	4.0	2.2	.6	9.9	4.3	
Do you practice crossbreeding? (%)						
Yes	24.2	24.7	25.5	23.0	24.4	0.931
No	75.8	75.3	74.5	77.0	75.6	
If yes has it been benefit to you? (%)						
Yes	97.1	88.3	52.2	63.7	71.3	0.000
No	2.9	11.7	47.8	36.3	28.7	
How is this cross breeding done? (%)						
Random mating	87.1	69.0	76.1	75.7	76.5	0.074
Organized (controlled mating)	11.4	31.0	23.9	24.3	23.2	
Both	1.4	0.0	0.0	0.0	.3	

**Other exotic breeds were Delco, Rhode Island Red and few breeds with brown colour*

***The other local chicken was mainly known as inyarwanda while only one farmer has mention the cross of inganda and indayi while the other one was not know the name of his local chicken*

4.1.10. Selection criteria of breeding stock

The selection criteria for a breeding stock in Rwanda are presented in Table 10. The big body size was the most dominant in selection criteria for a breeding cock with 31.6% followed by tall, high growth rate, plumage colour and high vigour, big comb size and other* with 19.3%, 11.5%, 5.6% and 1.6% respectively. The big body size was the main criteria to be chosen during cock selection in Southern Province (34.0%).

The good layer was the most dominant in selection criteria for a breeding hen with 28.5% followed by big body size, high hatchability, good mothering ability, high growth rate, tall, small size and other****** with 23.5%, 18.7%, 11.5%, 7.9%, 5.4%, 3.1% and 1.3% respectively. The good layer was the most criteria to be chosen during hen selection in Southern Province (40.2%).

Table 10: Selection criteria of breeding stock

Selection criteria of breeding stock	Provinces				
	North	South	East	West	overall mean
Selection criteria for a breeding cock (%)					
Big body size	32.6	34.0	31.6	29.7	31.6
Tall	25.9	25.8	15.0	16.3	19.3
High growth rate	17.3	12.3	23.7	18.7	18.9
Plumage colour	8.6	10.1	14.1	11.4	11.5
Big comb size	2.6	3.8	4.8	9.2	5.6
High vigour	10.9	11.0	10.5	13.0	11.5
Other*	2.2	3.1	.4	1.6	1.6
Selection criteria for a breeding hen (%)					
Big body size	26.9	27.4	18.9	15.8	23.5
Small size	1.7	3.4	4.6	3.6	3.1
Good layer	21.7	23.8	36.6	40.2	28.5
High hatchability	21.4	17.9	15.8	18.3	18.7
Tall	8.5	6.8	1.6	1.4	5.4
High growth rate	8.5	9.4	7.1	5.3	7.9
Good mothering ability	10.2	10.4	13.9	13.0	11.5
Other**	.9	1.0	1.4	2.5	1.3

***Other attributes include: Size of the shank, shank colour, Size of the wattle. Etc*

4.1.11. Housing and maintenance

Housing and maintenance for IC were the highest significance ($p < 0.001$) in four agro-ecological zones (Table 11). The complete enclosure was the most observed with 56.6% followed by shared the same house with the owner, on the veranda, kitchen and other with 31.9%, 5.2%, 5.1% and 1.2% respectively. The complete enclosure was high dominant in Eastern Province (72.0%). Regular sweeping of IC house was the most done with 94.8% followed by cleaning and changing litter, other** and cleaning and disinfecting with 3.4%, 1.3 and 0.5% respectively.

Regular sweeping in chicken house was the highest level in Western Province (98.5%). Disposal wastes of local chickens were the most used as manure with 89.0% and Eastern Province was the most used chicken disposal wastes as manure with 96.2%.

Table 11: Housing and maintenance

Housing and maintenance	Province				Overall	P Value
	North	South	East	West		
Housing structures (%)						
Chicken house with complete enclosure	54.5	36.2	72.0	64.0	56.6	0.000
Shared the same house with the owner	21.4	52.8	22.5	30.6	31.9	
On the veranda	11.3	6.6	1.5	1.6	5.2	
Kitchen	11.3	2.8	4.0	1.9	5.1	
Other	1.5	1.6	0.0	1.9	1.2	
Housing facility maintenance (%)						
Regular sweeping	89.9	94.9	96.9	98.5	94.8	0.000
Cleaning and changing litter	7.0	3.8	1.5	0.5	3.4	
Cleaning and disinfecting	0.9	0.4	0.5	0.0	0.5	
Other**	2.2	0.8	1.0	1.0	1.3	
Chicken wastes disposal (%)						
Used as manure.	83.1	84.3	96.2	92.5	89.0	0.000
Not put to use in any way	16.9	15.7	3.8	7.5	11.0	

**Other includes udutete, trees, cowshed, etc ** other the building of perch (udutanda) and shifting chicken*

4.1.12. Price of chickens products and their markets

Price of IC products and their markets in Rwanda are presented in Table 12. Mature cocks were the most expensive with 5,973 Rwandan francs followed by mature hen, growers, chicks and eggs with 4,055, 2,535, 1,663 and 87 Rwandan francs respectively. Average price

of mature cocks and eggs were the highest significant different ($p < 0.001$). Mature cocks and eggs were the highest price at Western Province 6,429 and 91 Rwandan francs. Average price of chicks was significant different ($p < 0.05$). The highest chick's price was the most observed in Southern Province (1,805francs). Average price of growers and mature hen were not significant different ($p > 0.05$). The highest price for grower chicken was 2,591francs at Northern Province and mature hen was 4,353francs at Western Province.

There was the highest significant different ($p < 0.001$) in marketing of chickens products. Sell to middlemen was the most dominant with 51.1% followed by sell directly to the consumers and both of them with 32.1% and 16.8% respectively. Sell to middlemen was the highest level at Northern Province (56.2%).

Table 12: Price of chickens products and their markets

Average price of chickens products and their markets	Provinces					
	North	South	East	West	Overall	P values
Chickens products (francs)						
Eggs	85	89	85	91	87	0.000
Chicks	1708	1805	1534	1659	1663	0.044
Growers	2591	2492	2546	2515	2535	0.796
Mature cocks	6264	5758	5432	6429	5973	0.000
Mature hen	3974	4144	3750	4353	4055	0.090
Marketing of chickens products (%)						
Sell to middlemen	56.2	42.9	52.3	53.1	51.1	0.000
Sell directly to the consumers	18.6	26.1	39.5	44.1	32.1	
Both of them	25.2	31.0	8.3	2.8	16.8	

4.1.13. Mortality levels and associated causes

Mortality levels and associated causes for local chickens in four agro-ecological zones are shown in Table 13. There was the highest significant different ($p < 0.001$) in mortality level for IC group. Chicks were the highest mortality rate (92.7%) followed by hens, growers and cocks with 3.6%, 2.0% and 1.7% respectively. Chick's mortality rate was high observed in Western Province (98.0%). The diseases were the major causes of mortality with 54.0%

followed by predators, weather, other*****, thieves and accidents with 39.0%, 3.5%, 0.2%, 1.8% and 1.4% respectively. The diseases were the most dominant cause of mortality at Eastern Province (61.3%). There was significant different ($p < 0.05$) in the period of the highest mortality rates. Rainy season was the most observed in chicken's mortality with 52.8% followed by dry season and both seasons with 42.7% and 4.5% respectively. At Eastern Province was the highest local chicken's mortality (80.0%).

Newcastle was the most prominent cause of mortality with 64.8% followed by respiratory diseases, coccidiosis, others*, salmonellosis and parasites with 16.9%, 7.8%, 5.0%, 3.5% and 2.1% respectively. Newcastle was the highest cause of mortality in Southern Province (75.0%).

Table 13: Mortality levels and associated causes

Mortality levels and associated causes	Provinces				Overall	P value
	North	South	East	West		
Chicken group that has the highest mortality rates (%)						
Chicks	90.5	89.6	92.4	98.0	92.7	0.011
Cocks	.9	3.7	1.5	.4	1.7	
Hens	5.7	4.1	3.8	1.2	3.6	
Growers	2.8	2.5	2.3	.4	2.0	
Major causes of mortality (%)						
Predators	38.9	42.3	36.9	38.9	39.0	
Diseases	48.7	49.4	61.3	54.0	54.0	
Accidents	2.4	2.7	0.9	0.4	1.4	
Thieves	0.6	1.7	0.2	4.6	1.8	
Weather	9.5	3.9	0.0	2.0	3.5	
Other*	0.0	0.0	0.7	0.0	0.2	
Period of the highest mortality rates (%)						
Dry season	55.9	29.3	16.6	58.7	42.7	0.000
Rainy season	42.1	68.1	80.0	31.6	52.8	
Both seasons	2.0	2.6	3.4	9.8	4.5	

Diseases causes of mortality (%)						
Newcastle	67.6	75.0	62.4	57.0	64.8	
Respiratory diseases	19.2	10.9	17.0	20.1	16.9	
Coccidiosis	4.8	6.3	7.0	12.0	7.8	
Salmonellosis	2.8	1.4	5.2	3.7	3.5	
Parasites	0.4	3.5	3.9	0.3	2.1	
Others*	5.2	2.8	4.6	6.9	5.0	

**Other include stress and heating and *Other include eye diseases, Fowl typhoid, Gomboro*

4.1.14. Vaccination

Vaccination of IC was significant different ($p < 0.05$) in four agro-ecological (Table 14). A great number of chicken farmers did not vaccinate their chickens (94.7%). They did not vaccinate their chickens in the highest level at Southern Province (96.3%). At Eastern Province; chicken farmers were done a vaccination at the highest level (6.9%). All reasons for not vaccinate their chickens were significant different ($p < 0.05$). Not aware about vaccination was the most observed with 83.6% followed by not available, expensive and other, specify* with 10.6%, 3.8% and 2.0% respectively. Not aware about vaccination was the most observed at Southern Province (88.9%).

Table 14: Vaccination

Vaccination	Provinces				Overall	P value
	North	South	East	West		
Do you vaccinate (%)						
Yes	6.4	3.7	6.9	4.2	5.3	0.011
No	93.6	96.3	93.1	95.8	94.7	
Reason for not vaccinating (%)						
Expensive	1.6	1.4	5.3	8.0	3.8	0.024
Not available	11.4	7.9	13.8	10.4	10.6	
Not aware about chickens vaccines	85.3	88.9	78.3	79.8	83.6	
Other, specify*	1.6	1.9	2.6	1.8	2.0	

**Other include short experience, lack of knowledge, local chicken are resistant, etc*

4.2. Phenotypic characterization

4.2.1. Plumage patterns and comb structures

Plumage patterns and comb structures of indigenous chickens across four agro-ecological zones are shown in Table 15. Uniform and Coronation plumage patterns were the most prominent with 24.7% followed by silver penciled, partridge, speckled, naked neck and mottled, rumpless and barred with 12.9%, 10.8%, and 8.6%, 7.5%, 2.2% and 1.1% respectively. Inshenzi was the most dominant in all plumage patterns with 60.2% followed by Sekaganda, Indayi and Umurangi with 19.4%, 15.1% and 4.3% respectively.

Erect comb structure was the most observed with 88.9% compared to droopy comb (11.1 %). Inshenzi was the most dominant in all comb structures with 60.0% followed by Sekaganda, Indayi and Umurangi with 21.1%, 14.4%, and 4.4% respectively.

Table 15: Plumage patterns and structure of comb

Plumage patterns	Name of the local chicken kept				Total
	Sekaganda (Inganda)	Indayi	Umurangi/ Umujosi	Inshenzi	
Mottled	1.1%	2.2%	1.1%	3.2%	7.5%
Silver penciled	3.2%	1.1%	-	8.6%	12.9%
Speckled	1.1%	1.1%	1.1%	5.4%	8.6%
Partridge	4.3%	3.2%	-	3.2%	10.8%
Uniform	5.4%	3.2%	-	16.1%	24.7%
Coronation	3.2%	2.2%	-	18.3%	24.7%
Barred	1.1%	-	-		1.1%
Rumpless	-	1.1%	-	1.1%	2.2%
Naked neck	-	1.1%	2.2%	4.3%	7.5%
Total	19.4%	15.1%	4.3%	60.2%	100.0%
Structure of comb					
Erect	20.0%	14.4%	3.3%	51.1%	88.9%
Droopy	1.1%	-	1.1%	8.9%	11.1%
Total	21.1%	14.4%	4.4%	60.0%	100.0%

Note: Empty space in this above table means not applicable for that chicken.

4.2.2. Comb forms and earlobes color

Comb forms and earlobes color of IC in Rwanda are shown in Table 16. Single comb was the most observed with 90.1% followed by double and rose varieties with 8.8% and 1.1%. Inshenzi was the most dominant in all comb forms with 60.4% followed by Sekaganda, Indayi and Umurangi with 20.9%, 13.2% and 4.4% respectively. Red earlobes were the most appeared with 58.9% followed by white and yellow with 28.4% and 12.6% respectively. Inshenzi was the most observed in all earlobe colors with 60.0% followed by Sekaganda, Indayi and Umurangi with 20.0%, 14.7% and 4.2% respectively.

Table 16: Comb forms and earlobes color

	Name of the local chicken kept				
Comb forms	Sekaganda (Inganda)	Indayi	Umurangi/ Umujosi	Inshenzi	Total
Single	20.9%	12.1%	4.4%	52.7%	90.1%
Double	-	1.1%	-	7.7%	8.8%
Rose varieties	-	-	-	-	1.1%
Total	20.9%	13.2%	4.4%	60.4%	100.0%
Earlobes color					
Red	12.6%	8.4%	4.2%	32.6%	58.9%
White	5.3%	1.1%	-	22.1%	28.4%
Yellow	2.1%	5.3%	-	5.3%	12.6%
Total	20.0%	14.7%	4.2%	60.0%	100.0%

Note: Empty space in this above table means not applicable for that chicken.

4.2.3. Earlobe shapes and beak structure

Earlobe shapes and beak structures of local chickens in Rwanda are presented in Table 17. Oval earlobe was the most dominant with 76.1% compared to round earlobe (23.9 %). Inshenzi was the most observed in all earlobe shapes with 59.8% followed by Sekaganda, Indayi and Umurangi with 20.7%, 14.7% and 4.3% respectively. The curve beak was the most dominant with 97.8% compared to straight beak (2.2%). Inshenzi was the highest observed in all beak structures with 60.4% followed by Inganda, Indayi and Umujosi with 19.8%, 14.3% and 4.4% respectively.

Table 17: Earlobe shape and beak structure

Earlobe shape	Name of the local chicken kept				Total
	Sekaganda	Indayi	Umurangi	Inshenzi	
Round	3.3%	3.3%	-	17.4%	23.9%
Oval	17.4%	10.9%	4.3%	42.4%	76.1%
Total	20.7%	14.1%	4.3%	59.8%	100.0%
Structure of beak					
Straight		1.1%	1.1%	-	2.2%
Curve	19.8%	13.2%	3.3%	60.4%	97.8%
Total	19.8%	14.3%	4.4%	60.4%	100.0%

Note: Empty space in this above table means not applicable for that chicken.

