CHARACTERISATION OF PRODUCTION SYSTEMS AND DEVELOPMENT OF BREEDING OBJECTIVES FOR INDIGENOUS CHICKEN IN RWANDA

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DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not, wholly or in part, been presented in this or any other University for an award of a degree.

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RECOMMENDATION

This thesis is the candidate's original work and has been prepared with our guidance and assistance; it has been submitted with our approval as the official University supervisors.

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ABSTRACT

Poultry production is one of the animal production enterprises with a promising future in Rwanda as 80.1% of all Rwandese raise chickens. Indigenous chickens (IC) are the most numerous and important species of poultry as they are found in most rural households in Rwanda. Currently, IC potential is underutilized due to the lack of well-defined production and breeding practices; the farmer, marketer and consumers' breed preferences and traits of economic importance are unknown. The objectives of this study were to characterise the IC production systems in Rwanda, to identify the breeding practices and traits of economic importance and to develop a bio-economic model and estimate the economic values for traits of economic importance. Data were collected using the structured questionnaires administered to farmers, marketers and consumers from November 2015-January 2016. Data were analysed using SAS and SPSS software. The production systems in all districts studied were mainly extensive (FRS) with minimum provision of supplementary feeds. Semi-intensive (SIS) and intensive (IS) systems were also practiced at low extend. The main challenges facing IC production were diseases outbreaks, lack of investment capital and predators were the major challenges. Indices for the traits perceived by farmers as of primary economic importance were egg yield (0.093), disease tolerance (0.091), high growth rate (0.089), prolificacy (0.088), high body weight (0.087) and egg fertility (0.083). The most importance traits considered by the marketers were body weight (BW), disease tolerance (DTOL), plumage colour (PCOL), egg yolk colour (EYC), meat quality (MQ), growth rate (GR) and egg yield (EN) whereas for consumers, meat quality, egg yolk colour, egg yield, body weight and growth rate were considered. The results from the model show that IC can be utilised profitably under free range system. A negative profit was observed in semi-intensive and intensive systems. The economic values for EN, live weight for grower (LWg), live weight for cock (LWcock) and live weight for hen (LWhen) were positive in all three production systems. Economic values for fertility (FER) and hatchability (HA) were Frw 185.21 and 171.42, –68.16 and –63.08, and -427.10 and –395.295 in FRS, SIS and IS, respectively. An increase of 1% in EN resulted in an increase in revenue of Frw 61.21, 112.12 and 143.95 in FRS, SIS and IS, respectively. Economic values for LWhen increased by Frw 1225.00, 1312.50 and 1662.50 while the revenues from LWcock increased by Frw 350.00, 375.00 and 475.00 of the total profits in the respective production systems. one percent increment in LWg resulted in a profit of Frw 187.02, 270.49 and 431.23 in FRS, SIS and IS. This study has presented the possibility of genetic improvement of productive and functional traits of IC in Rwanda.

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LIST OF ABBREVIATIONS

AD	Anno Domini
BC	Before Christ
CRFS	Confined full-ration system
CoELIB	Centre of Excellence for Livestock Innovation and Business
EICV	Enquête Intégrale sur les Conditions de Vie des Ménages
EACSOF	East African Civil Society Organizations' Forum
FAO	Food and Agriculture Organization
Frw	Francs Rwandais
GDP	Gross Domestic Product
IC	Indigenous Chicken
INCIP	Smallholder Indigenous Chicken Improvement Programme
Kg	Kilogram
Kcal	Kilo calorie
KgD	Kilo of Dry matter
MINAGRI	Ministry of agriculture and animal resources
ND	Newcastle Disease
NISR	National Institute of Statistic of Rwanda
NGOs	Non-Governmental Organizations
SAS	Statistical Analysis System
SPSS	Statistical Package for the Social Sciences
RAB	Rwanda Agricultural Board

CHAPTER ONE

GENERAL INTRODUCTION

1.1. Background information

Livestock production in Rwanda is a major agricultural activity contributing about 12% of the national GDP and 30% of the agricultural GDP (Rwanda Statistical yearbook, 2011). The livestock sector is supported by different species, but poultry are the most predominant in terms of numbers with an estimated population of 4.8 million heads (FAOSTAT, 2013). Out of 4.8 million poultry birds, 24,000 are ducks and 11,000 are geese and guinea fowls (FAOSTAT, 2013). Currently they contribute to the 3,000 tonnes of eggs and 2,144 tonnes of chicken meat produced annually (FAOSTAT, 2013).

The most common poultry species is chicken that is raised by over 80% of farmers especially for egg production making chicken production a promising animal enterprise for achieving rural development (NISR, 2011). Poultry farming particularly IC are the most numerous and important species found wherever there are human settlements in Africa (Mekonnen *et al.,* 2010). Their popularity among resource poor rural households and disadvantaged groups in developing countries is attributed to their low costs of production associated with less land requirement, low inputs, and low startup capital; adaptability to harsh scavenging conditions and poor nutrition and tolerance to parasite and diseases (Dana *et al.,*2010; Kingori *et al.,* 2010). Apart from providing protein, IC keeping contributes to the economy and poverty reduction because it serves as a source of income for farmers (MINAGRI, 2012).

Since 1994, after the Tutsi genocide, there have been many programmes to restock the family-farming sector with poultry including distribution of chickens to returning refugees and cockerel exchange programmes. Some of the refugees came back with chicken from the areas where they had lived (MINAGRI, 2012).

In 2012, the Ministry of Agriculture and Animal Resources (MINAGRI) initiated a strategy and investment plan to strengthen the poultry industry in Rwanda starting from 2012-2015 with aim of making the poultry a flagship of the Rwandan livestock (MINAGRI, 2012). One component of the project was to improve the village poultry production by tackling the factors affecting IC production through genetic improvement by crossbreeding IC with exotic breeds; health and disease control and improvement of IC husbandry (MINAGRI, 2012). The recently started crossbreeding trials with the “Kuroiler” synthetic breed are an example of such a programme to study the possibilities to increase productivity of this chicken production

(MINAGRI, 2012). Despite the effort made by the Government of Rwanda as well as other developing countries to recognize IC as an avenue to alleviate poverty and food insecurity reduction, little efforts have been made to improve their productivity which has been recognized as the major obstacle in their utilization and conservation. Their low productivity has hindered their potential to uplift the living standards of their custodians and contribution to rural development (Okeno *et al., 2*012).

In developing countries, previous attempts to improve the IC productivity through crossbreeding with commercial exotic breeds have largely been unsuccessful due to incompatibility of crossbreds with low-input production systems, lack of clear breeding objectives and operational breeding programmes to ensure constant supply of breeding stock to farmers (Natukunda *et al.,* 2011; Magothe *et al.*, 2012; Okeno *et al.,* 2012). Other major challenges to IC production identified were poor quality and inadequate feed resources, healthcare, marketing, housing and lack of breeding stock (Okeno *et al.,* 2011; Bett *et al.,* 2012). Second attempts were made in developing countries to increase the IC productivity. For instance, in 2006 through a collaborative programme, the Smallholder Indigenous Chicken Improvement Programme (INCIP) was initiated in Kenya. The objective of the programme was to undertake a comprehensive analysis of the entire IC value chain for the purpose of understanding the entire sub-sector (www.incip.org). Through INCIP, various steps for the development of breeding programmes which is the first step in IC genetic improvement (Bett *et al.,* 2011; Okeno *et al.,* 2012) were undertaken. For example, the production systems of the IC sub-sector in Kenya have been characterized by Bett *et al.* (2012) and Okeno *et al.* (2012a) and on-station production and reproduction parameters of different IC genotypes and ecotypes estimated by Magothe *et al.* (2010) and Ngeno (2011). The farmer's preferences in selection of IC genetic resources and IC disease and parasites prevalence were studied Kaingu *et al.* (2010). In addition, the breeding objectives accounting for the needs of all stakeholders along the value chain were also developed (Okeno *et al.,* 2012). Bio-economic models have been used to estimate profitability and economic values for traits of IC (Okeno *et al.*, 2013). In Rwanda, such studies are scarce. In addition, breeding objectives have not been documented to guide the farmers on how to implement genetic improvement of IC to improve their livelihoods. Therefore, there is need to develop breeding objectives accounting for the needs of all stakeholders along the production value chain in the IC production. This will call for comprehensive characterization of IC production systems.

1. 2. The statement of problem

In Rwanda, IC are the most numerous and important species of poultry as they are found in most rural households. Currently they play significant roles to women, widows and orphaned children in terms of food security and nutrition, cash income and savings. Despite IC contribution to the rural household development, they have remained less competitive compared to exotic breeds due to their low productivity. In developing countries, such as Rwanda, previous attempts to improve their productivity through crossbreeding with exotic chickens proved unsustainable because the resultant genotypes could not survive under extensive production systems. This has been attributed to poor understanding of the IC production systems as it was assumed that all production systems were homogenous with similar production objectives and management interventions. The best way to promote the competitiveness of IC is to improve their productivity without altering their morphological and environmental characteristics. This requires characterisation of their production systems and identification of the existing IC ecotypes and their features to producers as the first step. Characterization would help in formulation of realistic breeding objectives that are relevant to existing and future production conditions. Formulation of breeding objectives requires identification of traits of economic importance and estimation of their economic values, which is currently lacking.

1.3. Objectives

The main objective of this study was to contribute to the improved productivity of IC through characterisation of IC production systems and development of breeding objectives for IC in Rwanda. The specific objectives were:

i. To characterize the production and marketing systems of IC in Rwanda.

ii. To identify the breeding practices and traits of economic importance for IC genetic resources from the perspective of stakeholders along the IC value chain in Rwanda.

iii. To develop a bio-economic model and estimate economic values of traits of economic importance.

1. 4. Research questions

i. What are the characteristics of the production and marketing systems of indigenous chicken in Rwanda?

ii. What are the breeding practices, breeding goals and traits of economic importance in the selection of IC genetic resource?

iii. What are the economic value of the traits in the breeding objectives under different IC production systems?

1.5. Justification

Characterization of IC production, breeding and marketing practices helped to understand the production system under which IC are raised in Rwanda, the study explored the farmers, traders and consumer's breed preferences and traits of economic importance. The generated information has been used to define IC breeding objectives. The developed breeding objectives provided a clear basis tool to the development of sustainable breeding programme for genetic improvement and conservation of IC genetic resources.

CHAPTER TWO

LITERATURE REVIEW

2.1. Chicken production in Rwanda

Despite the low productivity of indigenous poultry genotypes compared to commercial strains, indigenous genotypes are widely distributed in rural and peri-urban of many developing countries, frequently in excess of 80 percent (Gabanakgosi *et al.*, 2013; Pym, 2010). In rural villages in most countries, the majority of families have small flocks of poultry, mainly chickens but sometimes other species including ducks, turkeys and guinea fowls, which provide family needs for poultry meat and eggs (Pym, 2010). These birds are invariably indigenous genotypes, or cross-breeds with a significant indigenous genotype component. Globally, IC produce 30% of all the white meat consumed (FAO,2014).

In Africa chickens and IC in particular, are the most numerous and important species of poultry as they are found wherever there are human settlements (Akinola *et al.,* 2011). Although, IC was primarily domesticated in Africa for cultural, ritual and social activities, their roles have changed over time (Okeno *et al.,* 2011). Currently they play various significant roles such as generating income and employment for various categories of people including poultry farmers, primary and secondary traders, processors and caterers from sale of birds and eggs. IC play significant gender roles to women, widows, and orphaned children in terms of food security and nutrition, cash income and savings. They provide a valuable source of protein in the diet (Kingori *et al.,* 2010; Okeno *et al.,* 2012a). The IC also play an important socio-cultural role and traditional medicine in many societies (Kingori *et al.,* 2010; FAO, 2014). Compared to other livestock species, IC have advantages in that they are hardy, adapting well to the harsh scavenging conditions and poor nutrition and tolerance to parasites and diseases, survive on low inputs and adapt to fluctuations in available feed resources. The IC have the advantages of having quick returns to investment and relatively simple management practices with numerous market outlets for their products (Kingori *et al.,* 2010).