4.2.4. Beak color and feather structure

Beak color and feather structure of IC across four agro-ecological zones are shown in Table 18. Brown beak was high observed with 36.7% followed by black, yellow and white with 28.4%, 27.8% and 6.7% respectively. Inshenzi was the most prominent in all beak colors with 61.1% followed by Sekaganda, Indayi and Umurangi with 18.9%, 14.4% and 4.4% respectively. Inshenzi was the most prominent in smooth feather structure with 60.4% followed by Inganda, Indayi and Umujosi with 19.8%%, 14.3% and 4.4% respectively.

Table 18: Beak color and feather structure

Color of beak	Name of the local chicken kept				Total
	Sekaganda	Indayi	Umurangi	Inshenzi	
Yellow	4.4%	3.3%	2.2%	16.7%	27.8%
Black	7.8%	3.3%	1.1%	16.7%	28.9%
Brown	6.7%	6.7%	1.1%	22.2%	36.7%
White	-	1.1%	-	5.6%	6.7%
Total	18.9%	14.4%	4.4%	61.1%	100.0%
Feather structure					
Smooth	19.8%	14.3%	4.4%	60.4%	100.0%
Total	19.8%	14.3%	4.4%	60.4%	100.0%

Note: Empty space in this above table means not applicable for that chicken.

4.2.5. Eye and shank colors

Eye and shank colors of IC in Rwanda are presented in Table 19. Eye pink was the most dominant with 89.2 % followed by yellow and brown with 8.6% and 2.2% respectively. Inshenzi was the highest observed in all eye colors with 61.3% followed by Sekaganda, Indayi, and Umurangi with 18.3%, 15.1% and 4.3% respectively. Yellow shank was high dominant with 46.8% followed by white, black, greenish, pink and still blue with 35.1%, 9.6%, 6.4%, and 1.1% respectively. Inshenzi was the most prominent in all shank colors with 60.6% followed by Sekaganda, Indayi and Umurangi/ Umujosi with 19.1%, 14.9% and 4.3% respectively.

Table 19: Eye and shank colors

	Name of the local chicken kept				
Eye color	Sekaganda	Indayi	Umurangi	Inshenzi	Total
Pink	16.1%	14.0%	4.3%	53.8%	89.2%
Yellow	2.2%	1.1%	-	5.4%	8.6%
Brown	-	-	-	2.2%	2.2%
Total	18.3%	15.1%	4.3%	61.3%	100.0%
Shank color					
Pink	-	-	-	1.1%	1.1%
White	5.3%	5.3%	1.1%	23.4%	35.1%
Yellow	8.5%	8.5%	3.2%	25.5%	46.8%
Still blue	-	-	-	1.1%	1.1%
Greenish	2.1%	-	-	4.3%	6.4%
Black	3.2%	1.1%	-	5.3%	9.6%
Total	19.1%	14.9%	4.3%	60.6%	100.0%

Note: Empty space in this above table means not applicable for that chicken.

4.2.6. Average of different morphological and production parameters

Average of the different morphological and production parameters of indigenous chickens in Rwanda is shown in Table 20. The total body weight of IC was not significant different ($p > 0.05$) with 1.58±0.24kg. Umurangi has the highest body weight with 1.771 ±0.11kg followed by Indayi, Inshenzi and Sekaganda with 1.66±0.45kg, 1.59±0.005kg and 1.44±0.39kg respectively. The average of crest height of local chickens was not significant different ($p > 0.05$) with 1.49±0.09cm. Indayi has the highest crest height with 1.59±0.06cm followed by Sekaganda, Inshenzi, and Umurangi with 1.53±0.23cm, 1.48±0.05cm and 1.43±0.02cm respectively.

The overall mean of crest length of IC kept was not significant different ($p > 0.05$) with 3.43±0.23cm. Indayi has the highest crest length with 4.07±0.37cm followed by Umurangi, Sekaganda and Inshenzi with 3.75±0.15cm, 3.71±0.16cm and 3.20±0.23cm respectively. The total head length of IC kept was not significant different ($p > 0.05$) with 6.58±0.06cm. Umurangi has the most head length with 6.75±0.1cm followed by Indayi and Inshenzi are both equal and lastly Sekaganda with 6.61±0.02cm and 6.42±0.09cm respectively.

The overall mean of beak length was not significant different ($p > 0.05$) with 2.89±0.07cm. Umurangi was the most beak length with 3.13±0.14cm followed by Inshenzi, Indayi and Sekaganda with 2.89±0.00cm, 2.88±0.01cm and 2.86±0.02cm respectively. The average of wattle length of IC was not significant different ($p > 0.05$) with 1.89±0.07cm. Umurangi has the highest wattle length with 2.13±0.14cm followed by Indayi, Sekaganda and Inshenzi with 2.0±0.08cm, 1.92±0.02cm, and 1.83±0.03cm respectively.

The overall mean of neck length in local chicken kept was not significant different ($p > 0.05$) with 9.97±0.06cm. Umurangi has the most neck length with 10.25±0.16cm followed by Inshenzi, Indayi and Sekaganda with 9.97±0.00cm, 9.93±0.02cm and 9.87±0.06cm respectively. The total diameter of the thorax in domesticated local chickens was not significant different ($p > 0.05$) with 10.09±0.45cm. Inshenzi has the highest thorax diameter with 10.35±0.15cm followed by Indayi, Sekaganda and Umujosi with 10.25±0.09cm, 9.71±0.22cm and 7.75±1.35cm respectively.

Overall mean of body length across the IC kept was not significant different ($p > 0.05$) with 20.31±0.59cm. Indayi was the most body length with 21.37±0.61cm followed by Inshenzi, Sekaganda and Umurangi with 20.56±0.14cm, 19.18±0.65cm and 18.63±0.97cm

respectively. The total tarsus diameter of local chickens kept was significant ($p < 0.05$) with 3.46±0.18cm. Umurangi was the highest tarsus diameter with 4.38±0.53cm followed by Indayi, Inshenzi and Sekaganda with 3.50±0.02cm, 3.49±0.02cm and 3.19±0.15cm respectively. The average of tarsus length of IC was not significant different ($p > 0.05$) with 11.16±0.27cm. Umurangi has the highest tarsus length with 11.50±0.19cm followed by both Inshenzi and Sekaganda and lastly Indayi with 11.37±0.12cm and 10.00±0.67cm respectively.

The total diameter of the shank of native chickens kept was not significant different ($p > 0.05$) with 1.36±0.21cm. Indayi was the most dominant in shank diameter with 1.48±0.64cm followed by Inshenzi, Sekaganda and Umujosi with 1.38±0.01cm, 1.24±0.07cm and 1.13±0.13cm respectively. The overall mean of shank length among the IC was not significant different ($p > 0.05$) with 7.28±0.07cm. Indayi has the most shank length with 7.5±0.13cm followed by Inshenzi, Umujosi, and Inganda with 7.26±0.01cm, 7.25±0.02cm and 7.07±0.12cm respectively.

The total wing length of the native chicken kept was not significant different ($p > 0.05$) with 13.82±0.29cm. Indayi has the most wing length with 14.60±0.45cm followed by Inshenzi, Sekaganda and Umurangi are both equal with 13.90±0.04cm and 13.25±0.33cm respectively. The average of wingspan across the IC kept was not significant different ($p> 0.05$) with 52.37±3.01cm. Indayi has the highest wingspan with 54.64±1.331cm followed by Inshenzi, Sekaganda and Umurangi with 53.0±0.38cm, 52.05±0.18cm and 34.75±10.17cm respectively.

The overall mean of female age sexual maturity across the IC was not significant different ($p > 0.05$) with 6.57±0.48months. Umurangi has the highest age of female sexual maturity with 9.00±1.40months followed by Inshenzi, Sekaganda and Indayi with 6.64±0.04months, 6.25±0.18months and 6.00±0.33months respectively. The overall mean of male age sexual maturity in IC kept was not significant different ($p > 0.05$) with 7.00±0.19 months. Umurangi has the highest age of male sexual maturity with 7.67±0.38 months followed by Inshenzi, Indayi and Sekaganda with 7.33±0.38months, 7.00±0.00 months and 6.00±0.57months respectively.

The total age at point of laying for all local chicken kept was the highest significant ($p < 0.001$) with 7.07±1.86months. Umurangi has the highest age at point of laying with 8.0months followed by Inshenzi, Sekaganda and Indayi 7.29months, 7.00months and 6.00

months respectively. The total number of eggs laying/clutch among the IC was not significant different ($p > 0.05$) with 13.79±0.77eggs. Umurangi has the most observed in great number of eggs laying/clutch with 18.00±1.18eggs followed Inshenzi, Indayi, Sekaganda with 14.25±0.94eggs, 13.38±0.23eggs and 12.50±0.74eggs respectively. The total number of clutches per year of IC kept was not significant different ($p > 0.05$) with 3.52±0.16. Umujosi has the highest in number of clutches per year with 4.00±0.27clutches followed Inshenzi, Sekaganda and Indayi with 3.68±0.09, 3.33±0.11, 3.173.17±0.20 clutches respectively.

The total of annual egg production across the IC kept was not significant different ($p > 0.05$) with 46.06±5.91eggs. Umujosi has the highest annual egg production with 72.00±14.97eggs followed Inshenzi, Sekaganda and Indayi with 49.50±1.98, 42.17±2.24eggs and 38.29±4.48eggs respectively. The hatching rate among local chickens kept was not significant different ($p > 0.05$) with 82.30%. Umurangi was the highest hatching rate with 99.00% followed Indayi, Sekaganda and Inshenzi with 88.71%, 82.00% and 79.81% respectively.

The hatchability rate under natural incubation for all local chicken kept was not significant different ($p > 0.05$) with 81.11%. Umurangi has the most hatchability rate under natural incubation with 99.00% followed Indayi, Sekaganda and Inshenzi with 87.00%, 82.00%, 78.53% and 62% respectively.

Table 20: Average of different morphological and production parameters

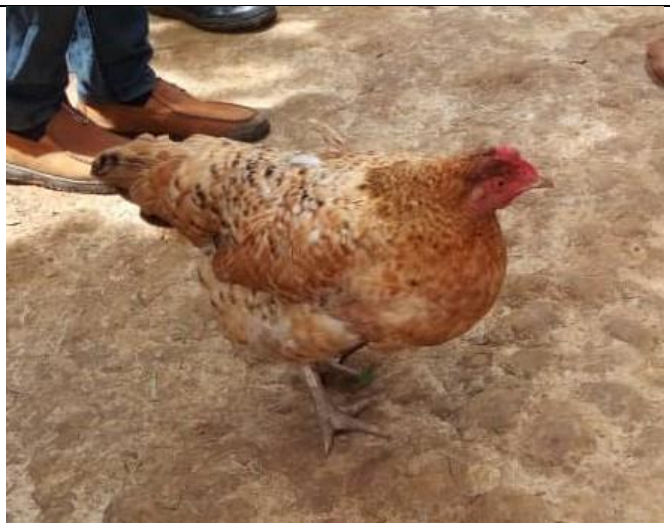
Morphological Parameters	Sekaganda (Inganda)	Indayi	Umurangi/ Umujosi	Inshenzi	Total	P Value
Weight measurements in kg	1.43±0.39	1.66±0.45	1.77±0.11	1.59±0.005	1.58±0.24	0.752
Crest height measurements in cm	1.53±0.23	1.59±0.06	1.45±0.02	1.48±0.05	1.49±0.09	0.903
Crest length measurement in cm	3.71±0.16	4.07±0.37	3.75±0.15	3.20±0.23	3.43±0.23	0.178
Head length measurement in cm	6.42±0.09	6.61±0.02	6.75±0.1	6.61±0.02	6.58±0.06	0.911
Beak length measurement	2.86±0.02	2.88±0.01	3.13±0.14	2.89±0.00	2.89±0.07	0.963

Wattle length measurements in cm	1.92±0.02	2.03±0.08	2.13±0.14	1.83±0.03	1.89±0.07	0.988
Neck length measurement in cm	9.87±0.06	9.93±0.02	10.25±0.16	9.97±0.00	9.97±0.06	0.979
Diameter of the thorax in cm	9.71±0.22	10.25±0.09	7.75±1.35	10.35±0.15	10.09±0.45	0.412
Body length in cm	19.18±0.65	21.37±0.61	18.63±0.97	20.56±0.14	20.31±0.59	0.640
Diameter of the tarsus in cm	3.19±0.15	3.50±0.02	4.38±0.53	3.49±0.02	3.46±0.18	0.021
Length of the tarsus in cm	11.37±0.12	10.00±0.67	11.50±0.19	11.37±0.12	11.16±0.27	0.170
Diameter of the shank in cm	1.24±0.07	1.48±0.64	1.13±0.13	1.38±0.01	1.36±0.21	0.219
Shank length in cm	7.07±0.12	7.50±0.13	7.25±0.02	7.26±0.01	7.28±0.07	0.434
Wing length in cm	13.25±0.33	14.60±0.45	13.25±0.33	13.90±0.04	13.82±0.29	0.624
Wingspan measurement in cm	52.05±0.18	54.64±1.331	34.75±10.17	53.03±0.38	52.37±3.01	0.092
Production Parameters	Sekagandа (Inganda)	Indayi	Umurangi/ Umujosi	Inshenzi	Total	P Value
Age to sexual maturity for females	6.25±0.18	6.00±0.33	9.00±1.40	6.64±0.04	6.57±0.48	0.291
Age at point of lay	7.00±0.34	6.00±0.92	8.00±6.00	7.29±0.18	7. 07±1.86	0.000
Age to sexual maturity for males	6.00±0.57	7.00±0.00	7.67±0.38	7.33±0.19	7.00±0.19	0.333
Number of eggs laying/clutch	12.50±0.74	13.38±0.23	18.00±1.18	14.25±0.94	13.79±0.77	0.777
Number of clutches per year	3.33±0.11	3.17±0.20	4.00±0.27	3.68±0.09	3.52±0.16	0.953

Annual egg production	42.17±2.24	38.29±4.48	72.00±14.97	49.50±1.98	46.06±5.91	0.382
Hatching rate (%)	82.00±0.17	88.71±3.7	99.00±9.64	79.81±2.06	82.30±3.89	0.135
The hatchability rate under natural incubation	82.00±0.51	87.00±3.40	99.00±10.32	78.53±1.48	81.11±3.92	0.138

Table 21: Morphologically features of identified four local breed chickens

S/N	Names	Phenotypic characteristics	Pictures
1	Imirangi	- Lack of feathers on the neck actually called necked neck, - Medium to big size - Weight = 1.77-2.5kg - Eggs/year=72 - Hatchability rate= 99% - More preferable by consummers	 Male necked neck 

			Female necked neck 
	Indayi	- Normal feathers' - Big in size than others - Weight = 1.66-2kg - Egg/year= 38 - Harchability rate: 89% - Preferable by consumers on the market show to be big some can reach 2 kg	

			
	Inshenzi	- Normal feathers - Small size - Weight= Between 1-1.5kg - Eggs per year =49.5 - Hatchability rate=80% - Good in mothering abilitty - Not preferable on the local market because of small size less than 1.5 kg	  Inshenzi small size, most are black with black legs

	Inganda (Sekaganda)	- Normal feathers - Smaller size - Eggs /year= 42 - Number of clatches/year = 3 - Hatchability rate = 82 - Good in mothering abilitty -Weight = 0.8kg-1.3kg	

4.3. Genetic characterization

4.3.1. SNP related to beak length (B L)

The SNP related to selected beak length of indigenous chickens across four agro-ecological zones are presented in Table 22. The related gene STX18 was significant different ($p < 0.05$). It had a real position of 78612470 and located on 4th chromosome with related to 100044766.36.A.G markers. This related gene was responsible for disease resistance. The related gene RFX6 was significant different ($p < 0.05$). It had a real position of 63678051 and located on 3rd chromosome with related to 100039945.53.T.C markers. This related gene was crucial role in egg production and reproductive performance.