In the East African region, archaeological dates (calibrated) for the presence of chickens are more recent; the earliest is mid-seventeenth century BC in Sudan compared to 800 AD in coastal Kenya and in Akameru and Cyinkomane in Rwanda. However, the subsequent pattern and chronology of dispersion of the species within the continent remain unclear (Mwacharo *et al.,* 2013).

In Rwanda, since 1994 there have been many programs to restock the family-farming sector with poultry including distribution of chickens to returning refugees, cock exchange program etc. Some of the refugees came back with chicken from the areas where they had lived. The recently started crossbreeding trials with the “Kuroiler” synthetic breed are an example of such a program to study the possibilities to increase productivity of this poultry production sector. Up to date poultry population is estimated at 4,838,000 million heads (chickens, ducks and turkeys).

Poultry industry in Rwanda is characterised by the coexistence of 2 systems; rudimentary village poultry and industrial poultry which is at its infancy. These systems are faced with scarcity of inputs to fully exploit their potential. The problem of low productivity is wide spread in the country (MINAGRI, 2012). This is mainly attributed to the high mortality of chicken occasioned by outbreaks of Newcastle disease (ND), fowl pox and fowl cholera; poor management and insufficient food in quality and quantity (MINAGRI, 2012).

The exotic chicken breeds found in Rwanda are exotic layer breeds such as Leghorn, Sussex, Rhode Island Red, Derco, Isa Brown, Norman with a laying performances range from 300 to 350 eggs per hen per year (MINAGRI, 2012). The exotic Broiler breeds are Cobb 500, Hubbard, and Derco and in ideal conditions, they reach 2kg in 45 to 50 days (MINAGRI, 2012). A substantial portion of the meat and eggs consumed in Rwanda are derived from commercial broilers and layers respectively. The exotic chickens are kept under commercial poultry production system provided with feeds, shelter and clean water and regularly vaccinated against common poultry diseases such as New Castle Disease. However, in some farms exotic chicken are kept in various place with low to minimal biosecurity. For example, a caged layer farm with birds in open sheds, a farm with birds spending most of the time outside the shed or a farm producing chickens and waterfowl (MINAGRI, 2012). The emergence of high-performance exotic poultry industry is closely linked to the developed of the poultry feed industry whose nonexistence compelled farmers to produce the diets themselves. As a result, feed prices are higher due to the lack of economies of scale, not to mention quality problems. Many ingredients used are relatively scarce in the domestic market and very expensive. There is also an unpredictability of prices that fluctuate strongly over the year (MINAGRI, 2012).

The IC breeds like in other developing countries are dominant than the exotic chicken in Rwanda and therefore tend to supply more families with eggs and meat than the commercial chicken. The IC ecotypes found in Rwanda are dwarf, Normal and frizzled feathers, Naked neck, cross and non-distinctive breeds utilised as dual-purpose birds producing both eggs and meat. They are characterised with small flock size which varies seasonally and their laying performance ranging from 40 to 100 eggs per hen per year. They are mostly kept under subsistence production systems with minimal biosecurity (MINAGRI, 2012).

2.1.1. Chicken production systems

In the tropics, a number of production systems under which IC are raised have been identified with variable management regimes (Kingori *et al.,* 2010). They include the free-range, backyard, semi-intensive and intensive production systems.

Free-range production system (FRS)

In FRS, the management of the chickens is mainly based on available indigenous technical knowledge. Both the chicks and the mature chicken are mostly left to scavenge for feeds during the day and confided at night (Kingori *et al.,* 2010). They scavenge for insects, food and kitchen leftovers, green grass, leafy vegetables and any scattered grains (Moges *et al.,* 2010). Occasionally the birds are supplemented with household crop leftovers such as maize, millet, sorghum, ripe pawpaw seeds, amaranth's seeds, cassava meal, cereal bran, wheat (Kingori *et al.,* 2010; Gabanakgosi *et al.*, 2013). Supplements vary based on season and availability. They are placed either on ground or into unprepared feeders. Drinking water is irregularly given in tins or broken clay pot pieces (Kingori *et al.,* 2010). Housing under free scavenging system is not developed and where it exists it is mainly for birds' protection against predators and extreme weather (Kingori *et al.,* 2010). The FRS system is characterised by low outputs-egg and meat production per bird, but requires low capital input and hence low economic risks (Dessie *et al.,* 2011). Replacement stocks are obtained from own hatching chicks or are purchased from the local market, or from neighbours or given as gift. Marketing channels for products and live birds are undefined. During the time when there is urgent need of money or when birds are sick or when hatching is not required, live birds and eggs are sold at the gate or in the local market (Dessie *et al.,* 2011). About 95% of the IC are raised under FRS by rural smallholder farmers in the tropics (Dessie *et al.,* 2011).

Semi-intensive system

The semi-intensive or semi-scavenging system (SIS) is practiced in small households where families are financially able more than the rest of the household who practice the scavenging system (Kingori *et al.,* 2010). Chickens are partly confined, especially in relation to the prevailing activities in arable agriculture, e.g., when crops are at stage where foraging chickens could destroy them (Moges *et al.,* 2010). Chickens are confined to avoid conflicts, but they get crop residues, grains and kitchen leftovers as supplement for their daily feed requirements. The chickens reared under this system are mainly crosses between indigenous and exotic breeds. Water and sometimes veterinary or ethno-veterinary care is provided though not adequately and mortality is 40-60% in young chicks (Moges *et al.,* 2010; Kingori *et al.,* 2010).

Intensive system

The intensive system or confined full-ration system (IS), is the production system where flock is confined all the time and supplied with a balanced diet (Moges *et al.,* 2010). Vaccination against endemic diseases is common under this system. This system is not common in most tropical field situations because of high input requirements (Harrison *et al*., 2010; Msoffe *et al.,* 2010).

2.1.2. Marketing systems for chickens and their products

In Rwanda, poultry farmers sell live birds and eggs through two main channels: directly to consumers (at farm gate) and through village level primary markets or delivered directly to retail outlets. More often primary collectors at the primary markets sell live birds to retailers who operate in secondary markets in urban centres/cities. These secondary collectors in turn sell directly to consumers or to other traders or to hotels or restaurants. Although eggs are mainly used for home consumption, a small quantity is sold to passengers to Democratic Republic of Congo (DRC), Uganda and Burundi along the major highways.

During normal demand and supply season the offtakes rates for IC was estimated to be 10% which increased from 50 to 60% during high demand season such as opening of schools, public holidays and festive seasons. High supply is also observed during the crop season when farmers increase off take to avoid high confinement costs (feeds and housing) of birds throughout the day (MINAGRI, 2012). Main marketing challenges include reduced income attributed to low farm gate prices, season fluctuation in prices attributed to seasonal changes in demand and supply; low supply of IC due to low productivity; and disruptions of markets; high mortality of poultry in the marketing process due to inadequate disease control in the poultry value chain (MINAGRI, 2012).

Like in many countries in the region, there are no poultry designated markets and therefore live poultry are sold in other goods and services markets constructed by central and local government in trading centres, large towns and cities. Figure 1 shows the IC value chain in Rwanda.

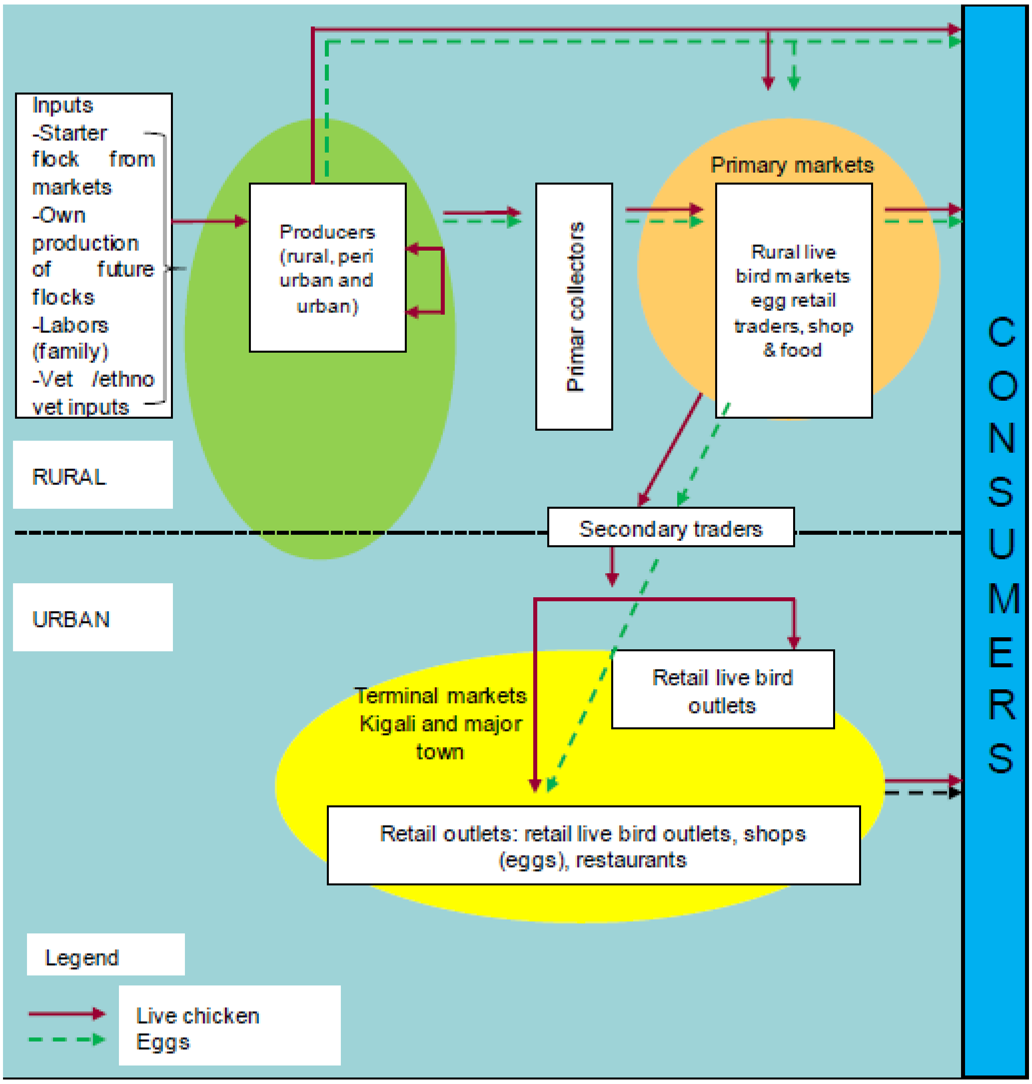

Figure 1. Indigenous chicken value chain in Rwanda.

(Source: FAO / Tabitha Kimani and Alex Nyarko 2011)

2.1.3. Chicken breeding

In Rwanda, national supply of one-day chicks for both eggs and meat production are virtually nonexistent. Almost all the chicks are imported, mostly from Uganda, Belgium and Netherlands. Chicks from Uganda are cheaper (500 rwf vs. 700; 850 vs. 950 for laying chicks) but the delivery times are long (2 to 3 months). Moreover, Rwanda faces competition from RDC (Goma) and South Sudan which have strong demand. The National hatchery (Rubilizi hatchery) and other small hatcheries located in different districts obtain parent stock directly from international breeders and rear them for purposes of producing fertile eggs. Both layer and broiler parent stock are kept on deep litter system, but provided with nest so as to avoid getting dirty or broken eggs. During the growth of the parent stock, careful monitoring of live weight gain is done so as to prevent the parent stock from achieving their growth potential and thus create problems in fertility and hatchability.

The Incubation capacity, however, is misleading because most of these hatcheries operate only partially. This is confirmed by the fact that the Rubilizi hatchery, which account for 28% of the national chick production capacity, and the subsequent imports to fill the gap. Previous study by MINAGRI (2012) indicated that the total parental stock was 15,468 hens and incubation capacity was 95, 618 eggs. The fertile eggs are hatched and day old chicks are bought by farmers on hatchery gate who transport chicks at their farms located in the urban and peri-urban areas mostly surrounding Kigali city and the boundaries of Rwanda and Democratic Republic of Congo. The farmers are given manuals on broiler and layer chicken production and some attend poultry farming training organised by the National Agriculture board. Generally, a substantial proportion of eggs and meat consumed in the country are produced from specialized eggs and meat stock. At the end of their productive life, layers and broiler parent stock are sold to be slaughtered for meat.

IC breeding in Rwanda like other developing countries is relatively individual affair and the farmer decides what characteristics to proliferate (Menge, 2008). Some farmers have, however, indicated that they prefer prolific chicken with high disease resistance while others have shown preference for chicken with colours that are not bright for the purposes of camouflaging the chicken from airborne predators as they are scavenging for feed (Moges *et al.,* 2010; Essien *et al.,* 2011; Cabarles, 2013). Recently in 2014, FAO in collaboration with Rwanda Agriculture Board (RAB) have launched a project worth US$800,000 to help improve poultry farming in the country. This project aims to assist small scale poultry farmers to increase production and promote their linkages to markets. To achieve the major objective, the project adopted IC and their crosses and provided equipment like incubators, fund construction of poultry shelter and long-term loans to the farmers. United Nation (UN) organisation offered training in poultry, especially how to shorten the production cycle and reduce the associated risks for small scale farmers so that they can provide high quality pullets.

2.1.4. Constraints to chicken production

Usually poor management and inappropriate construction of the house in the tropics especially in sub-Sahara Africa does not allow for the maintenance of proper sanitation and there is no regular dusting and use of antibiotics in minimal. The IC healthcare is poorly undertaken across the countries (Asmara, 2014; Okeno, *et al.,* 2012). This leads to high pest infestation and frequent disease outbreaks, resulting in high mortalities. Various diseases have been identified in FRS as major constraint both in terms of costs of prevention, treatment and/or loss due to resulting mortality or reduced productivity. Expenditure on disease control is minimal and chick mortalities average 40-60% over the first 8-weeks. Newcastle Disease (ND) is the most prevalent and fatal in poultry in tropics (Moges *et al.,* 2010; Okeno *et al.,* 2012; Gabanakgosi *et al.,* 2013; Addisu *et al.,* 2014). Other common diseases are fowl pox, fowl typhoid and coccidiosis (Kingori *et al.,* 2010; Mtileni *et al.,* 2012). Other constraints identified in IC production among smallholder in the tropics include costly and/ or poor quality feeds, lack of high-quality breeding stocks, lack of finances, limited marketing channels, small flock size, inadequate IC performance, low levels of literacy, lack of access to extension and healthcare services (Moges *et al.,* 2010; Okeno *et al.,* 2012; Gabanakgosi *et al.,* 2013).

2.2. Performance of indigenous chicken genotypes and their crosses

The traits influencing productivity include the annual egg number, live weight at sexual maturity, egg weight, fertility, hatchability and chick survival rate are important because they influence the of eggs spared for consumption or sale and generation of replacement stocks (Menge, 2008). Traits such as resistance to diseases, incubation behaviours, scavenging efficiency, plumage colour, naked necks and homing instinct are also essential for suitability to particular environments (Menge, 2008).

A number of studies in the tropics have reported production and reproduction performance of IC under FRS, SIS and IS. Table 1 shows the production and reproduction performances of IC in several countries. Bekele *et al.* (2010) and Victor *et al.* (2014) reported that in backyard and semi-intensive production systems, age at first egg ranges from 180 to 240 days in Tanzania and Sri Lanka. However, this has been shown to reduce to 166 days under intensive management. This could be a clear indicator of genotype x environment interaction effect under improved intensive system. The number of clutches per year ranges from 2 to 3 in FRS and SIS and 4 clutches per year in IS (Kitalyi *et al.,* 2002; Asresie *et al.,* 2015). The number of eggs per clutch ranges from 10 to 18 eggs in FRS and 22 eggs in SIS systems whereas in IS it goes up to 30 eggs per clutch (Kitalyi *et al*., 2002; Njenga, 2005; Akinola and Essien, 2011). The mean egg weight in all production systems range between 38-48 g. Fertility and hatchability range between 60-93 % and hatching weights are often low, ranging between 30 to 43g (Table 1). The chick survival range between 13-84% in backyard and about 86% in IS (Olwande *et al.,* 2010; Akinola and Essien, 2011; Cabarles, 2013). IC are relatively active and hardy thus have better ability to withstand the disease challenges associated with free-ranging and the tropical heat stress than chicken genotypes obtained from temperate areas (Menge, 2008).

Table 1. Mean production and reproduction performance of indigenous chickens

Trait	Mean performance			
	IS	SIS	FRS	References
Age at first egg (days)	166.0	203.0	224.0	Bekele *et al*. (2010);Victor *et al.* (2014)
No. of clutches/year	4.0	3.0	2.5	Kaudia and Kitalyi (2002);Asresie *et al.* (2015)
No. of eggs/clutch	30.0	21.2	11.1 – 18	Kaudia and Kitalyi (2002); Njenga (2005);Akinola and Essien (2011)
Egg weight (g)	42.7	-	38 - 48	Njenga (2005); Magothe *et al.* (2010); Olwande *et al.* (2010)
Fertility (%)	61.8	-	-	Njenga (2005)
Hatchability (%)	74.2	77.0	84-93	Kaudia and Kitalyi, (2002); Njenga (2005); Kingori *et al.* (2010);Olwande *et al.* (2010); Dana *et al.* (2010)Akinola and Essien (2011); Cabarles (2013) Victor *et al* (2014);
Chick survival rate (%)	86.0	-	13 - 84	Olwande *et al.* (2010); Akinola and Essien (2011); Cabarles (2013)
Annual egg production	120.0	75	40 - 60	Kaudia and Kitalyi (2002); Akinola and Essien (2011)
Chick weight at hatch (g)	32.7	43	-	Magothe *et al.* (2010); Adeleke *et al.* (2011)
Chick weight at 8 weeks (g)	438.9	-	-	Magothe *et al.* (2010)
Body weight at first egg (g)	1162-1630.0	-	-	Victor *et al.* (2014);Musa *et al.*(2015); Adeleke *et al.* (2011)
Mature body weight (g)	2210^{m} 1660^{f}	- -	$1500 - 2096^{m}$ $1320 - 1599^{f}$	Njenga (2005); Magothe *et al* (2010); Olwande *et al.* (2010); Dana *et al* (2010) Akinola and Essien (2011); Cabarles (2013)

^{m}male, ^{f}female.

Hens lay about 45 eggs per year with a range between 40-75 eggs under FRS and SIS. However, when supplemented with concentrates some lay up to 120 eggs under intensive systems (Kitalyi *et al., 2*002; Akinola and Essien, 2011). The body weights of IC at first egg are in the range of 1.1 to 1.6 kg under IS. Males grow faster and are heavier than females, with an average mature body weight of 2.2 and 1.3 kg in all production systems respectively.

Crossbreeding the IC with exotic breeds has been shown to improve the growth traits, such as live weights, feed conversion efficiency, daily gains and egg production traits. Studies on the growth performance of Nigerian local chickens' cross with exotic broiler breeder (Anak Titan) showed that crosses involving Anak Titan sire x Naked neck dam had highest growth performance. They revealed that genetic variations existed in crossbreeding the local chickens with exotic breed on body weight, breast girth and keel length (Adeleke *et al.,* 2011). In Ethiopia, it was found that under farmers' management conditions, the F_1 crosses (Fayoumi-crosses and RIR-crosses) had the highest egg production potential compared with that of IC (Alewi *et al.,* 2012). This could probably be due to heterosis effects. In addition to heterosis effects, the higher mature body weight of crosses compared to IC would also have contributed to the higher rates of live weight gain (Chimonyo and Dzama, 2007).

2.3. Development of breeding objectives

Definition of breeding objectives is the first step in genetic improvement as it defines the direction of selection and genetic merits of performance traits (Bett *et al.,* 2011; Okeno *et al.,* 2013). Development of breeding objectives involve the genetic evaluation, selection and mating schemes with the aim of modifying animal performance. It involves definition of traits that influence profitability and estimation of their economic values. Breeding objectives should, therefore, reflect the production and economic environment under which the animals are raised (Okeno *et al.,* 2013). Development of breeding objectives requires a critical analysis of costs and returns associated with the production system. There are four distinct phases in the development of a breeding objective

i. Specification of the breeding, production and marketing system
ii. Identification of sources of income and expense
iii. Determination of biological traits influencing revenues and costs,
iv. Derivation of the economic value of each trait in the breeding objective.

2.3.1. Specification of the breeding, production and marketing systems

Characterisation of the breeding, production and mating system is a good starting point for the definition of the breeding objective (Okeno *et al.,* 2011). It helps to understand the production and management practices of farmers and the associated challenges and opportunities which are essential for holistic improvement (Okeno *et al.,* 2011; Addisu *et al.,* 2014.). The breeding objective should reflect production and economic conditions in those environments in which breeding animals have a genetic influence.

2.3.2. Identification of sources of income and expenses

In the description of the production and marketing system, inputs and outputs should be quantified. Inputs are related to the cost, while incomes can be measured in terms of money that are generated from the sale of the farm's products (Åby *et al.,* 2012; Gebre *et al.,* 2012). Inputs cost can be categorized into either variable or fixed. Variable cost depend on the level of production (Mbuthia *et al.,*2015). Fixed cost are the costs incurred by the producer independent of level of production of the flocks or herds (Bett *et al.*, 2012; Okeno *et al.*, 2013). The description should be holistic and the following should be specified: the sources of income (sales of surplus eggs, growers, culled hens and cocks; sale of unselected cockerels for breeding) and expenses (cost of feeds according to each class of chicks; cost of labour, building and equipment) are all necessary for fully description on production systems (Okeno *et al.,* 2012; Mbuthia *et al.,* 2015).

2.3.3. Determination of biological traits influencing income and expenses

In principle, all traits influencing revenues and costs should be included in the breeding objectives (Bett *et al.*, 2011) even if one or more production traits cannot be measured directly. The profit equation is expressed as a function of the principal biological traits contributing to each source of income and expense. The traits that are considered important differ between each farmers (Producers), marketers and consumers. Okeno *et al.* (2012) indicated that body weight, production and reproductive performance and the survival rate are important traits affecting sources of income and expenses in poultry production in Kenya. Development of a breeding objective requires a critical analysis of costs and returns associated with the production. A profit equation that identify and evaluate all costs and revenues have been used. The economic contributions of changes in biological performance were used to establish the effect of genetic change on profit (Okeno *et al.,* 2012b; Mbuthia *et al.,* 2014). Those studies found that the distribution of fixed and variable costs across the enterprises changed when considering the value of genetic change in both market and breeding animals because of partitioning cost among different element of performance. Emphasis should be put on farm profit (Okeno *et al.,* 2012).