The related gene CDK19 was significant different ($p < 0.05$). It had a real position of 66408840 and located on 3rd chromosome with related to 100041210.14.C.A markers. This related gene was responsible for egg and meat quality. The related gene SGK1 was significant different ($p < 0.05$). It had a real position of 56158908 and located on 3rd chromosome with related to 100099665.64.T.C markers. This related gene was targeted for meat quality. The related gene CITED2 was significant different ($p < 0.05$).

It had a real position of 53903475 and located on 3rd chromosome with related to 100045868.7.C.T markers. This related gene was responsible for resistance to harsh environment for indigenous chickens. The related gene ENSGALG00000012941 was significant different ($p < 0.05$). It had a real position of 73032184 and located on 2nd chromosome with related to 100049572.56.A.G markers. This related gene was intervened in egg production and growth.

The related gene PHLDB2 was significant different ($p < 0.05$). It had a real position of 89772462 and located on 1st chromosome with related to 100080273.27.A.G markers. This related gene was played important role in disease resistance. The related gene ENSGALG00000049712 was significant different ($p < 0.05$). It had a real position of 2281 and located on 3rd chromosome with related to 100136093.24.G.C markers. This related gene was responsible for disease resistance and stressful condition.

The related gene ENSGALG00000053660 was significant different ($p < 0.05$). It had a real position of 79874338 and located on 1st chromosome with related to 100081949.68.C.T markers. This related gene was intervened in egg laying at optimum level.

Table 22: SNP related to beak length (B L)

SNP	Chr	Pos	FDR_Adjusted_P-values	Related genes	Locus
100044766.36.A.G	4	78612470	7.09E-05	STX18	within
100039945.53.T.C	3	63678051	0.001479	RFX6	U31820
100041210.14.C.A	3	66408840	0.001479	CDK19	within
100099665.64.T.C	3	56158908	0.002586	SGK1	U46627
100045868.7.C.T	3	53903475	0.002586	CITED2	U156192
100049572.56.A.G	2	73032184	0.002586	ENSGALG00000012941	within
100080273.27.A.G	1	89772462	0.002586	PHLDB2	within
100136093.24.G.C	3	2281	0.002586	ENSGALG00000049712	within
100081949.68.C.T	1	79874338	0.002945	ENSGALG00000053660	within

4.3.2. SNP related to wattle length (W L)

The SNP related to selected wattle length of indigenous chickens across four agro-ecological zones are presented in Table 23. The related gene ADPRH was significant different ($p < 0.05$). It had a real position of 93661553 and located on 1th chromosome with related to 100045966.25.C.G markers. This related gene was responsible for meat and egg quality. The

related gene ENSGALG00000050573 was significant different ($p < 0.05$). It had a real position of 25655729 and located on 4th chromosome with related to 100054325.62.A.G markers. This related gene was played role in growth and weight gain for local chickens. The related gene ENSGALG00000050989 was significant different ($p < 0.05$). It had a real position of 15870065 and located on 8th chromosome with related to 100095277.27.A.G markers. This related gene was intervened to reproduction and growth.

The related gene ENSGALG00000046839 was significant different ($p < 0.05$). It had a real position of 57592228 and located on 5th chromosome with related to 100153470.22.T.C markers. This related gene was intervened to egg production. The related gene SEC14L1 was significant different ($p < 0.05$). It had a real position of 4094235 and located on 18th chromosome with related to 100028819.26.G.C markers. This related gene was highly resistance to stressful condition.

The related gene SLC25A29 was significant different ($p < 0.05$). It had a real position of 48728971 and located on 5th chromosome with related to 100162872.64.C.T markers. This related gene was responsible for egg and meat quality. The related gene ENSGALG00000054818 was significant different ($p < 0.05$). It had a real position of 2222 and located on 1st chromosome with related to 100165698.21.G.T markers. This related gene was responsible for egg and meat quality and quantity.

The related gene NQO2 was significant different ($p < 0.05$). It had a real position of 66369841 and located on 2nd chromosome with related to 100050457.18.G.A markers. This related gene was responsible for egg production.

Table 23: SNP related to wattle length (W L)

SNP	Chr	Pos	FDR_Adjusted_P-values	Related genes	Locus
100045966.25.C.G	1	93661553	1.78E-06	ADPRH	within
100054325.62.A.G	4	25655729	1.78E-06	ENSGALG00000050573	D13975
100095277.27.A.G	8	15870065	1.78E-06	ENSGALG00000050989	D313
100153470.22.T.C	5	57592228	1.78E-06	ENSGALG00000046839	within

100028819.26.G.C	18	4094235	0.000172	SEC14L1	within
100162872.64.C.T	5	48728971	0.000769	SLC25A29	U1270
100165698.21.G.T	1	2222	0.001649	ENSGALG00000054818	U3051
100050457.18.G.A	2	66369841	0.004975	NQO2	D4300

4.3.3. SNP related to head length (H L)

The SNP related to selected head length of indigenous chickens in Rwanda are presented in Table 24. The related gene EPS15 was significant different ($p < 0.05$). It had a real position of 24427568 and located on 8th chromosome with related to 100045814.61. C.A markers. This related gene was played significant role in growth and productivity. The related gene AUTS2 was significant different ($p < 0.05$). It had a real position of 2115462 and located on 19th chromosome with related to 100086967.33.C.T markers. This related gene was intervened in growth rate.

The related gene PRR5 was significant different ($p < 0.05$). It had a real position of 69759741 and located on 1st chromosome with related to 100099368.67.T.C markers. This related gene was played important role in growth rate. The related gene SPATA5 was significant different ($p < 0.05$). It had a real position of 53378062 and located on 4th chromosome with related to 100128859.59.C.A markers. This related gene was responsible for growth. The related gene NPHP1 was significant different ($p < 0.05$). It had a real position of 3082972 and located on 3rdchromosome with related to 100097113.59.T.C markers.

This related gene was responsible for chicken's resistance to harsh environment. The related gene ENSGALG00000053126 was significant different ($p < 0.05$). It had a real position of 96156813 and located on 1stchromosome with related to 100136984.39.C.A markers. This related gene was responsible for egg quality.

Table 24: SNP related to head length (H L)

SNP	Chr	Pos	FDR_Adjusted_P-values	Related genes	Locus
100045814.61.C.A	8	24427568	0.004295	EPS15	within
100086967.33.C.T	19	2115462	0.004295	AUTS2	within
100099368.67.T.C	1	69759741	0.004295	PRR5	within
100128859.59.C.A	4	53378062	0.004295	SPATA5	U3672
100097113.59.T.C	3	3082972	0.004295	NPHP1	within
100136984.39.C.A	1	96156813	0.004295	ENSGALG00000053126	D4905

4.3.4. Nearest genes related to identified SNP

The nearest genes related to identify SNP of indigenous chickens in Rwanda are presented on Table 25. The nearest gene LOC776067, CDC16 had a real position of 137692275 and located at NC_006088.4 on 1st chromosome with related to T marker. It was responsible for meat quality and quantity. The nearest gene DHRSX, CD99, LOC107051960 had a real position of 129958897 and located at NC_006088.4 on 1st chromosome with related to C marker. It played role in meat quality. The nearest gene LOC101750813, MX1 had a real position of 101256943 and located at NC_006088.4 on 1th chromosome with related to T marker.

It played role in viral disease resistance. The nearest gene LOC107053692, GRAP2 had a real position of 50383558 and located at NC_006088.4 on 1st chromosome with related to A marker. It was responsible for egg production. The nearest gene JARID2, PRL, LOC10751657 had a real position of 61140781 and was located at NC_006089.4 on 2nd chromosome with related to C marker. It had a great impact to local environment adaptation.

The nearest gene CALB1, mRNA: XM_0049399117.3 had a real position of 119443614 and located at NC_006089.4 on 2nd chromosome with related to T marker.

It was responsible for egg quality. The nearest gene ADCYAP1, CDH2 had a real position of 93149588 and located at NC_006089.4 on 2nd chromosome with related to C marker. It was responsible for eggshell quality. The nearest gene ALB, IL8L2 had a real position of 51805394 and located at NC_006091.4 on 4th chromosome with related to A marker. It played crucial role in immune response. The nearest gene LOC10756603 had a real position of 8453 and located at NT_461106.1 on 4th chromosome with related to G marker.

It played important role in body weight development. The nearest gene C8H14ORF80 had a real position of 4304485 and located at NC_006095.4 on 8th chromosome with related to C marker. It was against over development of ovarian tumor. The nearest gene LOC10751673, CDS: XP_015149132.1 had a real position of 4304485 and located at NC_006095.4 on 8th chromosome with related to A marker. It had the adaptive feature to hard environment. The nearest gene GABRB2, CDS: XP_015149132.1 had a real position of 8272097 and located at NC_006100.4 on 13th chromosome with related to A marker.

It played role in development of body and egg weight. The nearest gene LECT2, CDS: XP_015149132.1 had a real position of 16352162 and located at NC_006100.4 on 13th chromosome with related to A marker. It was responsible for increasing of egg production. The nearest gene NOTCH, UBC1, CDS: XP_0153010.1 had a real position of 8458226 and located at NC_006104.4 on 17th chromosome with related to C marker. It contributed to better adaptation to bad conditions in local area. The nearest gene SPNS3, CDS: XP_015151456.1, mRNA: 015295970.2 had a real position of 3336281 and located at NC_006106.4 on 19th chromosome with related to A marker.

It played a great role in increasing of egg production. The nearest gene RASSF5, XP_015151456.1, MRNA: 0155298926.2 had a real position of 3336281 and located at NC_006106.4 on 19th chromosome with related to A marker. It contributed to growth and meat quality. The nearest gene PBX1 had a real position of 5672840 and located at NC_006095.4 on 8th chromosome with related to T marker. It intervened in growth and immunity. The nearest gene RXRG, FMO3, GLUL gene had a real position of 5672840 and located at NC_006095.4 on 8th chromosome with related to T marker.

It was responsible for development and meat color quality. The nearest gene LOC107054293, CEBPA had a real position of 10145725 and located at NC_006098.4 on 11th chromosome with related to T marker. It contributed to an increase of body weight. The nearest gene LOC107054316, BCO1, CDH13 had a real position of 15831341 and it was located at NC_006098.4on 11th chromosome with related to T marker. This nearest gene played crucial role in meat quality and growth weight. The nearest gene DHRS11, LHX1, ACACA had a real position of 8356215 and located at NC_006106.4 on 19th chromosome with related to A marker.

It was associated with an increase of egg production. The nearest gene ALB, IL8L2, FGF2, ANXAS had a real position of 51805394 and located at NC_006091.4 on 4th chromosome with related to A marker. It was responsible for an improvement of egg and weight traits.

Table 25: The nearest genes related to identified SNPs

Locus	CHR	Real positon	Nearest gene	Marker
NC_006088.4	1	137692275	LOC776067 CDC16	T
NC_006088.4	1	129958897	DHRSX, CD99, LOC107051960	C
NC_006088.4	1	101256943	LOC101750813, MX1	T
NC_006088.4	1	50383558	LOC107053692, GRAP2	A
NC_006089.4	2	61140781	JARID2, PRL LOC10751657	C
NC_006089.4	2	119443614	CALB1 mRNA: XM_0049399117.3	T
NC_006089.4	2	93149588	ADCYAP1, CDH2	C
NC_006091.4	4	51805394	ALB, IL8L2	A
NT_461106.1	7	8453	LOC10756603	G
NC_006095.4	8	4304485	C8H14ORF80	C
NC_006095.4	8	4304485	LOC10751673 CDS:XP_015149132.1	A
NC_006100.4	13	8272097	GABRB2 CDS:XP_015149132.1	A
NC_006100.4	13	16352162	LECT2 CDS:XP_015149132.1	A
NC_006104.4	17	8458226	NOTCH UBC1 CDS:XP_0153010.1	C

NC_006106.4	19	3336281	SPNS3 CDS: XP_015151456.1 mRNA: 015295970.2	A
NC_006113.4	26	2497963	RASSF5 XP_015151456.1 MRna:0155298926.2	T
NC_006095.4	8	5672840	PBX1,	T
NC_006095.4	8	5672840	RXRG, FMO3, GLUL	T
NC_006098.4	11	10145725	LOC107054293, CEBPA,	T
NC_006098.4	11	15831341	LOC107054316, BCO1,CDH13	T
NC_006106.4	19	8356215	DHRS11 LHX1 ACACA	A
NC_006091.4	4	51805394	ALB, IL8L2, FGF2, ANXAS	A

4.3.5. Homozygosity of indigenous chicken

Homozygosity (Ho) of indigenous chicken in Rwanda is presented in Table 26. This current study showed that Umurangi was the lowest in homozygosity with 0.140088 followed by Inshenzi, Inganda and Indayi with 0.15327, 0.154654 and 0.158944 respectively.

Table 26: Homozygosity of indigenous chicken

Generation	Inganda	Indayi	Inshenzi	Umurangi
0	189924	188564	570849	83931
1	38431	39497	114261	15230
2	20141	20435	60378	9556
Ho	0.154654	0.158944	0.15327	0.140088

4.3.6. Genetic distance of indigenous chicken

Genetic distance of indigenous chickens in Rwanda is shown in Table 27. This present study indicated that between Umurangi and Inshenzi was the lowest genetic distance with 0.022467 followed by between Umurangi and Inganda with 0.02471 and between Umurangi and Indayi with 0.031528 respectively.

Table 27: Genetic distance of indigenous chicken

Fst	Inganda	Indayi	Inshenzi	Umurangi
Inganda	1	-	-	-
Indayi	0.00684	1	-	-
Inshenzi	0.002248	0.009087	1	-
Umurangi	0.02471	0.031528	0.022467	1

Note: Empty space in this above table means not applicable for that chicken.

CHAPTER FIVE: DISCUSSION

Our research proved the hypothesis as the management systems of indigenous chickens, their phenotypic and genetic diversity in terms of production aren't enough compare to their full genetic potential. The present findings were similar to the study conducted by Faruque et al (2010) who identified preferred traits from poultry farmers to use genetic superior of indigenous chicken and kept them for genetic improvement. In additionally, this finding was reported by NIANG (2012) who proved that the sale of chicken cuts would increase demand among lower-income customers.