2.3.4. Derivation of economic values of traits

The economic value of the heritable traits is calculated from the change in predicted profit, based on a single unit change in that breeding objective trait, holding all others traits constant (Rewe *et al.,* 2011; Mbuthia *et al.,* 2015). The two ways of economic values derivation are applied using either positive approach which analyses field data or normative approach (data simulation also referred to as bio-economic modelling). In both approaches, derivation of profit necessitates a profit maximization function that must include all economic traits goals. The advantages of using the profit maximization function approach is the relative ease with the economic weights can be recalculated for different market preferences, production systems and sub-population or flock average. The profit maximization is the goal in any production system. However, Kahi and Niger (2004) advised that in smallholder dairy or poultry production systems in the tropics, minimisation of costs is important due to the limited amount of inputs. Determination of economic value for genetic improvement of different traits goals requires description of the production systems because the difference between revenue and cost can be used to determine the economic value of traits (profit function).

The biological value of a trait is the change in biological efficiency due to a unit change in genetic merit of a trait of interest, all other traits being constant. Traits in the breeding objectives are not expressed at the same time or at the same frequency. In order to account for these two methods are used: the first method consists of calculation of all income and costs (expenses) in one year for a given flock or herd while the second method use the discounted gene flow approach. In this procedure, the number of discounted expressions of a trait is expressed as a function of the number of progeny or later descendants of an animal plus an annual discount factor (Åby *et al.,* 2012).

2.4. Genetic and phenotypic parameters in chicken breeding

Estimates of genetic and phenotypic (co)variances are essential for prediction of breeding values and expected response to selection and monitoring genetic progress. Knowledge of genetic parameters is the basis of sound livestock improvement programs.

Estimate of heritability and genetic correlations are essential population parameters required in animal breeding research and in design and application of practical animal breeding programs. Genetic parameters are a characteristic of the population in which they were estimated and may change overtime due to selection and management decisions (Missanjo *et al.*, 2013).

Genetic and phenotypic parameters such as heritability and correlations have been estimated on different populations of IC at different stages of selection in several countries. Table 2 shows some genetic and phenotypic parameters of some production and reproduction traits in IC. Table 2 also shows that the parameter estimates even for the same trait are quite varied. Direct heritability estimates for LW1, LW12 and LW16 range between 0.36 to 0.56, 0.29 to 0.57, 0.14 to 0.23, respectively. Heritability estimates for LW12 were, therefore, higher than direct heritability estimates for LW16 (Table 2). The reasons for variations observed may include the fact that the heritability estimates were made on populations with different variance structures. Bahmanimehr (2012) found that EGW30 has high heritability (0.56) than EGW1 (0.2). In general, heritability estimates for EW ranges from 0.44 to 0.50 (Table 2).

Table 2. Genetic and phenotypic parameters of some production and reproduction traits in indigenous chicken

Trait1	h^2	σ_p	Trait2	h^2	σ_p	r_g	r_p	References
LW16	0.14	150.31	ADG	0.44	6.00	-0.62	-0.74	Iraqi *et al.* (2002)
EW	0.50	0.59	EYC	0.01	0.13	0.25	0.19	Alipanah *et al.* (2013)
LW1	0.56	2.83	EGW1	0.20	4.12	0.51	0.094	Bahmanimehr (2012)
LW12	0.51	72.49	EGW30	0.56	3.15	0.64	0.247	Bahmanimehr (2012)
ASM	0.40	-	LW12	0.57	-	-	-	Dessie *et al.* (2011)
EN	0.25	-	LW16	0.23	-	0.81	0.73	Dana *et al.* (2011)
EN	0.16±0.13	-	ASM	0.22±0.41	-	0.95±0.02	-	Ebrahimzadeh *et al.* (2015)
LW12	0.29	-	ASM	0.36	-	0.19	0.91	Shahram *et al.* (2012)
LW1	0.36	-	LW12	0.41	-	0.19	-	Ngambi (2006)
EW	0.44	0.70	EN	0.28		-0.39	-0.23	Oleforuh-okoleh (2011)
LW	0.54	-	EN	0.30	-	-	-	Osei-Amponsah *et al.* (2013)

EN-egg number/year; EW-egg weight (g); LW-body weight (g); LW1-body weight at hatch (g); LW12-body weight (g) at 12 weeks; LW16- body weight (g) at 16 weeks; EYC-egg yolk color; ASM-age at sexual maturity; EGW1-egg weight at first day; EGW30-egg weight at 30 days; h^2 heritability; σ_p phenotypic standard deviation; r_g genetic correlation, r_p phenotypic correlation.

Heritability estimates for EN ranges from 0.16 to 0.30. Ebrahimzadeh-Allahabad *et al.* (2015); Shahram *et al.* (2012) and Dessie *et al.* (2011) all reported low to moderate heritability for ASM (0.22, 0.36 and 0.40, respectively). In Egypt, a moderate heritability estimate for ADG was obtained for indigenous chickens (Iraqi *et al.*, 2002).

Phenotypic and genetic correlations are used in connecting traits within the selection criterion with traits in the breeding objective. Phenotypic correlations are association between phenotypic values of traits which can be directly observed and which occur as a result of genetic and environmental causes. Genetic correlations on the other hand are association between breeding values of two traits caused by pleiotropy and linkage (Menge, 2008).

As presented in Table 2, LW was positively correlated to EW, EN, and ASM. This means that selection for body weight may result to high egg weights and selection for high body weight may result in earlier sexual maturity and high egg number during the chicken productive life cycle Dana *et al.* (2011), Bahmanimehr (2012) and Shahram *et al.* (2012). However, Iraqi *et al.* (2002) found that LW16 was genetically and phenotypically negatively correlated with ADG. The trait EN has positive genetic correlation with ASM implying that earlier sexual maturity may result in high egg number (Ebrahimzadeh-Allahabad *et al.*, 2015). On the other hand, the trait EN has negative and phenotypic correlations with EW (Oleforuh-okoleh, 2011). This means that, the more IC lay more egg, the more they become small in size.

2.5. Selection index theory

It is necessary to make a clear distinction between breeding goal and selection criteria. The breeding objective comprises of traits which the producer attempts to improve genetically because they influence returns and costs while selection criteria are the characteristics used in assessing the breeding value of individuals. Traits in the selection criteria need not necessarily be the traits in the breeding goal. The selection criteria can be combined in a selection index whereby each characteristic is weighted so that the correlation between aggregate genotype and selection response is maximized.

Selection index methodology was developed by (Hazel *et al.*, 1994) to estimate the genetic value of an animal using observation for particular traits. The selection index can be represented by an equation as:

$$I = b_1X_1 + b_2X_2 + ... + b_nX_n$$

where I is the index value for the information source, b_1, b_2 …b_n are the weighting factors for the source of information X_1, X_2 … X_n on an individual animal or its relatives. The selection index coefficients are derived from the formula

$$b = P^{-1}Ga$$

where b is a vector containing the coefficients of the index traits, P is phenotypic variance-covariance matrix of the characters in the selection index, G is the genetic variance-covariance matrix between the characters in the index and traits in the breeding goal and a is a vector of economic values of the traits in the breeding goal to be estimated. Assuming a selection intensity of 1.0, the genetic gain (g) achieved after one round of selection is calculated as:

$$g = b'G/\sigma_I$$

where σ_I is the standard deviation of the selection index and $\sigma_I = \sqrt{b'Pb}$

where b, P and G are as defined above.

CHAPTER THREE

CHARACTERISATION OF INDIGENOUS CHICKEN PRODUCTION SYSTEMS IN RWANDA

3.1 Introduction

Livestock sector in Rwanda is supported by different species, but poultry is the most predominant in terms of numbers with an estimated population of 4.8 million heads (FAOSTAT, 2014). The most common poultry species are indigenous chickens (IC) that are raised by over 80% of farmers especially for egg production making poultry production a promising animal enterprise for achieving rural development (NISR, 2011). They play significant roles to women, widows and orphaned children in terms of food security and nutrition, cash income and savings.

Despite IC's contribution to the rural household development, they have remained less competitive compared to exotic breeds due to their low productivity. In Kenya, Magothe *et al.* (2012a), reported that mostly low IC productivity is caused by low genetic potential of the chickens, inadequate nutrition and diseases outbreaks and poor marketing channel which reduce their contribution to rural development. Akinola *et al.* (2011) reported that rural poultry productions systems in Africa is solely based on subsistence production where birds are kept as scavenger and they usually get little or no inputs such as feeding, health care and housing. Farmers rely on broody hens to perform brooding and taking care of chicks, which results in long reproductive cycles. All chicks hatched stay with their mother hens when scavenging, thus exposing them to predators, harsh environmental conditions and diseases. Thus, a high mortality rate in early life (six to eight weeks of age) ranging between 40 to 80% *(Kingori et al.,* 2010). Additionally, scavengeable feedstuffs available are insufficient in nutritional requirements and chicks have to compete for food with aggressive older chickens, leading to malnutrition which may finally lead to impaired growth, drop in performance or death (Kingori *et al.,* 2010; Akinola *et al., 2*011; Magothe *et al.,* 2012b).

In developing countries such as Rwanda, previous attempts to improve their productivity through crossbreeding with exotic chickens proved unsustainable because the resultant genotypes could not survive under extensive production systems (Dana, 2011; Natukunda *et al.,* 2011; Bett *et al.,* 2012; Magothe *et al.,* 2012; Okeno *et al.,* 2012). This was attributed to poor understanding of the IC production systems as it was assumed that all production systems were homogenous with similar production objectives and management interventions (Okeno *et al.,* 2012). The best way to promote the competitiveness of IC is to improve their productivity without altering their morphological and environmental characteristics. This requires characterisation of their production systems and identification of the existing IC ecotypes and their features to producers as the first step. Therefore, this study was initiated with the aim of characterising the IC production systems, management, feeding and constraints faced by IC farmers in Rwanda.

3.2 Materials and methods

3.2.1 Description of study area

The study was conducted in five districts of four provinces of Rwanda selected based on population of IC. These included Kicukiro (2°00′S/ 30°09′E), Rwamagana (1°57′09″S/ 30°26′16″E), Muhanga (2° 5' 0.00"S/ +29° 45' 0.00"E), Ruhango (2°12′S/ 29°46′E) and Rulindo (1°44′S/ 30°00′E) districts (Figure 2). These districts have the highest populations of IC raised in rural households and access to the feeder roads (access to the main roads, access to the market) (NISR, 2011). Rwanda has a temperate tropical highland climate, with lower temperatures than are typical for equatorial countries due to its high elevation. The temperature ranges between 12 ^{o}C and 27 ^{o}C, with little variation through the year (NISR, 2011). The study was conducted from November, 2015 to January 2016 with the aim of understanding socio-economic characteristics, management of IC, production parameters, feed resources and constraints faced by farmers rearing IC in Rwanda. Figure 2 shows the administrative map of the studied districts.