Furthermore, the same author confirmed that, the indigenous chickens have an ideal mothers and foragers to have particular characters that contribute to survivability and reproduction under harsh climates (Jesuyon and Salako, 2013).

5.1. Management system of indigenous chickens

5.1.1. Chicken production system

Chicken production system was the highest significance ($p < 0.001$) in Rwanda (Table 1). Scavenging only and scavenging + seasonal supplementation were the most dominant in all chicken production system. According to Abdurahman (2016) who reported the quietly similar result, scavenge with additional supplementation was the most dominant.

5.1.2. Flock productivity

Sexual maturity for cocks, sexual maturity for hen, egg laying cycles per year, eggs given for incubation, chicks hatched per cycle, number of weaned chicks and chicks' mortality rate were the highest significant ($p < 0.001$) across four agro-ecological zones (Table 2). Sexual maturity for cocks and hens was varied 6.5months for male and 6.7 months for female. According to Mahoro (2017); quietly similar result was obtained where 6.7months and 7.5months were responsible for male and female sex maturity. There is variation of age at sexual maturity for both sexes of local chickens (Hirwa et al, 2019).

Egg laying cycles per year was the average of 3.0. The founding was conformity to report of Simainga et al (2011); where *Tswana* chickens produces three clutches per year. The quantity of eggs produced per cycle was not significant different ($p > 0.05$) with 17.7eggs. In agreement with Mwalusanya et al (2001); the average number of eggs laid per clutch under scavenging condition was ranges from 6 to 28 eggs per clutch. The chicken egg laid per year was an average of 47.9 eggs. The same result was confirmed by Simainga et al (2011); where

the IC laid the average of 46 eggs per year. The average chicks hatched per cycle was 7.6 chicks per 8.8 eggs under natural incubation. Similar to the founding of Simainga et al (2011); who reported the average of 8 chicks were hatched from clutch size of 15 eggs.

5.1.3. Feeding Practices

The present of this study indicated the significant different ($p < 0.05$) in the feeding practices and scavenge with supplement was the most dominant with 51.9±0.9 followed by total scavenging and entirely on commercial diet with 42.8±3.33 and 7.1±0.4 respectively (Table 6). Similar to the founding of Abdurahman (2016) in Ethiopia where highly level was the chickens scavenge with additional supplementation followed by spread feed simply on ground and entirely on commercial diet.

5.1.4. Provision of water

The result of this study showed significant different ($p< 0.05$) and a great part of IC farmers was provided water to their chickens with 91.3% (Table 7). Part of a jerry cans entirely were the mainly water provision equipment used with 51.1% followed by sauce pan, other (specify)*****, drinker and broken Pots with 27.2%, 9.5, 6.9 and 5.3% respectively. In line with Gezali Abafaji (2017); where almost of the respondents provided water to their chickens and the great number of chicken farmers (57.7%) used any broken material while 40.6% used plastic materials and watering trough from wood.

5.1.5. Major constraints on feeding management

According to this present study; expensive feeds was the most constraint on feeding management (Table 8). The same research was conducted by Wachira et al (2010); where the poor quality and cost of feed was an important production constraint to local chicken farmers.

5.1.6. Breeds and breeding management of chickens

Our study results showed that; carrying out selection of local chickens was significant different ($p < 0.05$) in Rwanda (Table 9). In agreement with Faruque et al (2015); a great number of chicken farmers of Bangladesh were focused on improvement of both body weights at 8 weeks and egg production up to 40 weeks of age through selective breeding. There was not significant different ($p > 0.05$) in few chicken farmers who were done crossbreeding (24.4%).

Contrary to the results reported by Mearg Fitsum (2017); where chicken farmers did a breeding practice in improving their chicken productivity through cross breeding method (60.3%).

5.1.7. Selection criteria of breeding stock

Our study results on selection of breeding stock (Table 10); showed that a cock with big body size, tall and high growth rate was the most dominant criteria. According to Duguma (2009), similar result was obtained where a size/conformation was also focused on live chicken in traditional poultry markets. A selection a hen with a good layer, big body size, hatchability and mothering ability were the most dominant criteria in this current study. Egg number, egg size, hatchability and mothering ability were the most chosen criteria for hen selection (Mearg Fitsum, 2017).

5.1.8. Housing and maintenance

The complete enclosure of this present study was high significant different ($p< 0.05$) with 56.6% followed by shared the same house with the owner, on the veranda, kitchen with 31.9%, 5.2% and 5.1% respectively (Table 11). According to Addisu et al (2013); similar result was obtained where 95.6% of the respondents in Lume districts constructs separate house entirely for poultry. Regular sweeping in chicken house of this current research was the most significant different ($p< 0.05$) with 94.8%. In line with Halima (2007); the 74.02 % of households cleaned their chickens' house once per day in northern Ethiopia.

5.1.9. Mortality levels and associated causes

There was high significant different ($p < 0.05$) in chick's mortality rates (92.7%) across four agro-ecological zones (Table 13). In agreement with NAERLS (2000); the chick mortality was highest during the dry season. The majority cause of chickens 'death; diseases was the most dominant and among them; Newcastle was the mainly cause of death. According to Alemayehu G and Solomon A (2018); the same result was reported where diseases were the highest level cause of mortality and Newcastle was the highest cause of mortality for local chickens (FAO, 2019).

The rainy season was high significant different ($p < 0.05$) in chicken's mortality rates. The risk of highest mortality was in the rainy season (Chauhan, 2015).

5.1.10. Vaccination

Vaccination of IC was significant different ($p < 0.05$) in Rwanda (Table 14). A great number of chicken's farmers were not vaccinating their chickens with 94.7%. According to Habte et al (2013); the same results was reported where 95.6% of chicken farmers did not vaccinate their chickens. There was high significant different ($p < 0.05$) from chicken farmers who did not aware about vaccination to their chickens (83.6%). In accordance with Emebet (2015); the chicken farmers had any experience from vaccination and the level of awareness was still low.

5.2. Phenotypic characterization

5.2.1. Plumage patterns

This present study showed that uniform and coronation plumage patterns were the most dominant in all local chicken kept with 24.7% followed by silver penciled, partridge, speckled, naked neck and mottled, rumples and barred with 12.9%, 10.8%, 8.6%, 7.5%, 2.2% and 1.1% respectively (Table 16). Quietly result was reported by E. A. Rotimi (2016); the three feather types were observed; normal feather, frizzled feather and naked neck with 88.49%, 6.20% and 5.31% respectively.

Dissimilar founding was reported where barred plumage pattern was the most observed plumage patterns with 46.55% followed by solid and mottled with 27.2% and 26.3% (Onasanya et al, 2018).

5.2.2. Earlobes color and comb forms

Our study result indicated that red and white earlobes color were the most dominant with 58.9% and 28.4% (Table 17). According to Biswas (2005); similar result was found where the red earlobe color of Desi chicken was 58 % followed by white earlobe of 45.8%. Single comb form for this present study was most dominant with 90.1% (Table 17). In line with Hailu et al (2013); the 59.7% of males and 72.2% of females were mainly characterized by single comb. According to Liyanage et al (2015); who were proved the same result that single comb was the dominant over any other comb types.

5.2.3. Beak color and feather structure

Brown and black beak colors of IC in this current study were the most dominant with 36.7% and 28.4% (Table 18). This result is quietly similar to the report of Odah et al (2019); where

black (48.90%) was the most wildly distributed beak color. All local chicken kept in our study results was smooth feather structure (Table 18). Dissimilar result was reported by Agbaje and Alabi (2018); where normal feather was the most dominant with 91.7%.

5.2.4. Eye and shank Color

Pink eye color of native chickens in our study was the most dominant with 89.2 % followed by yellow and brown with 8.6% and 2.2% respectively (Table 19). Contrary to Ikeobi et al (1996); the eye color among chicken populations studied was frequently black and light–brown with 44.72% and 14.91% respectively. The yellow and white shank colors of this current study were the most prominent with 46.8% (Table 19). In accordance with Addisu et al (2013); the yellow and white colors were highly appearance in shank colors.

5.2.5. Average of different morphological and production parameters

Average of different morphological and production parameters of indigenous chickens in Rwanda is shown in (Table 20). The total body weight of IC was not significant different ($p > 0.05$) with 1.58±0.24kg. According to Hirwa et al (2019); this result was quietly similar where I C weight was a mean of 1.4kg. In line with Yami and Dessie (1997); the mean body weight of hens was 1.41 kg and cocks 1.69 kg in the central highlands of Ethiopian. The overall mean of crest length of local chickens kept was not significant different ($p > 0.05$) with 3.43±0.23cm. In agreement with Odah et al (2019), the crest length was 3.9cm.

The overall mean of head, beak and wattle length of native chickens kept were not significant different ($p > 0.05$). The overall mean of head length was 6.58±0.06cm. In accordance with D. M. Ogah (2011); head length (cm) for Male had mean of 9.39±0.21 with minimum of 7.80 and maximum was 11.50 and female had mean of 6.71±0.16 with minimum 6.00 and maximum was 8.00. The average of beak length was 2.89±0.07cm. Conformity to Odah et al (2019); the beak length was 3.8cm. The average of wattle length was 1.89±0.07cm. According to Odah et al (2019); dissimilar results was reported where wattle length (3.30 ± 0.21cm).

The total neck length of IC was not significant different ($p > 0.05$) with 9.97±0.06cm. According to Odah et al (2019); quietly similar result to the current study was observed of moderate neck length (8. 9±0.50cm). Overall mean of body length of local chickens was not significant different ($p > 0.05$) with 20.31±0.59cm. As the same founding to Badubi et al (2006); average body length was recorded as 18.00 cm and 20.00 cm for male and female

local chickens in Botswana. The total tarsus diameter for native chickens kept was significant ($p < 0.05$) with 3.46±0.18cm. According to the report of Hirwa et al (2019); contrary result was conformed where 1.5cm was measured for IC's tarsus diameter. The average of tarsus length of IC was not significant different ($p > 0.05$) with 11.16±0.27cm. In line with Hailu (2018); the maximum length of the tarsus in cm was 10.9 ± 1.5 and minimum of 8.6 ±1.5. The total diameter of the shank of local chickens kept was not significant different ($p > 0.05$) with 1.36±0.21cm. In agreement with D. P. SAHOO et al (2017); the shank width (cm) had the maximum of 1.73±0.05 for one test and the 1.32±0.03 for another test.

The overall mean of shank length of IC kept was not significant different ($p > 0.05$) with 7.28±0.07cm. According of Melesse and Negesse (2011); quietly similar results were obtained where 9.4 cm was the shank length for male adult chickens. The total wing length for all local chicken kept was not significant different ($p > 0.05$) with 13.82±0.29cm. Dissimilar result was obtained where the wing length in cm was 25.0 (Uza, 2001). The average of wingspan across the IC was not significant different ($p > 0.05$) with 52.37±3.01cm.

According to Guni et al (2013); dissimilar result was reported where mean wingspan of Sheka chicken populations was 47.6 cm for chickens reared in the Southern highlands of Tanzania. The total female age sexual maturity of IC was not significant different ($p > 0.05$) with 6.57±0.48months. In agreement with Hirwa et al (2019); the mean age of sexual maturity for female in Rwanda was at 6.67 months. Aberra et al (2013) described the same result in different agro-ecological zones of Amhara region (6.6 months).

The overall mean of age sexual maturity for male in all local chicken kept was not significant different ($p > 0.05$) with 7.00±0.19 months. According to the report of Hirwa et al (2019); the same founding was conformed where 7.39 months was responsible for male local chicken in Rwanda to reach age sexual maturity. Dissimilar to the report of Yadessa et al (2017); the mean of male sexual maturity of IC in benchi-Maji zone were about 5.2months. The total age at point of lay for all IC kept was the highest significant ($p < 0.001$) with 7.60±1.86months. In line with Hirwa et al (2019); the local female chickens in Rwanda was started to lay eggs at 7.31 months.

According to Aberra et al (2013); reported quietly similar to the current study where age at first egg of scavenging chickens in different agro-ecological zones of Amhara region was 6.6 months. Average number of clutches per year was not significant different ($p > 0.05$) in all

local chicken kept with 3.52±0.16. The same result was reported in Central Tigray where the average clutch number per year was 3.15 to 3.2 and 3.2 at lowland and midland agro-ecologies, respectively (Alem, 2014). Furthermore result was reported by Melkamu and Wube (2013) in Debsan Tikara Kebele at Gonder Zuria Woreda where the average clutch numbers were 3 per year. Dissimilarity result was reported by CSA (2016); where the national average clutch number of Ethiopia indigenous chicken was 4 per year.

The total number of eggs laying/clutch of IC was not significant different ($p > 0.05$) with 13.79±0.77eggs. In accordance with Mulgeta and Tebikew (2013); a hen was laid 9-15eggs/clutch. The total annual egg production was not significant different ($p > 0.05$) for all local chicken kept with 46.06±5.91eggs. According to CSA (2016) in Ethiopia; similar results was obtained where indigenous chickens produce 48 small eggs per hen per year at farmers' management conditions.

Furthermore, similar result was reported by Alganesh et al (2003); where the egg production potential of local chicken is 30-60 eggs/year/hen under village management conditions. Hatching rate (%) of IC in this current study was not significant different ($p > 0.05$) with 82.30%. In agreement with Adeleke et al (2012); the hatching traits between frizzled and normal feathered chickens, presented 90.5 and 84.8% fertility, respectively, and Anak Titan and Naked Neck presented 80.1 and 76.7% hatchability, respectively.

The hatchability rate under natural incubation was not significant different ($p > 0.05$) for all native chicken kept with the total of 81.11%. In line with Ahmed et al (2012); the hatchability under natural incubation of Naked Neck and Full feathered was 87.40% and 86.98%) respectively. The same founding was reported by Sumy (2010); where hatchability was at 85%-89% and 80%-92% (Dunya et al, 2014).

5.3. Genetic characterization

5.3.1. SNP related to beak length (B L)

The SNP related to selected beak length of indigenous chickens across four agro-ecological zones are presented in Table 22. The related gene STX18 was significant different ($p < 0.05$). This related gene was responsible for disease resistance. The similar result was reported by Beilharz et al (1993), where there was an intervention of this gene to disease resistance. The related gene RFX6 was significant different ($p < 0.05$). This related gene was crucial role in egg production and reproductive performance.

The same outcome was reported by Tadelle et al (2003) in southern Ethiopia, where it has played role in hatching their produced eggs. The related gene CDK19 was significant different ($p < 0.05$). This related gene was responsible for egg and meat quality. Conformity result was reported by Moula et al (2010), where it has eggshell thickness which is slightly thinner compared to other shell zones and had meat quality regarded to the pH after 24 h of H'mong breed where 5.8 for pectoral muscles and between 5.8 for females and 5.9 for males for thighs meat muscles (Phuong, 2017).

The related gene SGK1 was significant different ($p < 0.05$). This related gene was targeted for meat quality. In line with Isidahomen et al (2012), this gene had a better carcass trait. The related gene CITED2 was significant different ($p < 0.05$). This related gene was responsible for resistance to harsh environment. The result was conformity to the observation of Welc SS (2013); it played role in response to stress. The related gene ENSGALG00000012941 was significant different ($p < 0.05$). This related gene was intervened in egg production and growth.