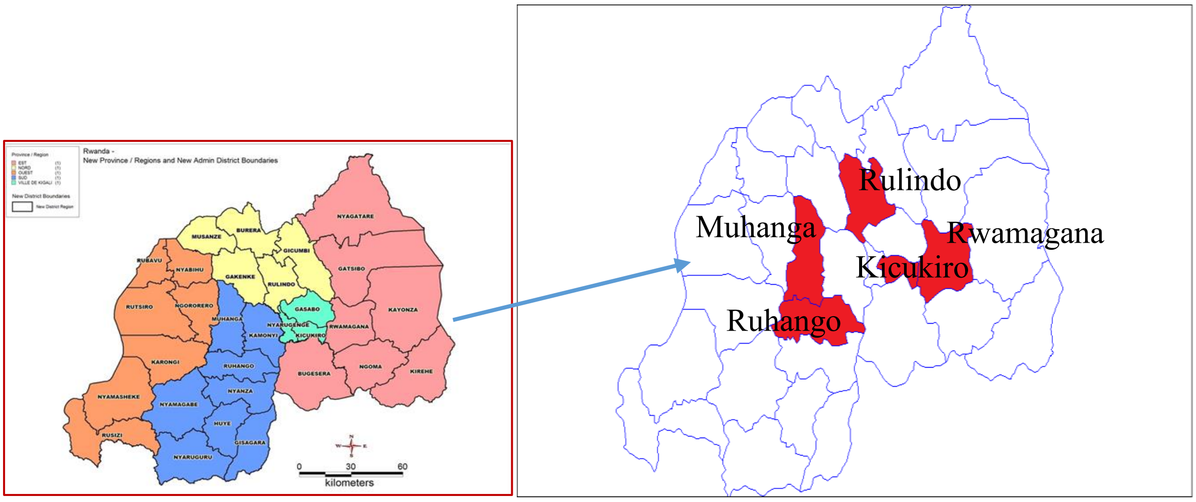

Figure 2. Administrative map of Rwanda showing four provinces and Kigali city (NISR, 2011).

3.2.2 Sampling framework and data collection procedures

In this study, qualitative and quantitative research approaches were employed. Qualitative data were obtained through observations made by enumerators and researcher and group discussions held with farmers, whereas quantitative data were obtained by interviews. A pretested structured questionnaire was used to gather information. During pretesting, local enumerators were employed in each district and trained by the researcher. Local enumerators were hired for ease of acceptability and communication within the communities. During visits, farmers were explained the objectives and benefits of the survey. The required total respondents were determined using the formula by Cochran (1963) for infinite population (infinite population ≥ 50,000).

$$N_o = Z^2 pq / e^2$$

where N_o = required sample size.

Z^2 = is the abscissa of the normal curve that cuts off an area at the tails (1-α) (95%= 1.96)

e= is the margin of error (e.g. ± 0.05% margin of error for confidence level of 95%)

p= is the degree of variability in the attributes being measured refers to the q=1-p. (p)(q) are the estimate of variance.

$$N_o = Z^2 pq / e^2 = [(1.96)^2 x (0.16)(0.84)] / (0.05)^2 = [3.8416 x 0.1344] / (0.0025 = 206 \text{ households}$$

The households in villages with at least five IC and above were recorded. Simple random sampling procedure was used to select households for interviews by randomly picking 40 names of the households in each district. A total of 206 respondents were interviewed.

3.2.3 Data collection and analysis

Data were collected through direct observations and interviews with the farmers. Information on households and the IC management characteristics were collected. The farmers' characteristics including age, level of education, occupation, household size, household status, farm size, land ownership, livestock species, number and reason of keeping them. The IC management characteristics were, production systems, housing, nutrition, extension services and challenges to IC production.

Data were analyzed using SPSS (version 22, 2013) and the general linear model procedure of SAS (version 9.00, 2002). PROC FREQ and PROC MEANS were used to carry out the frequency analysis and descriptive statistics, respectively.

3.3 Results and discussion

3.3.1 Household characteristics

The household characteristics of IC owner and farms are presented in Table 3a and b. From the total of 206 interviewed, 128 (62.4%) were male and 78 (37.6%) were females. The average age of the respondents was 40.4 years with the age ranging from 15-83 years. However, there was a significant difference between the age of respondents among the districts (*P<0.05*) studied. Majority of the respondents (83.6%) had formal education with 16.3% having basic education (reading and writing), 50.76% primary education and 16.48% had secondary and post-secondary education whereas only 16.4% were illiterate. All family members were involved in the chicken husbandry practices. However, women (78%) were highly responsible for IC management activities such as cleaning of chicken's house, feeding, collecting and selling eggs. Children (18.6%) also participated in several husbandry activities like provision of supplementary feed and water and cleaning of bird's house.

The family size averaged 5 persons (ranged 2-13) per household and the main source of their livelihood was farming (66%), off-farm business (14.7%), informal (10%) and formal employment (9.3%). There seems to be a decline in percentage of household depending on off farming compared to 2014 when 80% was reported to depend on agriculture (EACS, 2014). This may be due to the continued land subdivisions caused by the increasing human population, conversion of land to other uses such as construction of new apartments (estates, villages) and creation of new employment other than agriculture.

3.3.2 Land holding and livestock flock size

Land was privately owned by farmers (84%) with mean holding of 0.87 ha per household, but there was no significant difference *(P>0.05)* in the land holding between the districts Table 3b. The findings agree to those reported by NISR, (2011) that on a national level, 84% of cultivating households hold less than 0.9ha of land. As presented in Table 3b, pigs and IC were ranked as sources of income in the households among other livestock species with an average of 9.5 and 11. 8 respectively. There was a significant difference among livestock species between districts *(P<0.05)*. Cattle, goats, sheep and rabbits played a role as source of livestock income to a lesser extent than pig and poultry. This might be due to the short generation interval and low inputs required in pigs and poultry farming and increasing demand for white meat and IC products in the rural and urban area.

Table 3a: Socio-economic status of indigenous chicken owners and farms in the study districts of Rwanda

	Districts						
	Rwamagana *(n=40)*	Rulindo *(n=40)*	Ruhango *(n=40)*	Muhanga *(n=40)*	Kicukiro *(n=46)*	Overall mean	Range
Farmer's characteristics							
Gender of the respondents (%)							
Male	52.5	85.0	55.0	65.0	54.3	62.4	
Female	47.5	15.0	45.0	35.0	45.7	37.6	
Education level (%)							
No formal education	17.5	17.5	22.5	5.0	19.6	16.4	
Read and write	12.5	20.0	17.5	10.0	21.7	16.3	
Primary	50.0	52.5	50.0	60.0	41.3	50.8	
Secondary	17.5	10.0	2.5	20.0	8.7	11.4	
Post -secondary	2.5	0.0	7.5	5.0	8.7	4.4	
Major occupation (%)							
Formal employment	11.8	6.8	8.9	6.0	13.0	9.3	
Farming	70.1	75.3	65.8	74.8	43.9	65.9	
Informal employment	13.1	7.8	11.1	10.1	8.1	10.1	
Off-farm business	5.0	10.1	14.2	9.1	35.0	14.7	
Age (years)	39.2±2.6bc	45.7±2.3a	41.2±2.2b	37.1±2.6c	38.8±1.3bc	40.4±2.2	15-83

Table 3b. Socio-economic status of indigenous chicken owners and farms in the study districts of Rwanda

	Districts						
	Rwamagana *(n=40)*	**Rulindo** *(n=40)*	**Ruhango** *(n=40)*	**Muhanga** *(n=40)*	**Kicukiro** *(n=46)*	**Overall mean**	**Range**
Family members size	5.5±0.2a	5.1±0.2a	5.6±0.4a	5.1±0.3a	5.8±0.3a	5.4±0.3	2-13
Livestock flock size							
Indigenous chicken	9.9±1.1b	13.7±4.1a	12.7±2.2a	11.6±1.1a	11.2±2.1a	11.8±2.1	5-170
Cattle	2±0.8a	1.8±0.2a	1.2±0.2a	1.1±0.1a	0.3±0.2b	1.3±0.3	1-30
Goats	0.5±0.2	0.6±0.3	1.6±0.3	1±0.2	0.9±0.2	0.9±0.2	1-20
Sheep	0.9±0.6	0.3±0.2	0.13±0.1	0.3±0.1	0.3±0.11	0.4±0.2	1-6
Rabbits	0.2±0.1	1±0.4	0.95±0.3	3.2±0.7	2.5±0.6	2.8±0.4	1-20
Pigs	9±8.1a	8.5±7.1b	10.7±2.3b	8.7±1.7	10.4±2.1b	9.5±4.3	1-600
Farm's characteristics							
Land size (ha)	0.9±0.8	1.1±0.1	0.9±0.9	1±0.1	0.6±0.5	0.9±0.5	0.2-3
Land ownership (%)							
Own	21.4	22.5	20.2	19.7	16.2	83.9	
Lease	3.3	0.0	16.7	20.0	60.0	14.6	
Others	66.7	33.3	0.0	0.0	0.0	1.5	

Means followed by different letters in the same row are statistically different (P<0.05). ± Standard deviation

The mean chicken flock size per household in the current study was 11.8. This is in line with studies in other developing countries where an average flock size between 12 and 24 per household has been reported (Dana *et al.,* 2010; Harrison and Alders, 2010; Moges *et al.,* 2010; Okeno *et al.,* 2012; Bwalya *et al.,* 2014).

Table 4 presents the percentage for IC production systems, housing and feeding practices in the study area. The study indicated that FRS was the dominant production system practiced by farmers (87.9%), followed by SIS (10.2%) and the least practiced production system was IS (1.9%). The result obtained in this study was similar with the findings reported in the literature (Dana *et al.,* 2010; Mekonnen *et al.,* 2010; Moges *et al.,* 2010 and Okeno *et al.,* 2012). The study revealed that IC owners had, on average, 8.68 years of experience in chicken rearing. The major source of breeding stocks (87.9%) and replacement stocks (60.68%) was market purchases and hatching, respectively. The results concurs with those reported by Moges *et al.* (2010) and Dana *et al.* (2011) in Ethiopia. The study demonstrated that replacement stocks were obtained through natural incubation using broody hens.

3.3.3 Chicken management

In this study, out of 206 participants interviewed, 83 farmers (40.3%) reported housing chicken at night in the kitchen house, followed by farmer's main house (37.4%), chicken's house (13.6%), perched in trees (7.3%) and hand woven baskets (1.5%) (Table 4). Majority farmers (94.17%) cleaned chicken houses and more than half (71.1%) did so every day. The results observed in this study agree with those reported in other developing countries like Ethiopia (Dana *et al.,* 2010; Moges *et al.,* 2010) and Kenya (Kingori *et al.,* 2010; Magothe *et al.,* 2012a; Okeno *et al.,* 2012) that IC are mainly housed in kitchen and household's houses. During the day, birds are set free to move around to scavenge for feed, thereby becoming an easy target for predators, thieves and spread of diseases. This concurs with the study by Asresie *et al.* (2015). There is a need to sensitize and train poultry farmers on importance of housing birds in separate chicken houses to reduce the spread of diseases and predator's problem

Like in any other village poultry systems in developing countries, all districts studied were generally characterized by extensive scavenging management (96.6%) with 53.4% of the farmers providing supplementary feeding occasionally, especially during the cropping season. Watering of the chickens was practiced by 55.3% of the respondents (Table 4).

Table 4: IC production systems, housing and feeding practices

Variables	Districts					
	Rwamagana *(n=40)*	**Rulindo** *(n=40)*	**Ruhango** *(n=40)*	**Muhanga** *(n=40)*	**Kicukiro** *(n=46)*	**Overall mean** *(%)*
Production systems (%)						
Intensive	-	-	7.5	-	2.2	1.9
Semi-intensive	10.0	7.5	-	27.5	6.5	10.2
Extensive	90.0	92.5	92.5	72.5	91.3	87.9
Housing at night (%)						
Kitchen	45.0	32.5	40.0	47.5	37.0	40.3
Family house	45.0	42.5	47.5	20.0	32.6	37.4
Perch on trees	-	-	5.0	10.0	19.6	7.3
Hand woven basket	-	2.5	-	-	4.3	1.5
Chicken's house	10.0	22.5	7.5	22.5	6.5	13.6
Feeds and feeding systems (%)						
Chicken scavenging	100	100	85.0	100	97.8	96.6
watering	75.0	65.0	57.5	52.5	30.4	55.3
Feed supplementation	47.5	52.5	62.5	70.0	37.0	53.4
Feeding procedures (%)						
Using a container	15.0	14.3	16.0	12.5	21.8	15.9
Throw at ground	85.0	85.7	84.0	87.5	78.2	84.1

During the cropping season, birds were confined by tethering in the home compound or small shelters for most part of the day. This was mostly done to avoid any kind of conflicts or disputes with neighbors due to destruction of crops by chickens. Small amounts of grains (cereals), kitchen and households' leftovers, multi-vitamins trees (e.g kimali, *MacDonald tree)* and insects were occasionally offered to the chickens. Concerning feeding procedures, 78.2% of farmers reported throwing feeds on the ground whereas only 21.8% of farmers placed the feeds in container. As a result, feed was rarely adjusted to the needs of the birds. Therefore, chicks and adult birds had to compete for feed implying that the young and less aggressive birds rarely got sufficient feed. The feeding management in this study is similar to those reported elsewhere (Kingori *et al.,* 2010; Mekonnen *et al.,* 2010; Akinola and Essien, 2011; Magothe *et al.,* 2012; Okeno *et al.,* 2012; Asresie, 2015).

The reasons reported for not supplementing chicken in the current study were high feed cost (45.5%) followed by lack of cash and feed availability (33.6%) and lack of awareness (19.8%) about chicken's supplementation. As Rwanda is a small country where nearly all population has less than 1 ha acreage of land and increasing population pressure, there is a risk of food competition between humans and livestock. Therefore, it is important to look for alternative feed resources for chickens. Feeding termites to chicken provides a mechanism for converting unusable cellulose into food for human consumption with benefits to the ecosystem (Okeno *et al.,* 2012). Studies to analyze and record the proximate compositions of commonly used local nonconventional feeding materials such as multi-vitamins trees (e.g kimali, *MacDonald tree*), insects (e.g termites) and cereal crops are required.

3.3.4 Production purpose, health management and constraints faced by IC in the study area

Table 5a and 5b presents the ranks in percentage of purpose of raising chicken, health management and constraints faced by indigenous chicken. The main reasons of keeping IC were egg production (47.1%) and income generation (37.9%). Other uses such meat production and production of breeding stock were ranked lower at 9.2% and 5.8%, respectively. Similarly, Moges *et al.* (2010) and Okeno *et al.* (2012) reported that aims of rearing indigenous chickens were source of food, cash income, production of breeding stock, cultural and religious ceremonies in both Kenya and Ethiopia.

All respondents reported natural incubation method using broody hens during egg incubation period. Nearly all respondents (98.1%) provided nesting/bedding material during incubation period with herbs and old clothes being the most used. Regarding mating system, all respondents indicated that birds mated freely (uncontrolled) while scavenging. This indicates a high risk of increasing rate of inbreeding as the flock size is small. The farmers should control birds mating by exchanging breeding cocks with households of different villages. Extension services were scarce as only 17.5% of respondents reported to have received extension services from livestock officers. Records keeping is very important in farm monitoring, evaluation and decision making. In this study, only 9.7% of respondents reported to keep records either for egg laid per week or number of chicks hatched.

Health management

Majority of respondents (70.4%) experienced chicken disease outbreaks (Table 5a). The majority of farmers (51.9%) recognized that green watery feces, difficulty breathing, drooping wings, twisted neck and many deaths are signs of a disease locally called *Umusinziro* (Newcastle disease) as the most important disease causing high mortality of young and adult birds. Salmonellosis (15%) and coccidiosis (8.3%) were also found to be among the diseases highlighted in this study whereas listlessness, coughing and sneezing signs were reported by 7.3% of the farmers. The findings concurs with other studies conducted in other developing countries (Harrison and Alders, 2010; Moges *et al.,* 2010; Okeno *et al.,* 2012) where New castle disease was reported to be the major cause of chickens' death.

The result showed that 40.7% of respondents were locally treating the birds against diseases. Majority of interviewed farmers (93.1%) reported treating birds with green pepper, cutting the wing's vein, burning the bird's head feathers and only 6.9% of respondent were calling a veterinarian to treat their chickens (Table 5a). This calls for research studies to determine the veterinary properties and efficacy of these locally used medications. Nearly all IC owners (98.1%) had not vaccinated their birds against any disease. About 21.8% of respondents carried out ecto and endo-parasites control when need arose. The result of this study concurs with the studies by Moges *et al.* (2010) and Dana *et al.* (2010) who reported that immunization services are almost nonexistent for village chickens in Ethiopia.

Table 5a: Production purpose, health management and constraints faced by IC in the study area

Variables	Districts					
	Rwamagana *(n=40)*	**Rulindo** *(n=40)*	**Ruhango** *(n=40)*	**Muhanga** *(n=40)*	**Kicukiro** *(n=46)*	**Overall mean** *(%)*
Purpose of raising chickens (%)						
Eggs production	45.0	55.0	15.0	75.0	45.7	47.1
Meat production	7.5	7.5	2.5	2.5	8.7	5.8
Breeding stock	7.5	5.0	17.5	7.5	8.7	9.2
Financing	40.0	32.5	65.0	15.0	37.0	37.9
IC management (%)						
Bedding material						
Herbs	97.5	85.0	67.5	67.5	76.1	78.6
Wood shavings	-	15.0	10.0	-	-	4.9
Old clothes	-	-	22.5	32.5	23.9	16.0
Sandy	2.5	-	-	-	-	0.5
Incubation method (%)						
Natural (broody hen)	100	100	100	100	100	100
Mating system						
Uncontrolled, natural	100	100	100	100	100	100
Records keeping	-	25.0	7.5	15.0	2.2	9.7
Purposive culling of birds	95.0	87.5	82.5	95.0	80.4	87.9
Seeking livestock advisers	17.5	15.0	17.5	25.0	13.0	17.5
Health management (%)						
Disease outbreaks	72.5	80.0	80.0	65.0	56.5	70.4
Chicken treatment	34.5	50.0	34.4	40.0	44.4	40.7
Chicken vaccination	-	-	5.0	5.0	-	1.9
Ecto-and endo-parasites control	7.5	32.5	37.5	20.0	13.0	21.8

Table 5b: Production purpose, health management and constraints faced by IC in the study area

	Districts					
	Rwamagana *(n=40)*	**Rulindo** *(n=40)*	**Ruhango** *(n=40)*	**Muhanga** *(n=40)*	**Kicukiro** *(n=46)*	**Overall mean** *(%)*
Constraints to IC production (%)						
Diseases	40.0	42.5	50.0	32.5	28.3	38.3
Lack of breeding stock	2.5	15.0	2.5	5.0	-	4.9
Feed shortage	2.5	2.5	5.0	5.0	2.2	3.4
Lack of capital	7.5	32.5	7.5	32.5	32.6	22.8
Price fluctuation	-	-	2.5	2.5	-	1.0
Theft	10.0	-	12.5	5.0	2.2	5.8
Lack of housing	-	2.5	7.5	2.5	15.2	5.8
Lack of information	5.0	-	2.5	2.5	2.2	2.4
Predators	32.5	5.0	10.0	12.5	17.4	15.5

3.3.5 Indigenous chicken ecotypes, flock structure, dynamics and reproduction performance

Indigenous chicken ecotypes

The results (Table 6) show that a large proportion of chickens (38.84%) were dwarf followed by frizzed feathers (27.9%) and normal feathers (18.68%) whereas naked neck (8.34%) and improved breeds/crosses (6.24%) were the least common in the study area. This results almost agrees with what was reported by Magothe *et al.* (2012) that the major genotypes available in Kenya are normal feathered, naked-neck, frizzle-feathered, dwarf, crested-head, feathered shanks and rump-less. However, the study indicated that local chickens are not strictly indigenous as they have been crossed with exotic breeds which might be the case of Rwanda as there is no study carried out to conclusively describe them either phenotypically or genotypically. Such studies require molecular characterization which was beyond the scope of the current study.

Table 6. Indigenous chicken genotypes in the study area

Variables	Districts					
	Rwamagana *(n=40)*	**Rulindo** *(n=40)*	**Ruhango** *(n=40)*	**Muhanga** *(n=40)*	**Kicukiro** *(n=46)*	**Overall mean** *(%)*
IC genotypes (%)						
Dwarf	40.0	42.5	50.0	40.0	21.7	38.8
Frizzed feathers	27.5	27.5	25.0	22.5	37.0	27.9
Normal feathers	15.0	22.5	20.0	25.0	10.9	18.7
Necked neck	10.0	5.0	2.5	2.5	21.7	8.3
Improved breed	7.5	2.5	2.5	10.0	8.7	6.2

Flock structure and dynamics

In this study the mean flock size was 11.8±2.1. In terms of population structure, the flocks were dominated by chicks (6.3±0.6), pullets (3.8±0.7), hens (3.4±0.5), cockerels (3.3±0.5) and the least were cocks (1.6±0.4) (Table 7). However, there was a significant difference between districts *($P<0.05$)* in terms of flock composition. The mean ranking of flock dynamics indicated that replacement stock was mainly sourced from on-farm hatching (23.01±2.5) and purchased chicken (3.7±0.6), while death/predators (7.9±0.8), sales (3.7±0.6), and consumption (1.9±0.4), lent (1.7±0.4), stolen (1.6±0.3) and donation (1.4±0.2), were the major sources of chicken exits. The results were significantly different ($P<0.05$) in the sources of replacement and breeding stocks between the districts.

Table 7. Indigenous chickens stock structure and dynamics

Variables	Districts						
	Rwamagana *(n=40)*	**Rulindo** *(n=40)*	**Ruhango** *(n=40)*	**Muhanga** *(n=40)*	**Kicukiro** *(n=46)*	**Overall mean** *(%)*	**Range**
Flock structure (Mean)							
Chicks	6.7±0.5a	6.1±0.6a	7.1±1.1a	5.8±0.6b	6.2±0.6a	6.4±0.6	
Cockerels	3.9±0.6a	3±0.7a	3.7±0.6a	2.6±0.6b	3.5±0.6a	3.3±0.6	
Pullets	3.6±0.6a	4.1±1.1a	3.8±0.6a	4±0.7a	3.9±0.7a	3.9±0.7	
Hens	3±0.3b	5.1±1.2a	3.2±0.4b	3±0.3b	2.9±0.5b	3.5±0.5	
Cocks	1.6±0.4a	1.8±0.7a	1.5±0.3a	1.6±0.4a	1.9±0.5a	1.6±0.4	
Flock dynamics (Mean)							
Hatched	28.7±2.1a	23.9±2.9bc	24.1±2.7bc	18.7±1.9c	19.7±3.1c	23±2.6	1-150
Died/predators	11.5±0.9a	7.9±1.4b	8.8±0.6b	4.7±0.5c	6.7±0.7b	7.9±0.8	1-40
Purchased	2.9±0.7b	5.2±0.7a	2.9±0.5b	5.1±0.8a	2.4±0.4b	3.7±0.6	1-30
Sold	5.3±1.2a	5.3±0.8a	3.2±0.8b	2.3±0.4b	2.7±0.3b	3.7±0.7	1-40
Exchanged/ Lent	1.7±0.4b	2.9±1.3a	1.4±0.3b	1.5±0.3b	1.4±0.2b	1.8±0.5	1-9
Consumed	1.2±0.3b	3±0.6a	1.5±0.3b	1.6±0.4b	2.7±0.7a	1.9±0.6	1-30
Gifts/ donation	1.3±0.1a	1.7±0.3	1.6±0.3	1.4±0.2	1.5±0.2	1.5±0.3	1-8
Stolen	2.5±0.6a	1.5±0.3b	1.4±0.2b	1.13±0.2b	1.3±0.2b	1.6±0.3	1-15

Means followed by different letters in the same row are statistically different *(P<0.05).*

Production and reproduction performance

The productive and reproductive performance of IC are presented in Table 8. The average age at first laying and mating were 7.05±0.13 and 6.24±0.14 months respectively. The males were reported to grow faster than females. The results are in line with what was reported by Magothe *et al.* (2012) in Kenya that in the backyard and semi-intensive production systems, age at first egg ranges from 6 to 8 months, but it was slightly different to the findings of Moges *et al.* (2010) who reported that in West Ethiopia, the average age of local cockerels at first mating and pullets at first egg were 6.15 and 6.87months, respectively.