In agreement with Dana et al (2010), it had the growth and egg production traits which are responsible to pro-poor for small holder chicken farmers. The related gene PHLDB2 was significant different ($p < 0.05$). This related gene was played important role in disease resistance. According to Axford et al (2000); similar result was observed where the MHC alleles of this gene are worked with genetic resistance to diseases like avian leucosis, fowl cholera, *Salmonella* and coccidiosis. The related gene ENSGALG00000049712 was significant different ($p < 0.05$).

This related gene was responsible for disease resistance and stressful condition. The similar result was found by Walugembe et al (2019); it was important for IC to adapt to a variety condition such as high altitude, aridness and stressful factors like disease resistance, poor nutrition, oxidative and heat stresses. The related gene ENSGALG00000053660 was significant different ($p < 0.05$). This related gene was intervened in egg laying at optimum level. In accordance with Bridle et al (2006); it was responsible for immune response which should influence the genetics on laying hen welfare.

5.3.2. SNP related to wattle length (W L)

The SNP related to selected wattle length of indigenous chickens across four agro-ecological zones are presented in Table 23. The related gene ADPRH was significant different ($p < 0.05$). This related gene was responsible for meat and egg quality. In line with Choo et al

(2014); it was related to the level of tenderness with the age at slaughter. Eggshell quality is crucial factor in egg production (Roberts, 2004). The related gene ENSGALG00000050573 was significant different ($p < 0.05$). This related gene was played role in growth and weight gain. According to Allais S et al (2019); the same result was obtained where it was responsible for body weight and body size which are the keys factors for the body development of chicken.

The related gene ENSGALG00000050989 was significant different ($p < 0.05$). This related gene was intervened to reproduction and growth. This was conformity to the founding of Muchadeyi et al (2009); it played a crucial role in reproductive performance, growth and survival in harsh conditions. The related gene ENSGALG00000046839 was significant different ($p < 0.05$). This related gene was intervened to egg production. According to Kranis et al (2013), who was observed the same result, that the QTLs of this gene were associated with egg production traits.

The related gene SEC14L1 was significant different ($p < 0.05$). This related gene was highly resistance to stressful condition. In agreement with Apuno et al (2011); it had the quality of thermo-regulation for indigenous chickens. The related gene SLC25A29 was significant different ($p < 0.05$). This related gene was responsible for egg and meat quality. The similar founding was confirmed by Duc (2008); it was played role in an egg production in good range from 55 to 66 eggs/year and it has the water retention which favor for meat sweetness (Choo et al, 2014).

The related gene ENSGALG00000054818 was significant different ($p < 0.05$). This related gene was responsible for egg and meat quality and quantity. In line with Award (2015); this gene was related to meat or egg production in indigenous chicken. The related gene NQO2 was significant different ($p < 0.05$). This related gene was responsible for egg production. In agreement with Tadelle et al (2000); it was intervened in average egg production per year for local hen of 43.4eggs and her highest was 54.3 eggs.

5.3.3. SNP related to head length (H L)

The SNP related to selected head length of indigenous chickens in Rwanda are presented in Table 24. The related gene EPS15 was significant different ($p < 0.05$). This related gene was played significant role in growth and productivity. Our result was in accordance with Alabi (2013); this gene was associated with fed nutrients (protein, lysine and energy) to local chickens must reach optimally and maximum productivity. The related gene AUTS2 was significant different ($p < 0.05$). This related gene was intervened in growth rate.

The similar founding was confirmed by Emmerson (2003), where this gene was contributed in early growth selection trait among the broiler local chickens at 40-50days The related gene PRR5 was significant different ($p < 0.05$). This related gene was played important role in growth rate. In agreement with Kingori et al (2007), where fed them a protein at level of 16% with aged 14-21 weeks was optimizing the feed intake and growth. The related gene SPATA5 was significant different ($p < 0.05$).

This related gene was responsible for growth. According to Kingori et al (2007), it was a similar result for optimizing growth which was not depending on highest level of protein. The related gene NPHP1 was significant different ($p < 0.05$). This related gene was responsible for chicken's resistance to harsh environment. The similar founding was reported by Van Marle-Köster (2009); it was responsible for better adaptation to stressful environmental conditions. The related gene ENSGALG00000053126 was significant different ($p < 0.05$). This related gene was responsible for egg quality.

The same founding was observed by Alipanah (2013), where it contributed to genetic and phenotypic correlation in terms of egg quality.

5.3.4. The nearest genes related to identified SNP

The nearest genes related to identify SNP of indigenous chickens in Rwanda are presented on Table 25. The nearest gene LOC776067, CDC16 was responsible for meat quality and quantity. According to Wang et al (2006); similar founding was observed where it involved in growth and meat quality. Furthermore, it intervened in muscle development with associated to fatness traits (Dunislawska et al, 2020). It can be used in improvement of growth performance (Habimana, 2021). The nearest gene DHRSX, CD99, LOC107051960 was played role in meat quality.

In agreement with Jump et al (2005); it intervened in meat quality by control liver and whole-body fatness. The nearest gene LOC101750813, MX1 was played role in viral disease resistance. This was conformity to the founding of Rautenschlein et al (2020). Its Mx proteins induced by an infection with avian influenza virus are able to block an early step of the viral replication cycle. In additionally, the chicken Mx gene is highly polymorphic and it has antiviral activity (Seliger, 2012). Furthermore, this nearest gene was responsible for influenza virus resistance (Habimana, 2021).

The nearest gene LOC107053692, GRAP2 was responsible for egg production. The same result was found by Kamali et al (2007); it contributed in the highest value of cumulative egg production for first 12 weeks. The nearest gene JARID2, PRL, LOC10751657 had a great impact to local environment adaptation. According to Matsuzaki et al (2017), similar result was reported where it contributed in neuron proliferation that responsible for acclimation. The nearest gene CALB1, mRNA: XM_0049399117.3 was responsible for egg quality.

As described the same result by Le Roy (2017); it played crucial role in eggshell quality due to accumulation of calcium carbonate. The nearest gene ADCYAP1, CDH2 was responsible for eggshell quality. In accordance with Jonchère et al (2010), this nearest gene was associated with eggshell quality. Furthermore, it contributes to egg strength (Moreki et al, 2011). The nearest gene ALB, IL8L2 was played crucial role in immune response. According to Taylor et al (2004); the similar result was observed where it was mainly intervened in IFN dependent host resistance to a number of intracellular pathogens.

The nearest gene LOC10756603 played important role in body weight development. In line with Gous et al (1999); it was responsible for development of muscle and body growth rate for the broiler chicken. The nearest gene C8H14ORF80 was intervened in against over development of ovarian tumor. Conforming to Yeung et al (2017); it can mimic the multiplication of ovarian cancer cells. The nearest gene LOC10751673, CDS: XP_015149132.1 had the adaptive feature to hard environment. According to Eriksson et al (2007); the same founding was reported where intervention of this nearest gene was reflecting to the level of fitness through nutritional status and health.

The nearest gene GABRB2, CDS: XP_015149132.1 played role in development of body and egg weight. Similar result was reported by Bahmanimehr (2012); where it had responsible for body and egg weight. The nearest gene LECT2, CDS: XP_015149132.1 was responsible for increasing egg production. Higher values were reported by Kamali et al (2007); where this nearest gene was responsible for egg production with heritability of 0.49 for Iranian indigenous fowls in the first 12 weeks. The nearest gene NOTCH, UBC1, CDS: XP_0153010.1 was contributed to better adaptation to bad conditions in local area. Confirming to Aberra (2000); this nearest gene in Naked-neck has heat resistance in tropic zones.

The nearest gene SPNS3, CDS: XP_015151456.1, mRNA: 015295970.2 was played a great role in increasing egg production. In agreement with Kamali et al (2007), it was responsible for egg production in Iranian indigenous fowls. The nearest gene RASSF5, XP_015151456.1, MRna: 0155298926.2 was contributed to growth and meat quality.

According to Demeure et al (2013); similar result was reported where it has the traits which were responsible for growth or fat accretion. The nearest gene PBX1 intervened in growth and immunity. Conformity to Ohta et al (1999); it has the pituitary specific transcription factor which can bind to and transactivate promoters of growth hormone- and prolactin-encoding genes, and has an important regulatory effect on animal growth and immunity. The nearest gene RXRG, FMO3, GLUL was responsible for development and meat color quality.

In accordance with Le Bihan- Duval et al (2011); it has played role in meat quality appreciation. The nearest gene LOC107054293, CEBPA contributed to an increase of body weight. The same founding was reported by Fish et al (2013); where it was related to an increase of body weight in association between the mean value for neck length (12.77 cm) and shank length (7.84 cm). The nearest gene LOC107054316, BCO1, CDH13 played crucial role in meat quality and growth weight.

According to AACMC (1984); it contributed to body weight of indigenous chickens with 1.5 kg live weight at 24 weeks of age. The nearest gene DHRS11, LHX1, ACACA was associated with an increase of egg production. In agreement with Kamali et al (2007); it was responsible for egg production for the first 12 weeks in Iranian indigenous fowls. The nearest gene ALB, IL8L2, FGF2, ANXAS was responsible for an improvement of egg and body weight traits. According to El-Wardany et al (1992); this nearest gene was intervened to an increase of egg production and body weight. Further research was supported our study whereby it contributed to an increase number of eggs per year (Woldegiorgiss, 2015).

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

Our research revealed that; the management systems, phenotypically and genetic diversity among the indigenous chickens influence their production. Furthermore, the related and nearest genes from selected local chickens based on low homozygosity (0.140088 and 0.15327) and low similarities (0.022467) among those four indigenous chickens proved that Imirangi and Inshenzi have the highest genetic diversity and performance in production traits (egg and body weight) than two others (Indayi and Inganda).

The results are significant importance because they will help design and implement conservation strategies. In fact, the conservation of these breeds may also have positive impacts on the local economy, niche traditional markets, and offering a source of high-quality products to consumers. In this context, genomic information may play a crucial role in the management of local breeds.

Our observations may guide us in selection and breeding indigenous chicken with high genetic potential and provide new clues for further study in breeding program of indigenous chicken.

6.1. STUDY LIMITATIONS

This study was met with confusion from some chicken farmers during the naming of their local chickens and unestablished breeding program of indigenous chickens in Rwanda may end up with their conservation difficulty.

REFERENCES

AACMC (AUSTRALIAN AGRICULTURAL CONSULTING AND MANAGEMENT

Abd El-Halim HA (1999). Selection and genetic analysis of some meat and egg production traits in local chickens. Unpublished M.Sc. Thesis, Faculty of Agriculture, Alexandria University, Egypt.

Abdurahman Kedir Terie (2016). Studies on poultry management practices, marketing system and effect of feeding fish meal on growth performance and carcass characteristics of koekoek chickens in Bora District ,East Shoa Zone.

Abdurehman, A (2014). Study of production practices, fertility, hatchability and egg quality of rural chicken in gorogutu district, eastern Hararghe, Ethiopia. MSc. Thesis, Haramaya University.

Aberra M (2000). Comparative studies on performance and physiological responses of Ethiopian indigenous (Angete Melata) chickens and their f1 crosses to long term heat exposure. PhD dissertation, Martin-Luther University, Halle-Wittenberg Germany.

Aberra Melesse, Zemene Worku and Yosef Teklegiorgis (2013). Assessment of the prevailing handling and quality of eggs from scavenging indigenous chickens reared in different agro-ecological zones of Ethiopia. J. Env. Occu. Sci. 2(1):1-8.

Addisu H, Hailu M, Zewdu W (2013). Indigenous chicken production system and breeding practice in North Wollo, Amhara region, Ethiopia. Poult Fish Wildl Sci 1: 108.

Adeleke MA, Peters SO, Ozoje MO, Ikeobi CON, Bamgbose AM, Adebambo OA (2012). Effect of crossbreeding on fertility, hatchability and embryonic mortality of Nigerian local chickens. Tropical Animal Health and Production 2012; 44:505–510.

Agbaje H.A and Alabi O.O (2018). Application of GIs for biodiversity conservation of indigenous chickens in ile-ife, Nigeria.*51: 3–47*

Ahmed MF, Nishibori M, Islam MA (2012). Production and price of indigenous Naked Neck and full feathered chicken reared under rural scavenging system in Bangladesh. *Journal of Agricultural Extension and Rural Development,* Vol. 4(4):92-97.

Alabi, O.J.; Ng'ambi, J.W.; Norris, D (2013). Dietary energy level for optimum productivity and carcass characteristics of indigenous Venda chickens raised in closed confinement. S. Afr. J. Anim. Sci. 2013, 43, 75–80.

Alem Tadesse (2014). Production and Reproduction Performance of Rural Poultry in Lowland and Midland Agro-Ecological Zones of Central Tigray, Northern Ethiopia. British Journal of Poultry Sciences 3 (1): 06-14. ISSN 1995-901X.

Alemayehu A (2017). Characterization of smallholder poultry production systems in Mezhenger, Sheka and Benchi-Maji zones of south western Ethiopia. Academic Research Journal of Agricultural Science and Research 5(1):10-19.

Alemayehu Guteta (2017). Characterization of scavenging and intensive chicken production and marketing system in Lume district, East Shoa Zone, Oromia region state, Ethiopia MSc Thesis Haramaya University, Dire Dawa. Vol. 11(1), pp. 8-20, January-March 2020.

Alemayehu Guteta and Solomon Abegaz (2018). Chicken Production Constraints in Lume District, East Shoa. Zone, Oromia Region State, Ethiopia. World Journal of Agricultural Sciences 14 (5): 170-179, 2018.

Alganesh, T., Matewos, B. and Gizaw, K (2003). Survey on traditional livestock production system. Proceeding 11th Annual Conference of Ethiopian Society of Animal production, Addis Ababa, Ethiopia, August 28-30, 2003. pp. 141-150.

Alipanah, M., Deljo, J., Rokouie, M. & Mohammadnia, R (2013). Heritabilities and genetic and phenotypic correaltions of egg quality traits in KHAZAK layers. Trakia Journal of Sciences, 175–180 (2013).

Allais S, Hennequet-Antier C, Berri C, Salles L, Demeure O, Le Bihan-Duval E (2019). Mapping of QTL for chicken body weight, carcass composition, and meat quality traits in a slow-growing line. Poult Sci. 2019;98(5):1960–7.

Apuno, A.A.; Mbap, S.T.; Ibrahim, T (2011). Characterization of local chickens (Gallus gallus domesticus) in shelleng and song local government areas of Adamawa State, Nigeria. Am. J. Agric. Biol. Sci. 2011, 2, 6–14

Asresie, A., and E. Mitiku (2015). Traditional Chicken Production System and Marketing in Ethiopia: A review. J. Mark. and Cons.Res. 8:2422–8451.

Athar, T (2019). Village poultry and its impact on poverty alleviation. Technology Times.

Awad A, Eltarabany MS (2015). Association of single nucleotide polymorphism in bone morphogenetic protein receptor 1B (BMPR-1B) gene with growth traits in chicken. Kafkas Üniversitesi Veteriner FakÜltesi Dergisi. 2015;21(6):813–8.

Axford, R.F.E., Bishop, S.C., Nicholas, F. W. & Owen, J.B (2000). Breeding for disease resistance in farm animals, 2nd edition. Wallingford, UK, CABI Publishing.

A. Bahmanimehr (2012). "Selection for economic traits in chickens breeding program according to genetic parameters and correlation between traits," *World Applied Sciences Journal*, vol. 20,no. 10, pp. 1332–1335, 2012.

Beilharz, R.G., Luxford, B.G. & Wilkinson, J.L (1993). Quantitative genetics and evolution: is our understanding of genetics sufficient to explain evolution? *Journal of Animal Breeding and Genetics*, 110: 161–170.

Biswas, S.R (2005). Genetic dilution of indigenous chicken in selected villages. M.S. Thesis, Department of Poultry Science, Bangladesh Agricultural University, Mymensingh.

Bridle, B. W., Julian, R., Shewen, P. E., Vaillancourt, J.-P., & Kaushik, A. K (2006). T lymphocyte subpopulations diverge in commercially raised chickens. *Canadian Journal of Veterinary Research, 70,* 183–190.

Brown, M.M., Alenyorege, B., Teye, G.A. and Roessler, R (2017). Phenotypic diversity, major genes and production potential of local chickens and guinea fowl in Tamale, northern Ghana. *Asian-Australasian Journal of Animal Sciences*, 30(10),1372–1381.

Bughio, E (2018). Raise Rural (DESI) Poultry for Food Security and Poverty Alleviation. Avian Agro Veterinary News Central statistical Agency (2015). Agricultural sample survey volume II report on livestock and livestock characteristics Addis Ababa August 2015 573statical bulletin 573.

C. C. Li, K. Li, J. Li, D. L. Mo, R. F. Xu, G. H. Chen1, Y. Z. Qiangba2, S. L. Ji, X. H. TangB. Fan, M. J. Zhu, T. A. Xiong, X. Guan and B. Liu (2009). Polymorphism of Ghrelin Gene in Twelve Chinese Indigenous Chicken Breeds and Its Relationship with Chicken Growth Traits. Huazhong Agricultural University, Wuhan 430070, P. R. China.

Choo, Y.; Kwon, H.; Oh, S.; Um, J.; Kim, B.; Kang, C.; Lee, S.; An, B (2014). Comparison of growth performance, carcass characteristics and meat quality of Korean local chickens and silky fowl. Asian-Australas J. Anim. Sci. 2014, 27, 398–405.

Chouhan S (2015). Recovery of Salmonella and Shigella isolates from drinking water. European Journal of Experimental Biology, 5(7), 49–61.

COMPANY(1984). Livestock sub-sector review.Vol. Annex 3, MOA, Addis Ababa, Ethiopia. County Director of Agriculture (CDA), (2013). Government of Makueni County – Makueni County Agriculture profile.

CRAWFORD, A.M (1994). Determination of evolutionary relationships among sheep breeds using microsatellites. *Genome.* 22: 397-403.

CSA (2016). Agricultural sample survey report on livestock and livestock characteristics, volume II, Addis Ababa, Ethiopia.

D. M. Ogah (2011). Assessing size and conformation of the body of Nigerian indigenous turkey.

D. P. SAHOO, N. C. BEHURA, LIPISMITA SAMAL, B. NANDI, J. BAGH, G.D. NAYAK AND P.K. PATI (2017). Growth performance, feed efficiency and linear body measurements of triple cross progenies of Hansli, CSML and CSFL chickens.

Dahloum L, Moula N, Halbouche M, Mignon-Grasteau S (2016). Phenotypic characterisation of the indigenous chickens (*Gallus gallus*) in the northwest of Algeria. Arch Anim Breed 2016;59:79-90.

Dana, N., vander Waaij, L. H., Dessie, T. and van Arendonk, J.A.M (2010). 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, DOI 10.1007/s11250-010-9602-6.

Demeure, O, M Duclos, N Bacciu, G Le Mignon, O Filangi, F Pitel, A Boland, S Lagarrigue, L Cogburn, and J Simon (2013). 'Genome-wide interval mapping using SNPs identifies new QTL for growth, body composition and several physiological variables in an F2 intercross between fat and lean chicken lines', *Genet Sel Evol*, 45: 36.

Desalew T (2012). Management practice, productive performance and egg quality traits of exotic chickens under village production system in east shoa zone. Msc. Thesis Addis Ababa University College of veterinary medicine and Agriculture. Debra- Zeit 58pp.

Dessie T., Dana N., Ayalew W., Hanotte O (2012). Current state of knowledge on Indigenous chicken genetic resources of the tropics: domestication, distribution and documentation of information on the genetic resources. *World's Poultry Science Journal* 68(1):11–20.

DLS (Department of Livestock Services) (2015). Annual Report on Livestock, Division of Livestock Statistics, Ministry of Fisheries and Livestock, Farmgate, Dhaka, Bangladesh.

Dolberg, F (2016). Poultry production for livelihood improvement and poverty alleviation. Poultry in the 21st century. University of Arhus, Denmark.

Duah, K.K., Essuman, E.K., Boadu, V.G., Olympio, O.S. and Akwetey, W (2020). Comparative study of indigenous chickens on the basis of their health and performance. Poultry Science, 99, 2286–2292.

Duah, K.K., Essuman, E.K., Olympio, O.S., Akwetey, W., Gyimah, V. and Yeboah, J.O (2018). Consumers' acceptability of indigenous cockerel. Poultry Science, 97, 1768–1773.

Duc, N.V.; Long, T (2008). Poultry production systems in Vietnam. In GCP/RAS/228/GER Working Paper No. 4; Food and agriculture organisation: Rome, Italy, 2 February 2008; pp. 1–18.

Duguma R (2009). Understanding the Role of Indigenous Chickens during the Long Walk to Food Security in Ethiopia. Livest Res Rural Development 21.

Dumas S. E., Lungu L., Mulambya N., Lewis D., & Travis A. J (2018). Multidimensional assessment of small-scale egg production centers to promote maternal and child nutrition in rural Zambia.

Dunislawska, A.; Slawinska, A.; Siwek, M (2020). Hepatic DNA Methylation in Response to Early Stimulation of Microbiota with Lactobacillus Synbiotics in Broiler Chickens. Genes 2020, 11, 579.

Dunya AM, Husa H, Yusuf SZ, Usman Y, Makinta AA (2014). Fertility and hatchability in local chicken of Borno state, Nigeria. *Journal of Agricultural Science and Application,* Vol. 3(1): 20-23.

E. A. Rotimi,, J. O. Egahi and A. A. Adeoye (2016). Phenotypic characterization of indigenous chicken population in Gwer-West, Benue State, Nigeria.

Emebet M (2015). Phenotypic and genetic characterization of indigenous chickens in south west shoa and Gurage zone .PHD dissertation Addis Ababa University College of veterinary Medicine January, 2015 Debar Zeit.

Emebet, M., Singh, H., Sisaye, T., & Johansson, A. M (2014). Phenotypic Characterization of Indigenous Chicken Population in South West and South Part of Ethiopia.*British Journal of Poultry Sciences*, *3* (1), 15-19.

Emmerson, D (2003). Breeding objectives and selection strategies for broiler production. In: W.M. Muir and S.E. Aggrey (eds), Poultry Breeding, Genetics and Biotechnology, (CAB International, UK), 113-126

Endale Y, Dereje T, Ararsa B, Gezahegn M, Melkam A, Samuel S, Wendimeneh E, Emebet M, Hareppal S, Johansson A, Sisaye T, Sahile Z (2013). Characteristics of Indigenous Chicken Production System in South West and South Part of Ethiopia. Brit J Poult Sci 2: 25-32.

Eriksson, J., Larsen, G., Gunnarsson, U., Bed'hom, B., Tixier-Boichard, M., Stromstedt, L., Wright, D., Jungerius, A.,Vereijken, A., Randi, E., Jensen, P. & Andersson, L (2007). Identification of the yellow skin gene reveals the hybrid origin of domestic fowl. PLoS Genet., 4(2): e1000010 (doi: 10.1371/journal. pgen.1000010).

FAO (2011). Draft guide lines on phenotypic characterization of animal genetics resource. Food and agriculture organization, on genetic resources for food and agriculture Rome, pp: 6.
FAO (2016). Promoting Nutrition Sensitive Agricultural Diversification to Reduce Poverty, Fight Malnutrition and Enhance Youth Employment Opportunities in Eastern Africa" (GCP/SFE/001/MUL).

FAO (2019). Poultry Sector Ethiopia. FAO Animal Production and Health Livestock Country Reviews. No. 11. Rome.
Faruque S, Islam M N and Bhuiyan A K F H (2015). Ex-situ improvement of indigenous chicken in Bangladesh. *Tropical Agricultural Research* 26(4): 596–607.

Fisseha Moges, Azage Tegegne and Tadelle Dessie (2010). Indigenous chicken production and marketing systems in Ethiopia: Characteristics and opportunities for market-oriented development. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 24. Nairobi, Kenya, ILRI

Fisseha, M., Abera, M. and Tadelle, D (2010). Assessment of village chicken production system and evaluation of the productive and reproductive performance of local chicken

ecotype in Bure district, North West Ethiopia, *African. Journal of Agriculture Research,* 5: 1739-1748.

Getu A, Alemayehu K, Wuletaw Z (2014). Phenotypic Characterization of Indigenous Chicken Ecotypes in North Gondar Zone, Ethiopia. *Glob Vet* 12: 361-368.

Gezali Abafaji (2017). Assesment of poultry production constraints and evaluation of different concentrate on production performance and parasitic burden of exotic chickens in kersa district of jimma zone. Ethiopia.

Gilmour, A.R., Gogel, B. J., Cullis, B.R. and Thompson, R., 2006. ASReml User Guide, Release 2.0, (NSW Department of Primary Industries, Australia).

GOP (2019-20). Economic Advisor's Wing. Ministry of Finance, Government of Pakistan Islamabad, Pakistan.

Goromela,E.H, Kwakkel R.P, Verstegen M.W.A. & Katule A.M., 2007. Identification, characterization and composition of scavengeable feed resources for rural poultry production in Central Tanzania. Afr. J. Agric. Res. 2, 380-393.

Gous RM, Moran ET Jr, Stilborn HR, Bradford GD, Emmans GC (1999). Evaluation of the parameters needed to describe the overall growth, the chemicalgrowth, and the growth of feathers and breast muscles of broilers. Poultry Sci. 1999;78:812–21.

Guni SF, Katule MA, Mwakilembe AAP (2013). Characterization of local chickens in selected districts of the Southern Highlands of Tanzania: II. Production and Morphometric traits. Livest Res Rural Development.

Habimana, R., Okeno, T. O., Ngeno, K., Mboumba, S., Assami, C.T., Keambou, P., & Yao (2018). Four gene pools of Rwandese indigenous chicken based on microsatellite markers. Egerton, Kenya.

Habimana. R, T.O Okeno, K. Ngeno, S. Mboumba, P. Assami, A. Gbotto C.T. Keambou, K. Nishimwe, J.Mahoro1and N.Yao (2019). Genetic diversity and population structure of indigenous chicken in Rwanda using microsatellite markers.

Habimana. R, K. Ngeno, Hirwa, C. D, T.O Okeno, C.T., Keambou and N.Yao (2021). Genome-Wide Association Study of Growth performance and Immune response to Newcastle Disease Virus of Indigenous Chicken in Rwanda.

Habtamu M. .Selamawit.D, Berhan A. and Asmamaw .Y (2015).Villagen chicken production performances assessment under scavenging management system in Amaro district, SNNPRS of Ethiopia Dilla University. College of Agriculture and Natural Resources Department of Animal and Range Sciences, Wudpecker *Journal of Agricultural Research* ISSN 2315-7259 Vol. 4(3), pp. 021 – 034.

Habte M, Ameha N, Demeke S (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(11):1014-1021.

Hailemichael, A., Gabremedhin, B., Gizwa, S. and Tegegne, A (2016). Analysis of village poultry value chain in Ethiopia: implications for action research and development. LIVES working paper 10. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Hailu A, Mazengia H, Wuletaw Z (2013). Indigenous chicken production system and breeding practice in North Wollo, Amhara region, Ethiopia. *Scholarly J Agric Sci* 3: 433 444.

Hailu Assefa1 and Aberra Melesse (2018). Morphological and Morphometric Characterization of Indigenous Chicken Populations in Sheka Zone, South Western Ethiopia.

Halima H., Phenotypic and genetic characterization of indigenous chicken populations in northwest Ethiopia. PhD thesis, Faculty of Natural and Agricultural Sciences, Department of Animal, Wildlife and Grassland Sciences, University of the Free State, Bloemfontein, South Africa. Pp 120-130 (2007).

HEDRICK, P.W., (1975). Genetic similarity and distance: Comments and comparisons. *Evol.*29 (2): 362-366.

Hirwa, C. D, Donald RK, Aline K, Tiba M, Fabrice S, Gaspard U (2019). Phenotypes, production systems and reproductive performance of indigenous chickens in contemporary Rwanda. Int J Livest Prod. 2019; 10: 213–231.

Hunduma D. Regassa Ch, Fufa D, Samson L, Endale B (2010).Socio- economic importance and management of village chicken production in rift valley of Oromia, Ethiopia. *Livestock. Research. Rural. Development*. 22 (11).

Ikeobi CON, Ozoje MO, Adebambo OA, Adenowo JA, Osonowo OA (1996). Genetic differences in the performance of local chicken in south-western Nigeria. Nig. J. Genetic. Vol XI: 1996; 30-39.

Isidahomen, E.C., Ilori, B.M and Akano, K. (2012). Genetic and sex differences in carcass traits of Nigerian indigenous chickens. *J. Anim. Sci. Adv.* 2: 637–648.

Jesuyon, O.M.A., and Salako, A.E (2013). Variability and predictability of productive and body traits of Fulani ecotype chicken. African Journal of Agricultural Research, 8, 6178-6184.

Jonchère V, Réhault-Godbert S, Hennequet-Antier C, Cabau C, Sibut V, Cogburn LA, Nys Y, Gautron J (2010). Gene expression profiling to identify eggshell proteins involved in physical defense of the chicken egg. BMC Genomics. 2010;11:57.

Jump DB, Botolin D, Wang Y, Xu J, Christian B, Demeure O (2005. Fatty acid regulation of hepatic gene transcription. J Nutr 2005, 135(11):2503–2506.

Kamali, M.A., Ghorbani, S.H., Moradi Sharbabak, M. and Zamiri, M.J (2007). Heritabilities and genetic correlations of economic traits in Iranian native fowl and estimated genetic trend and inbreeding coefficients, British Poultry Science, 48(4), 443-448.