In this study, the average egg production per hen per clutch, laying days per hen per clutch and the number of clutches per hen per year were 18.46±0.48, 28.1±0.58 and 2.602±0.22, respectively (Table 8).

Table 8. Productive and reproductive performance of Indigenous chickens

Variables	Districts						
	Rwamagana ***(n=40)***	**Rulindo** ***(n=40)***	**Ruhango** ***(n=40)***	**Muhanga** ***(n=40)***	**Kicukiro** ***(n=46)***	**Overall mean** ***(%)***	**Range**
Age at first laying (months)	7.5±0.1a	6.7±0.2a	6.9±0.1a	7.1±0.1a	6.9±0.1a	7.1±0.1	5-8
Age at first mating (months)	6.7±0.1a	6.3±0.2a	5.9±0.1a	6.4±0.1a	6±0.2a	6.3±0.1	5-8
Egg yield/hen/ clutch	18.3±0.8a	19.5±0.3a	19.6±0.4a	18.7±0.6a	16.4±0.4a	18.5±0.5	10-40
Days/ hen/clutch	27.3±0.7a	27.6±0.4a	29.1±0.4a	29±0.9a	27.6±0.5a	28.1±0.6	20-44
Clutches/ hen/year	2.6±0.8a	2.7±0.1a	2.6±0.2a	2.5±0.1a	2.7±0.1a	2.6±0.2	2-3
Eggs/set/ incubated	9.8±0.3a	11.1±0.4a	10.6±0.2a	10.3±0.2a	9.9±0.3a	10.3±0.3	7-14
Chicks hatched	8.1±0.3a	9.5±0.3a	8.2±0.1a	8.1±0.2a	7.7±0.2a	8.4±0.2	5-12
Chicks weaned/hen/clutch	4.8±0.3b	6.9±0.3a	3.9±0.2b	4.6±0.3b	4.3±0.2b	4.9±0.2	1-9
Egg weight (g)	33.2±0.3b	47.9±1.4a	41.2±1.2a	44.6±1.3a	44.1±1.3a	42.2±1.1	30-60

Means followed by different letters in the same row are statistically different *($P<0.05$).*

The average number of eggs per hen per clutch and number of clutches per hen per year identified in this study was similar to the reported 9-19 eggs and 2-3 clutches reported in other developing countries (Kingori *et al.,* 2010; Moges *et al.,* 2010; Magothe *et al.,* 2012b; Okeno *et al.,* 2012).

This study revealed that local broody hens were the only means of egg incubation and brooding young chicks. The average number of eggs per set per hen was 10.3±0.2 eggs (range 7-14 eggs) and average number of chicks hatched was 8.3±0.2 (range 5-12 chicks) (Table 8). This is in line with the findings of Moges *et al.* (2010) and Okeno *et al.* (2012) who reported that most of egg laid were incubated and mean hatchability were 82.6% and 83.6%, respectively. The average number of chicks surviving and attaining maturity per hen was 4.8±0.2. The low survival rate presented in this study might be attributed to the high disease prevalence and predation in the study area.

Regarding egg production, it was estimated that egg production per hen per year ranges from 30- 60 eggs with the average egg weight of 42.19±1.09 grams (range 30-60 grams). This was in conformity with what was reported by Magothe *et al.* (2012) that, IC hens lay about 45 eggs per year with a range between 30 and 75 eggs under free range and semi-free range systems with a mean egg weight of 47.4 g (range 36-52g).

3.3.6 Constraints to IC production

Generally, diseases outbreaks, lack of investment capital and predators were the major challenges in IC production ranked by 38.3%, 22.8% and 15.5% of farmers respectively. Others challenges like feed shortage, thieves, fluctuation of market price, lack of information of poultry rearing and lack of chicken house were also highlighted, but ranked low (Table 5b). The result obtained in this study is in agreement with studies carried elsewhere (Dana *et al.,* 2010; Harrison and Alders, 2010; Magothe *et al.*, 2012; Mekonnen *et al.*, 2010; Moges *et al.,* 2010; Okeno *et al.*, 2012) who reported that Newcastle disease and predators were the serious constraints to the poultry flock causing severe losses.

Majority of the respondents (70.1%) indicated that Newcastle disease, diarrhea and predation occur mostly during dry season between June and September. This might be attributed to the dry conditions favoring the spread of the disease-causative agents like microbes, virus and high chicken mobility, as the period coincides with the crop harvesting season. The same findings were also reported by Magothe *et al.* (2012a). Notification of the seasons of outbreaks (Okeno *et al.*, 2012) should be used to schedule vaccination programs against these diseases. This calls for all institutions involved in animal health and husbandry practices to sensitize all poultry farmers to vaccinate their birds, i.e chickens can be vaccinated during dry seasons as suggested by Okeno *et al.* (2012) to enable birds to develop immunity before the outbreaks in the wet seasons.

3.4 Conclusions

This study revealed that IC plays an important part in household livelihood in terms of food provision, income and employment generation. However, their productivity is low due to the associated constraints mentioned such as disease outbreaks, predators, lack of investment capital, price fluctuation and lack of breeding stock which need urgent mitigation measures to sustain their utilisation against the changing climatic and economic conditions. Studies on the locally used feeds and medications should be considered. There is a need to sensitize farmers to construct separate chicken houses to reduce the spread of diseases and predators. Therefore, individual, public institutions and non-governmental organisations efforts are required to develop a sustainable IC breeding objectives that account for whole production circumstances and farmer’s need.

CHAPTER FOUR

FARMERS BREEDING PRACTICES AND TRAITS OF ECONOMIC IMPORTANCE FOR INDIGENOUS CHICKEN IN RWANDA

4.1 Introduction

Despite the low productivity of indigenous poultry genotypes compared to commercial strains, they are widely distributed in rural and peri-urban areas and account for about 80% of the world's poultry stocks in many developing countries (Pym, 2010; Akinola and Essien, 2011; Gabanakgosi *et al.,* 2013). In Africa, IC are the most numerous and important species of poultry as they are found wherever there are human settlements (Akinola and Essien, 2011). They play numerous significant roles such as generating income and employment for various categories of people including poultry farmers, primary and secondary traders, processors and marketers from sale of birds and eggs (Akinola and Essien, 2011; Okeno *et al.,* 2012). IC play significant gender roles to women, widows, and orphaned children in terms of food security and nutrition, cash income and savings. They provide a valuable source of protein in the diet (Kingori *et al.,* 2010; Okeno *et al.,* 2012). They also play an important socio-cultural role and traditional medicine in many societies (Kingori *et al.,* 2010; Rakhmanin and Gennari, 2014).

Compared to other livestock species, IC have advantages in that they are hardy, adapting well to the harsh scavenging conditions and poor nutrition and tolerant to parasites and diseases, survive on low inputs and adapt to fluctuations in available feed resources (Dana *et al.,* 2010; Okeno *et al.,* 2011; Magothe *et al.,* 2012). Despite their importance, IC are under threat due to several factors such as poor nutrition, high mortalities, market fluctuation, lack of appropriate breeds and inadequate knowledge on consumer preference, changing of production systems and indiscriminate crossbreeding hampering their exploitation and ability to improve rural household livelihoods (Dana *et al.,* 2010; Okeno *et al.,* 2011). To tackle the highlighted challenges, development of breeding objectives and breeding programme accounting for all stakeholders' needs are required for genetic improvement programmes of IC to be successful.

In Rwanda like other developing countries, breeding objectives and programs for IC breeds are missing. Therefore, there is a need to develop the breeding objectives which will be further used to support genetic improvement programs. Characterisation of the production systems, identification of breeding practices, production objectives and traits of economic importance for IC farmers are key in the development of breeding objectives (Dana *et al.,* 2010; Okeno *et al.,* 2011). The objective of this study was therefore, to determine the breeding practices and traits of economic importance from the perception of farmers, marketers and consumers necessary for the development of IC breeding objectives in Rwanda.

4.2 Materials and methods

4.2.1 Study areas and data collection

The study was carried out in Rwamagana, Rulindo, Ruhango, Kicukiro and Muhanga districts of Rwanda. These districts were selected because of the high IC population and easy access to the feeder roads (NISR, 2011). Rwanda has a temperate tropical highland climate with a temperature ranging between 12 ^{o}C and 27 ^{o}C, with little variation through the year across the country. Table 9 shows the characteristics of the study areas.

Table 9. Characteristics of the study area

District	Location	Altitude (m a.s.l)	Rainfall (mm)	Land size (km^2)	Human population
Rwamagana	Eastern Province (1°57′09″S/ 30°26′16″E)	1400-1700	1000.0	682	313,461
Rulindo	Northern Province 1°44′S/ 30°00′E	1863	1243.3	567	287,681
Ruhango	Southern Province 2°12′S/ 29°46′E	1589	1188.0	627	319,885
Kicukiro	Kigali city (2°00′S/ 30°09′E)	1532	900.0 - 1150.0	167	318,564
Muhanga	Southern Province (2°5'0.00"S/ +29°45'0.00"E)	1788	1000 - 1100.0	648	319,141

Source: NISR (2011)

Data were collected through interviews with farmers, marketers and consumers using three set questionnaires and direct observations of chickens' management practices from October 2016 to January 2016. In the five districts, 206 farmers, 56 marketers and 80 consumers were interviewed. Information on flock composition, IC ecotypes, trait preferences as well as selection criteria that farmers follow were collected.

The importance of different traits as perceived by farmers, marketers and consumers were evaluated and ranked. Farmers, marketers and consumers were asked to state which traits they prefer for hen or cock and state if they consider a number of predefined traits to be good (Rank 1); average (Rank 2); poor (Rank 3), or if they do not consider the trait (Rank 4) for specific genotype.

4.2.2 Data analysis

Data were analysed using descriptive and inferential statistic procedures in SAS (version 9.00, 2002) and SPSS (version 22, 2013) softwares. Indices were calculated to provide an overall ranking for the traits preference as perceived by farmers, marketers and consumers. The indices denote weighted averages for all rankings for a particular trait or reason (Okeno *et al.,* 2011, Mbuthia *et al.*, 2015). The following equation from Bett *et al* (2011) was adopted to compute the index (I_i) for each trait.

$$I_i = \left[\begin{pmatrix}3\\2\\1\end{pmatrix}\left[\sum_{i-1}^{3} X_i\right]_j\right] \Bigg/ \sum_{k-1}^{n}\left[\begin{pmatrix}3\\2\\1\end{pmatrix}\sum_{i-1}^{3} X_i\right]_k$$

where X_i is the percentage of respondents ranking trait j in the i^{th} rank and k is the sum of ranks for n number of traits. Spearman's non-parametric correlation coefficient (r) procedure was used to compare the relationship between the traits considered important by farmers, marketers and consumers. The r was estimated as:

$$r = 1 - \left(10\Sigma d^2 \,/\, n(n^2 - 1)\right)$$

where d is the difference between the ranks of corresponding pairs of two traits and n is the number of observations.