Khawaja T, Khan SH, Mukhtar N, Parveen A, Ahmed T (2013). Comparative study of growth performance, meat quality and haematological parameters of three-way crossbred chickens with reciprocal F1 crossbred chickens in a subtropical environment. Journal of Applied Animal Research 2013; 41 (3): 300-308. doi: 10.1080/09712119.2013.782869.

Kibreab, Y., Dakamo Fiseha, Desseye Tessfaye, Dawit Habtegyorgis, Tagbaru Gebereselase and Cherenet Rate (2016). Survey on Chicken Production Performance and Marketing Systems in Kaffa and Benchmaji Zone, Southwest Ethiopia.

Kingori, A.M.; Tuitoek, J.K.; Muiruri, H.K.; Wachira, A.M.; Birech, E.K (2007). Protein intake of growing indigenous chicken on free-range and their response to supplementation. Int. J. Poult. Sci. 2007, 6, 617–621.

Kirkpatrick, S., Gelatt, C., and Vecchi, M.P (1983). Optimization by simulated annealing. Science, 220, 671–680.

Kitalyi, A.J (1998). Village chicken production systems in rural Africa: Household food security and gender issues. FAO animal production and health paper No 142, Rome.

Kranis, A.; Gheyas, A.A.; Boschiero, C.; Turner, F.; Yu, L.; Smith, S.; Talbot, R.; Pirani, A.; Brew, F.; Kaiser, P et al (2013). Development of a high density 600K SNP genotyping array for chicken. BMC Genom. 2013, 14, 59.

Laikre L (2010). Genetic Diversity is overlooked in international conservation policy implementation, Conserv. Genet., 11: 349-354.DOI 10.1007/S 10592-009-0037-4

Le Bihan-Duval, E., J. Nadaf, C. Berri, F. Pitel, B. Graulet, E. Godet,S. Y. Leroux, O. Demeure, S. Lagarrigue, C. Duby, L. A.Cogburn, C. M. Beaumont, and M. J. Duclos (2011). Detection of a Cis e QTL controlling BCMO1 gene expression leads to the identifi cation of a QTG for chicken breast meat color. Plos One. 6(7):e14825.

Liyanage RP, Dematawewal CMB, Silva GLLP (2015). Comparative Study on Morphological and Morphometric Features of Village Chicken in Sri Lanka. *Trop Agric Res* 26: 261-273.

M. Kunnasranta, M. Niemi, M. Auttila Saimaannorpan (2016). Conservation biology of the Saimaa ringed seal: from research to actions) Suomen Riista, 62 (2016), pp. 71-82.

Magothe, T. M., T. O. Okeno, W. B. Muhuyi, and A. K. Kahi (2012a). Small-scale family poultry production indigenous chicken production in Kenya: I. Current status. World's Poult. Sci. J. 68:119–132.

Mahoro TKM, Mbuza F, Habimana R, Kahi AK (2017). Characterization of indigenous chicken production systems in Rwanda, Poultry Science 96(12):4245-4252.

Markos, S., Belay, B. and Astatkie, T (2017). Evaluation of egg quality traits of three indigenous chicken e c o t y p e s k e p t u n d e r farmers 'management conditions. *International Journal of Poultry Science*, 16:180-188.

Matsuzaki, K., Katakura, M., Sugimoto, N., Hara, T., Hashimoto, M., and Shido, O (2017). Neural progenitor cell proliferation in the hypothalamus is involved in acquired heat tolerance in long-term heat-acclimated rats. *PloS One* 12, 1–16. doi: 10.1371/journal.pone.0178787.

Mearg Fitsum (2017). Production Objectives, Breeding Practices and Selection Criteria of Indigenous Chicken in Central Zone of Tigray, Northern Ethiopia.

Melesse A and Negesse T (2014). "Phenotypic and morphological characterization of indigenous chicken populations in southern region of Ethiopia". *Animal Generation Resources* 49 (2014): 19-31.

Melesse A, Negesse T (2011). Phenotypic and morphological characterization of indigenous chicken populations in southern region of Ethiopia. Anim Genet Resour 49: 19-31.

Melkamu Bezabih and Wube Atalel (2013). Constraints and Opportunities of Village Chicken Production in Debsan TiKara Keble at Gonder Zuria Woreda, North Gonder, Ethiopia. Inte. J. Sci. Res. Pub. 3 (9): 2250-3153.

Meseret M (2010). Characterization of Village Chicken Production and Marketing System. M.Sc. Thesis Submitted to the Department of Animal Science, Jimma University, College of Agriculture and Veterinary Medicine, School of Graduate Studies, pp: 110.

MINAGRI (2012). Strategic and investment plan to strengthen the poultry industry in Rwanda. Government of Rwanda Kigali.

MINAGRI, Animal production status, (2014).

Moges F. Aberra M. and Tadelle D (2010a). Assessment of village chicken production system and evaluation of the productive and reproductive performance of local chicken ecotype in Bure district, North West Ethiopia. *African Journal. Agricultural. Research*, 5 (13):1739-1748.

Momayi, D., Lagat, J.K. and Ayuya, O.I (2015) Determinants of Smallholder African Indigenous Leafy Vegetables Farmers' Market Participation Behaviour in Nyamira County, Kenya. Journal of Economics and Sustainable Development, Vol.6, No.13, 2015.

Moreda E, Singh H, Sisaye T, Johansson AM (2014). Phenotypic Characterization of Indigenous Chicken Population in South West and South Part of Ethiopia. *Brit J Poult Sci* 3: 15.

Moreki JC, Merwe HJVD and Hayes JP (2011). Effect of dietary calcium level on egg production and eggshell quality in broiler breeder hens from 36 to 60 weeks of age. Onl J Anim Feed Res. 2011; 1(1):1–7.

Moula, N.; Antoine-Moussiaux, N.; Decuypere, E.; Farnir, F.; Mertens, K.; De Baerdemaeker, J.; Leroy, P (2010). Comparative study of egg quality traits in two Belgian local breeds and two commercial lines of chickens. Arch. Geflügelkund. 2010, 74, 164–171.

Muchadeyi, F.C., Wollny, C. B. A., Eding, H., Weigend, S. and Simianer, H (2009). Choice of breeding stock, preference of production traits and culling criteria of village chickens among Zimbabwe agro-ecological zones, Trop. Anim. Health and Prod., 41, 403-412.

Mwalusanya, N.A., Katule, A.M., Mutayoba, S.K., Mtambo, M.M.A., Olsen, J.E. and Minga, U.M (2004). Productivity of Local Chickens under Village Management Conditions. Tropical Animal Health and Production, Springer Netherlands, Volume 34, Number 5, pp 405 – 416.

Nadaf, J, F Pitel, H Gilbert, M Duclos, F Vignoles, C Beaumont, A Vignal, T Porter, L Cogburn, and S Aggrey (2009a). 'QTL for several metabolic traits map to loci controlling growth and body composition in an F2 intercross between high-and low growth chicken lines', *Physiol Gen*, 38: 241-49.

NAERLS (2000). Improving the Performance of local chickens Extension Bulletin No 92 Poultry Series pp 6 –8.

Naqvi, A.N (2007). Application of Molecular Genetic Technologies in Livestock Production: Potentials for Developing Countries 13.

NEI, M (1978). Estimation of average heterozygosity and genetic distance from a small number of individuals. *Genet.* 89: 583–590.

NEI, M., (1972).Genetic distance between populations. *The Amer*. *Naturalist*. 106:283–292.

NEI, M., TAJIMA, F. & TATENO, Y (1983). Accuracy of estimated phylogenetic trees from molecular data. *J. Mol. Evo.* 19: 153–170.

NIANG (2012). Strategy and Investment Plan to strengthen the poultry industry in Rwanda, 2012).

Nigussie, D (2011). Breeding programs for indigenous chicken in Ethiopia: analysis of diversity in production systems and chicken populations. PhD Thesis, Wageningen University, the Netherlands,pp: 148.

NOTTER, D. R (1999). The importance of genetic diversity in livestock populations of the future.*J. Anim. Sci.* 77: 61-69.

Nys, Y., and N. Le Roy (2017). Calcium homeostasis and eggshell biomineralization in female chicken. Pages 361–382 in Vitamin D. 4th ed. Elsevier Inc, Stanford, California, USA.

Odah EO, Daikwo, S. I, Mbap S.T, and Okpanachi U (2019). Phenotypic Characterization of Local Chickens (*Gallus Gallus Domesticus*) In Bekwarra Cross River State, Nigeria.

Ohta, K.; Nobukuni, Y.; Mitsubuchi, H.; Ohtab, T.; Tohmab, T.; Jinno, Y.; Endo, F.; Matsuda, I (1999). Characterization of the gene encoding human pituitary-specific transcription factor, Pit-1. *Gene* 1992, *122*, 387–388, doi:10.1016/gene.1992.90234.

Okuthe, S.O (1999). Participatory epidemiology assessment of livestock production constraints in the western Kenya highlands. PhD Thesis, University of Reading, United Kingdom.

Onasanya Gbolabo O. Onasanya1, Christian O.N. Ikeobi2 and Samuel A. Amusan (2018). Morphostructural Profiling of Comb Types and Plumage Pigmentation and Their Influences on Ecometric Traits of Extensively-Managed Nigerian Indigenous Chickens.

Orsini, L., Jansen, M., Souche, E.L., Geldof, S., De Meester, L (2011). Single nucleotide polymorphism discovery from expressed sequence tags in the waterflea Daphnia magna. BMC Genomics 12.

Osei-Amponsah R, Kayang BB, Naazie A (2013). Phenotypic and genetic parameters for production traits of local chickens in Ghana. Anim Genet Res 2013;53:45-50.Pym, R. (2013). Poultry genetics and breeding in developing countries, Genetic diversity of genetic resources, School of Veterinary Science , The University of Queensland, Gatton, 4343, Queensland, Auatralia.

Oxford Dictionary (1990). Black's law dictionary. Definitions of the Terms and Phrases of American and English Jurisprudence, Ancient and Modern. ST. PAUL□ MINN. WEST PUBLISHING CO. 1990.

Pérez-Figueroa, A., Saura, M., Fernández, J., Toro, M.A., and Caballero, A (2009). METAPOP—software for the management and analysis of subdivided populations in conservation programs. Conservation Genetics, 10, 1097–1099.

Phuong, N.T.; Duy, N.V.; Ton, V.D (2017). The growth and meat quality of H'mong chicken raised by industrial farming. Vietnam J. Agri. Sci. 2017, 15, 438–445.

Pinard-Van Der Laan, M, B Bed'Hom, J Coville, F Pitel, K Feve, S Leroux, H Legros, A Thomas, D Gourichon, and J Repérant (2009). 'Microsatellite mapping of QTLs affecting resistance to coccidiosis (Eimeria tenella) in a Fayoumi× White Leghorn cross', *BMC Genomics*, 10: 31.

Purcell,S.N.B.,ToddBrown,K.,Thomas,L.,Ferreira,M.,Bender,D.,Maller,J (2007). PLINK: A toolset for Whole-Genome Association and Population Based linkage Analysis edu/Purcell /plink.

Qureshi M, Qadri AH, Gachal GS (2018). Morphological study of various varieties of Aseel chicken breed inhabiting district Hyderabad. Journal of Entomology and Zoology Studies 2018. 6 (2): 2043-2045.

Rautenschlein, S.; Cheng, H.H.; Lamont, S.J (2020). Host factors for disease resistance. In Diseases of Poultry, 14th ed.; Swayne, D.E., Ed.;Wiley-Blackwell: Oxford, UK, 2020; pp. 79–108.

REGE, J. E. O. & LIPNER, M. E., (1992). African Animal Genetic Resources: Their Characterization, utilization and conservation. Proc. the research plan workshop, 19-21 February 1992, ILCA, Addis Ababa, Ethiopia.

ROBERT V. KREJCIE and DARYLE W. MORGAN (1970). Determining sample size for research activities. EDUCATIONAL AND PSYCHOLOGICAL MEASUREMENT. Texas A. & M. University. University of Minnesota, Duluth. 30, 607-610.

Roberts, J.R (2004). Factors affecting egg internal quality and egg shell quality in laying hens. J. Poult. Sci. 2004, 41, 161–177.

S. Faruque et al (2010). Phenotypic characterization of Native Chicken reared under intensive management system. Department of Animal Breeding and Genetics, Bangladesh Agricultural University, Mymensingh-202 and 4Upazilla Livestock Officer, Ramgati, Lakshmipur J. Bangladesh Agril. Univ. 8(1): 79–82, 2010.

Schild H, Rammensee HG (2000). Gp96–the immune system's Swiss army knife. Nat Immunol. 2000;1:100–1. Science 96(12):4245-4252.

Seliger, C.; Schaerer, B.; Kohn, M.; Pendl, H.; Weigend, S.; Kaspers, B.; Härtle, S (2012). A rapid high-precision flow cytometry based technique for total white blood cell counting in chickens. Vet. Immunol. Immunopathol. 2012,145, 86–99.

Semik E. and Krawczyk J (2011). The state of poultry genetic resources and genetic diversity of hen populations, Ann. Anim. Sci., 11 (2): 181-191.

Shaun Purcell, Benjamin Neale, Kathe Todd-Brown, Lori Thomas, Manuel A. R. Ferreira, David Bender, Julian Maller, Pamela Sklar, Paul I. W. de Bakker, Mark J. Daly, and Pak C. Sham (2007). PLINK: A Tool Set for Whole-Genome Association and Population-Based Linkage Analyses

Simainga, S., Moreki, J.C., Band, F. and Sakuya, N (2011). Socioeconomic study of family poultry in Mongu and Kalabo Districts of Zambia. Livestock Research for Rural Development, 23 (02).

SINGH, R.A (2000). Poultry production. Kalyani publishers, New Delhi, India.

Slumber Socks Badubi, M. Rakereng and M. Marumo (2006). Morphological characteristics and feed resources available for indigenous chickens in Botswana. Livestock Research for Rural Development 18(1)

Stearns, S.C. (1976). Life-history tactics: A review of the ideas. The Quarterly Review of Biology

Sumy MC, Khokon MSI, Islam MM, Talukder S (2010). Study on the socio-economic condition and productive performances of backyard chicken in some selected areas of Pabna district. *Journal of Bangladesh Agricultural University*, Vol. 8 (1):45□50.

Tadelle, D (2003). Phenotypic and genetic characterization of chicken ecotypes in Ethiopia. Ph.D. Thesis, Humboldt University, Germany.

TEKETEL, F (1986). Studies on the meat production potentials of some local strains of chickens Ethiopia. Ph.D. Thesis, J. L. University Giessen, Germany.

Thiyagasundaram, T.S (2013). Conservation genetics in poultry breeding, Poulvet.com, Retrieved on 3/6/2013

Uza D.V, Olurunju S.A.S and Orkpeh J.M.T (2001). An assessment of the disease and production status of indigenous poultry in Benue and Nasarawa states of Nigeria. In: strategies for poverty Alleviation: Animal production option.

Van Marle-Köster, E.; Hefer, C.A.; Nel, L.H.; Groenen, M.A.M (2009). Genetic diversity and population structure.

Wachira, M.A., Mail, S.K., Munyasi, J.W., Nzioka, M., Mwangi, D.M., Kaguthi, P. and Kithome, J (2010). Uptake of improved technologies through dissemination by indigenous chicken service providers in Southern Rangeland of Kenya. In: Proceedings at the 12th KARI Biannual Scientific Conference in November 2010, KARI headquarters, Kaptagat road off Loresho, Nairobi. Pp: 1376-1382.

Walugembe, M. et al (2019). Detection of selection signatures among Brazilian, Sri Lankan, and Egyptian chicken populations under different environmental conditions. *Front. Genet.* 9, 737 (2019).

Wang J., Yue H., Wu S., Zhang H., & Qi G (2017). Nutritional modulation of health, egg quality and environmental pollution of the layers. Animal Nutrition, 3, 91–96.

Wang, Q., H. Li, N. Li, L. Leng, Y. Wang, and Z. Tang (2006). Identification of single nucleotide polymorphism of adipocyte fatty acid-binding protein gene and its association with fatness traits in the chicken. Poult. Sci. 85:429–434.

Weigend S., Romanov M.N., and Detlef R (2013). Methodologies to identify, evaluate and conserve poultry genetic resources, Institute for Animal Breeding Mariensee of the Federal Agricultural Research Centre, 31535 Neustadt, Germany, Retrieved on 6/3/2013.

Welc SS, Clanton TL, Dineen SM, Leon LR (2013). Heat stroke activates a stress-induced cytokine response in skeletal muscle. J Appl Physiol. 2013; 115(8):1126–37.

WEST, B. & ZHOU, B (1989). Did chickens go north? New evidence for domestication. *World's Poult. Sci.* 45: 205-218.

Wirot Likittrakulwong, Norakamol Laorodphan, Pisit Poolprasert, Rangsun Charoensook, and Tossaporn Incharoen (2018). Association of single nucleotide polymorphism in VLDL/VTG RECEPTOR gene polymorphism with egg production and growth performance traits in four chickens breeds. *Rajabhat J. Sci. Humanit. Soc. S*ci. 19(1): 287-296, 2018.

Woldegiorgiss WE (2015). Genetic improvement in indigenous chicken of Ethiopia. PhD Dissertation. Wageningen University, The Netherlands.

Yadessa E, Tulu D, Bogale A, Mengistu G, Aleme M, Shiferawu S, Esatu W, Amare A (2017). Characterization of smallholder poultry production systems in Mezhenger, Sheka and Benchi-Maji zones of south western Ethiopia. Research Journal of Agricultural Science Research 5(1):2360-7874.

Yami A & Dessie T (1997). The status of poultry research and development in Ethiopia. In: Fifth National Conference of Ethiopian Society of Animal Production (ESAP), Addis Ababa, Ethiopia.

Yao JF, Chen ZX, Xu GY (2010). Low-density lipoprotein receptor-related protein 8 gene association with egg traits in dwarf chickens, Poultry Science. 2010; 89: 83-86.

Yeung, T.-L.; Leung, C.S.; Wong, K.-K.; Gutierrez-Hartmann, A.; Kwong, J.; Gershenson, D.M.; Mok, S.C (2017). ELF3 is a negative regulator of epithelial-mesenchymal transition in ovarian cancer cells. *Oncotarget* 2017,*8*, 16951–16963.

Younis HH, and FA Abd EL-Ghany (2004). Direct and correlated response to selection for egg number in Silver Montazah chickens. Egyptian Poultry Science Journal, 24: 701-718.

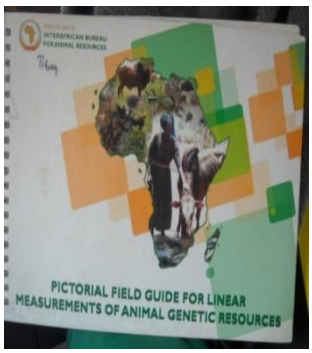
Zereu G, Lijalem T (2016). Production and reproduction performance of local chicken breeds and their marketing practices in Wolaita Zone, Southern Ethiopia. African Journal of Agricultural Research 11(17):1531-1537.

ZEUNER, F.E (1963). A history of domesticated animals. Hutchison, London.

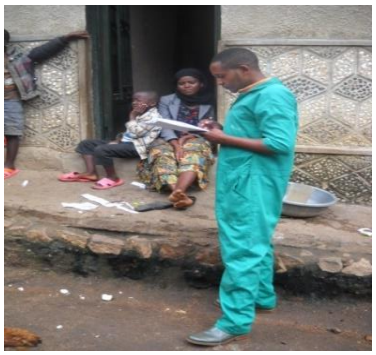
Zhang, J., Liu, T., Feng, R., Liu, C., Chi, S (2015). Genetic Map Construction and Quantitative Trait Locus (QTL) Detection of Six Economic Traits Using an F2 Population of the Hybrid from Saccharina , Longissima and Saccharina japonica

APPENDICES

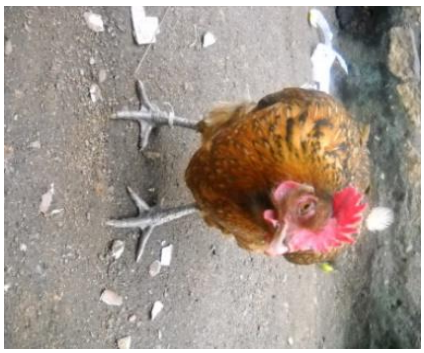
FIELD AND LABORATORY PHOTOS



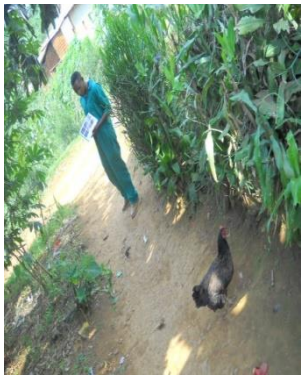
a) Book used



b) Interview to farmer

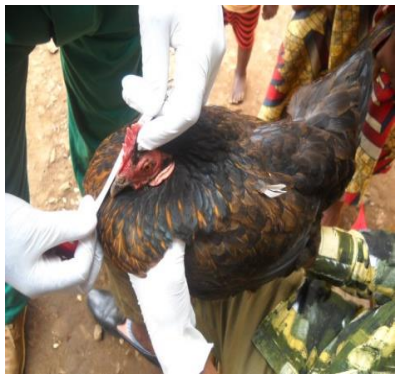


c)Indigenous chicken

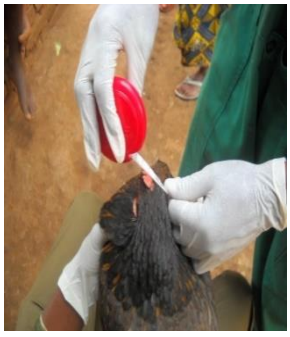


e) Phenotype characterisation

e) Body length



f) Length of crest



g) Height of crest

h) Height of wattle

i) Length of neck



j) Thorax diameter k) Wing length l) Wing span

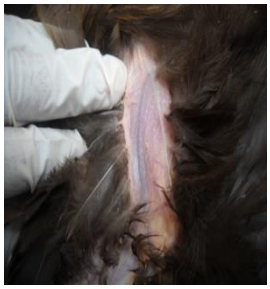


m) Tarsus diameter n) Tarsus length o) Shank diameter

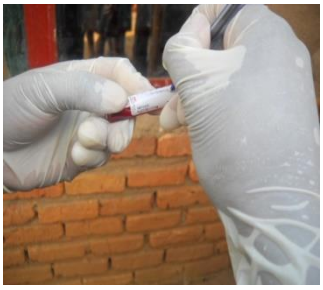

p) Shank length r) Body weight and heart gilt

Field photos 1: Phenotypic characterization of indigenous chickens

PHOTOS FOR GENETIC CHARACTERIZATION

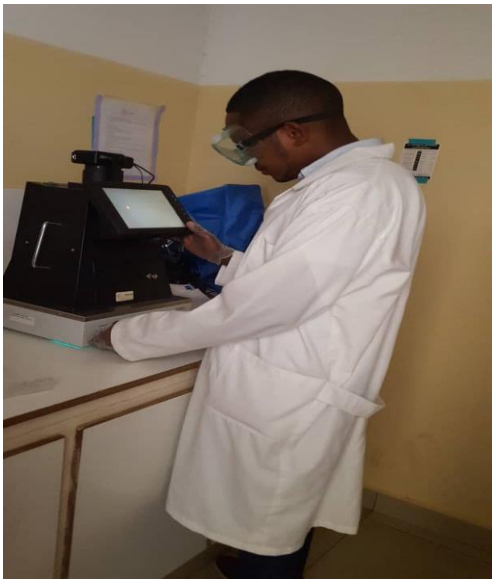


a) Pectal vein b) Blood collection at Nyanza c) Blood collection at Nyamasheke


d) Blood into Vacutainer tube e) Blood sample labelling f) Blood samples into cool box

Field photos 2: Blood collection for genotypic characterization of indigenous chicken

g) Post PCR and DNA amplification h) Gel room where DNA visualization takes place

Laboratory photos 1: DNA extraction and amplification for indigenous chickens at RAB/ Rubirizi Station laboratory.

QUESTIONNAIRES

Qn. No.

1. Chicken production in Rwanda

A Location

1 Date of interview …… 2 Village…….

3 Sector …… 4 Cell.....

5 Province …… 6 District…….....

B.General information on the Household Head

1 Name of household head..... 2 Phone contact.....

C Information on chicken production

1 Type of chicken production system practiced

	Free range (scavenging) only
	Free range (scavenging + Seasonal supplementation)
	Semi scavenging (free range + Regular supplementation)
	Intensive system

2 Age (months) when males start mounting

…….

3 Age (months) at which females start laying.

……

4 Egg laying cycles your hens have in a year

…….

5. Eggs the hens lay per cycle (clutch size)

……

6 Average number of eggs you give to your hens for natural incubation .....

7. Average number of chicks you get at a single hatching per cycle

.....

8 How many of the hatched chicks survive up to weaning? ……..

9 How do you hatch eggs? | Naturally | | Artificially |

If natural method, which one of these below do you use?

	Traditional nest
	Brooding box
	Other …….(specify)

D Feeding management

1 How do your birds feed?

	Total scavenging
	Entirely on commercial diets
	Scavenge but supplementary feeds are also provided.

2 If supplementary feeds are provided, what are the ingredients:

Carbohydrates/ Energy	Protein
Maize bran…..……..	Fish meal……..
Rice bran...……..	Soya bean…..……..
Maize grain……..	Cotton seed cake ……..……..
Wheat grain……..	Sunflower seed cake……..……..
Minerals/Salts	Vitamin
1. Bone meal……(Others)……	1. Premix. .……(Others)……..

During which seasons of the year (Dry or Rainy) are these feed resources most abundant?

Carbohydrates/ Energy…… Proteins…….

Minerals/Salts…… Vitamins…….

3 If you supplement, do you mix your own feed at home?

Yes ☐ No ☐

4 If yes in what proportion do you mix the different ingredients?

……

5 How are the feeds given to chickens?

☐ Feed put in troughs or containers.

☐ Feed is often scattered on the ground.

6 How many times do you distribute supplements to your chicken?

Once a day	Available all the time
Twice a day	

7 Do you provide drinking water to your chicken?

Yes ☐ No ☐

8 If yes which equipment do you use?

Drinker……Sauce pan…… Broken Pots (urujyo)…….. Part of jerry cans…… Other …..

9 How many times and at what time do you give water to your chickens?

Once a day..... Twice a day..... All the time.....

10 Which constraints do you face most in feeding of these chicken flocks?

……

E <u>Breeding management</u>

1 Which breed of chicken do you have?

☐ Local

☐ Exotic (specify) ……

☐ Crossbred (specify) ……..

2 Which kind of local chicken do you keep (give name and describe)

……

3 Do you carry out selection for your breeding stock?

Yes ☐ No ☐

4 If yes what attributes do you consider when selecting a breeding cock:

……

5 For how long do you keep a breeding cock in the flock…….

6 What attributes do you consider when selecting a breeding hen:

……

7 Do you carry out cross-breeding among chickens in your flock?

Yes ☐ No ☐

8 If yes has it been of benefit to you?

Yes ☐ No ☐

9 How is this cross breeding done?

☐ Random mating.

☐ Organized (controlled mating)

F <u>Housing</u>

1 In which facility do your birds shelter overnight?

☐ Chicken house with enclosure

☐ Shared the same house with the owner

☐ On the veranda

2 What management practices do you often undertake to maintain the housing facility in a good condition?

……

3 How do you dispose of the chicken wastes?

☐ Used as manure.

☐ Not put to use in any way.

G Production costs, profitability and marketing of chicken products

1 If sold what is the average price of :

An egg…… Mature cock…….. Mature hen.....Grower.....Chicks.....

2 How do you market your products?

☐ Sell to middlemen

☐ Sell directly to consumers.

H Mortality and Disease management

1 Which chicken group has the highest mortality rates?

☐ Chicks

☐ Cocks

☐ Hens

☐ Pullets and cockerels

2 What are the causes of mortality (rank)

1st……

2nd……...……

3rd……..……

4th……

3 Name the major four diseases

……..

4 During which periods of the year are the mortality rates highest?

.……

J Vaccination

1 Do you vaccinate your chickens Yes ☐ No ☐

2 If yes which diseases do you vaccinate…….....

3 what is the availability of the vaccines

Always available…… More often…….

Often…… Rare……..

Not available……..

2. Morphological measurement

Chickens Descriptive parameters	Tick	Observation if any
1. Plumage Patterns		
Mottled		
Birchen		
Silver penciled		
Speckled		
Partridge		
Uniform		
Coronation		
Barred		
Rumpless		
Naked neck		
Structure of comb		

Erect		
Droopy		
Comb		
Single		
Double		
Rose varieties		
Pea		
Earlobes color		
red		
white		
yellow		
Ear lobe shape		
Round		
oval		
Structure of beak		
straight		
curve		
Colour of the beak		
Yellow		
Black		
Brown		
white		

green		
Feather Structure		
Smooth		
Frizzled		
Superficially silky		
Silky		
Eye colour		
Pink Yellow		
Brown		
Orange		
Red		
Pear		
Shank colour		
Pink		
White		
Yellow		
Steel blue		
Greenish		
Black		

Body Measurement

Chickens Descriptive parameters	measurements	Observation if any
General characteristics		
Weight		
Body length		
Wingspan		
Head		
• Skull length Skull width		
• Comb length		
• Comb width		
• Beak length		
• Beak width		
• Ear lobes length		
• Ear lobes width		
• Wattles width		
Extremities		
• Thigh length		
• Folding wing length		
• Tarsus diameter		
Comb size		
Droopy		

Erect		
Breast circumference		
Body length		
Wing span		
Shank length		

Reproduction Parameters

- Age at point of lay [_____]
- Age to sexual maturity for males [_____]
- Age to sexual maturity for females[_____]
- Number of eggs laying/clutch [_____]
- Number of clutches per year [_____]
- Annual egg production [_____]
- Hatching rate (%) [_____]

The hatchability rate under natural incubation [_____]