4.3 Results and discussion

4.3.1 Chicken genotypes kept and their attributes in the study area

The ranking of the importance of different traits as perceived by farmers for each chicken genotype in the study area are presented in Table 10. Prolificacy, mature weight, disease tolerance, eggs yield, and heat tolerance were highly preferred across the different genotypes (Table 9). Other traits, including growth rate, mothering ability carcass weight and feed conversion efficiency were ranked lowly. However, there were no significant difference ($P > 0.05$) in the perceptions of those traits among farmers interviewed between the districts. The dwarf and normal feathered genotypes were rated highly by 46.1% and 19.9% farmers, respectively, because they were perceived to be highly prolific compared to other ecotypes. The naked neck (23.3%) and normal feathered (19.9%) ecotypes, were generally considered to be superior in terms of heat tolerance compared to the dwarf (14.1%) and frizzled feathered (7.3%) ecotypes. The naked neck and frizzled feathered ecotypes were less preferred in terms of egg production and disease tolerance. This might be attributed to its low adaptation to the climate conditions of Rwanda which is tropical climate modified by altitude and location to have cool and wet weather. Magothe *et al.* (2010) and Okeno *et al.* (2011) reported a high popularity and performance of the naked neck and frizzled feathered ecotypes in the hot climate areas of Kenya. This was attributed to the positive relationship between genotypes and phenotypes of naked neck and frizzled genes in terms of heat tolerance, growth rate, body weight, feed conversion, egg production and disease resistance.

The dwarf genotype was considered to be significantly smaller ($P <0.05$, $\chi^2 = 56.463$) and to have poorer growth rate and feed conversion efficiency, but to have better prolificacy than other IC genotypes. This might be due to the high egg fertility rate which results in increase of hatchability of eggs, thus enhancing the chances of more chicks surviving. The dwarf ecotype is assumed to have better resistance to diseases. This can explain the high number of dwarf IC raised by farmers in the study area. However, generally large-sized chicken are better than small-sized ones due to market preference (Bett *et al.*, 2011). Farmers' preferences are guided by the reasons of keeping IC, for example rearing for eggs, meat production, or dual purpose. Therefore small-sized and low-egg yielding chickens are undesirable (Bett *et al.*, 2011).

In general, there were no perceived differences in terms of mothering ability, eggs number, growth rate and feed conversion efficiency in the IC ecotypes (Table 10). The crosses/modern genotypes were preferred for their high eggs yield, mature weight and moderate growth rate over IC. However, they were considered unfavourable relative to indigenous genotypes for other traits such as disease and heat tolerance, prolificacy, mothering ability and feed conversion efficiency. The low productivity of IC is partly attributed to the prevailing poor management practices, in particular the lack of proper health care which results in high mortality, poor nutrition and housing (Kingori *et al.*, 2010; Bett *et al.*, 2011; Magothe *et al.*, 2012). Considering and improving these factors would result in greater growth rate and egg production (Kingori *et al.*, 2010). Dana *et al.* (2010) reported that in Ethiopia, most farmers claimed that modern chicken breeds were poor in terms of disease and stress tolerance and the ability to escape predators prevalent in their village conditions. These breeds generally require high level of management and are poor scavengers compared to IC (Dana *et al.*, 2010; Moges *et al.*, 2010).

Table 10. Percentage and numbera (in parentheses) of households perceiving different traits for each IC genotypes to be important in Rwanda

Trait	Chicken genotypes				
	Dwarf	**Normal feathers**	**Naked neck**	**Frizzled feathers**	**Crosses/modern breed**
Prolificacy	46.1(95)	19.9(41)	6.8(14)	8.3 (17)	3.4 (7)
Mature weight	5.3(11)	19.4(40)	4.4(9)	16.5(34)	15.5(32)
Heat tolerance	14.1(29)	7.3(15)	23.3(48)	19.9(41)	6.3(13)
Disease tolerance	15.5(32)	8.3(17)	18.9(39)	12.1(25)	2.9(6)
Mothering ability	3.9(8)	5.3(11)	5.3(11)	7.8(16)	2.9(6)
Growth rate	1.0(2)	5.8(12)	4.9(10)	9.2(19)	8.3(17)
Feed conversion efficiency	1.0(2)	1.9(4)	2.4(5)	2.4(5)	1.9(4)
Carcass weight	5.3(11)	5.3(11)	5.8(12)	1.0(2)	9.2(19)
Eggs yield	12.9(6)	6.8(14)	4.9(10)	9.2(19)	28.2(58)

[a] *Number of households presented in parentheses; * these percentages do not add up to 100% because some households owned more than one ecotype and others had no opinion in ranking.*

With regards to ecotype preference, majority of the respondents (data not shown) reported preference of dwarf and normal feathered ecotypes because of their prolificacy, disease tolerance and fighting ability against predators. The results are in line with those reported in Kenya by Okeno *et al.* (2011), that farmers preferred keeping normal-feathered, crested-head, naked-neck and giant ecotypes because of their high egg production, large body size, resistance to most diseases and parasites, faster growth rate and good mothering ability.

4.3.2 Farmer's flock selection practices

All farmers interviewed in the different districts practiced selection of breeding cocks and hens based on physical characteristics and performance history of the parental stock (Table 11). Selection of breeding cocks was based on disease tolerance, body weight at sexual maturity, body size, growth rate and high egg fertility. Breeding hens were selected based on egg yield, mothering ability, growth rate, body size, body weight at sexual maturity and disease resistance (Table 11). There was significant difference *(P< 0.05)* between districts in terms of breeding cock and hen's selection criteria. Other trait categories such as plumage colour, heat and drought tolerance were considered but ranked low (Table 11). Similar results have been reported in Kenya by Bett *et al.* (2011) and Okeno *et al.* (2011). The traits such as growth rate and live body weight are economically important when rearing cocks for sale, because heavy cocks fetch high prices in the market (Bett *et al.,* 2011).The findings disagrees with what was reported by Dana *et al.* (2010) and Hailu *et al.* (2014) that in Ethiopia, all farmers practiced selection on breeding and replacement males and females based on plumage colour, live weight, comb type and qumena (conformation, visual attraction, size).

Table 11. Percentage ranking of traits used by farmers when selecting male and female chicken for breeding purposes in selected districts of Rwanda

Category	Districts					
	Rwamagana	**Rulindo**	**Ruhango**	**Muhanga**	**Kicukiro**	**Total (%)**
Breeding cocks						
Body size	60.7	56.4	34.2	23.7	26.7	40.3
Body weight at sexual maturity	49.5	44.5	39.8	42.9	36.6	42.7
Disease tolerance	58.5	56.5	45.0	28.5	35.4	44.8
Egg fertility	14.5	15.7	8.5	15.4	18.7	32.8
Growth rate	36.5	28.9	42.3	32.6	39.8	36.0
Heat tolerance	12.5	16.7	12.5	12.5	14.5	13.7
Plumage colour	17.5	15.5	13.5	10.0	14.3	14.2
Breeding hens						
Body size	60.5	52.5	32.5	45.5	34.3	45.1
Body weight at sexual maturity	37.3	43.0	42.5	57.5	31.6	42.4
Disease tolerance	52.5	47.5	61.2	70.0	68.3	42.4
Drought tolerance	13.5	22.7	25.6	13.8	14.3	17.9
Egg yield	71.5	54.5	79.0	63.2	46.7	62.9
Egg fertility	11.5	19.8	29.5	17.5	31.3	21.9
Growth rate	67.5	42.5	58.7	47.5	44.5	52.1
Mothering ability	55.1	63.7	76.5	60.0	32.1	57.5
Plumage colour	12.0	20.0	22.5	19.5	22.2	19.2
Prolificacy	54.6	35.0	45.6	47.5	38.7	44.3

[a]*These percentages do not add up to 100% since households were selecting male and female breeding and replacement stock based on more than one trait category.*

4.3.3 Traits perceived by farmers, marketers and consumers as being of primary importance.

The ranking of traits perceived by farmers, marketers and consumers as being of primary economic importance is presented in Table 12. There was no significant difference *(P>0.05)* across all trait categories as perceived by farmers. In general, farmers wanted chickens which combined productive, reproductive, functional and aesthetic traits (Table 12). However, egg yield, disease tolerance, high growth rate, prolificacy, high body weight and egg fertility were highly preferred by farmers. This indicates that all perceived traits, though having various utility values, are important for breeding and selection purposes.

In this study, the most importance traits considered by the marketers were meat quality, egg yolk colour, plumage colour, disease tolerance, growth rate and body weight (Table 12). On the other hand, consumers are interested in chicken with heavy body weight and quality meat and eggs with yellow yolk (Table 12). Guèye, (1998) and (2002) revealed that the average IC meat prices in Dakar, Senegal, varied from US$ 2.54 to 3.93 per kg at markets and supermarkets, respectively. These represented increases of about 13% at market and 27% higher at supermarkets compared to prices of meat from commercial chicken. Abeykoon, *et al* (2013) has shown that in Sri Lanka, meat and egg production of village chicken is lower than the commercial chicken breeds, but there is a niche market for their meat and eggs Consumers with higher income group are willing to pay more to get indigenous meat (Padhi, 2016).

Some farmers recognized that chicken with certain colour for instance white colour were easily targeted by terrestrial and aerial predators. The ability of IC to camouflage in the surrounding environment is determined by plumage colour (Bett *et al.*, 2011). In Kenya and Ethiopia, cock's and hens' plumage colour influence the market value and the preferences of buyers Dana *et al.* (2010), Bett *et al.* (2011) and Hailu *et al.* (2013). Development of breeding program without considering the needs of all stakeholders has high chances of being rejected by end users (Bett *et al.,* 2011). Therefore, design of breeding objectives and breeding programmes of IC improvement should consider the traits perceived by farmers, traders and consumers.

The price of egg in this study was determined by the egg yolk and shell colour. This can be supported by the fact that the price of indigenous egg is almost twice the price of exotic's egg in the study area. Consumers preferred white and pale eggs' colour with a yellow egg yolk. Most of the consumers stated that they prefer IC over exotic because of the quality meat. Similarly, marketers and consumers in Ethiopia and Kenya considered morphological traits such as plumage colour, egg shell colour and comb type to have significant economic values

Table 12. Ranking of traits perceived by farmers, marketers and consumers as being of primary economic importance

Traits	Farmers					Marketers					Consumers				
	Rank1	Rank2	Rank3	Sum	Index	Rank1	Rank2	Rank3	Sum	Index	Rank1	Rank2	Rank3	Sum	Index
Body weight	112	62	29	203	0.087	50	6	-	56	0.133	56	19	-	75	0.164
Growth rate	102	95	12	206	0.089	30	26	-	56	0.117	47	23	-	70	0.149
Egg fertility	99	67	39	205	0.083	-	-	-	-	-	-	-	-	-	-
Prolificacy	102	85	17	204	0.088	23	13	-	36	0.078	-	-	-	-	-
Drought tolerance	66	75	18	159	0.065	-	-	-	-	-	-	-	-	-	-
Heat tolerance	72	68	14	154	0.065	-	-	-	-	-	-	-	-	-	-
Temperament	81	93	25	199	0.081	30	-	-	30	0.074	-	-	-	-	-
Disease tolerance	107	86	20	213	0.091	43	12	1	56	0.127	-	-	-	-	-
FCE)	68	53	18	139	0.058	-	-	-	-	-	-	-	-	-	-
Plumage colour	77	68	21	166	0.069	40	13	-	53	0.120	45	25	6	76	0.152
Egg yield	147	34	12	193	0.093	35	15	-	50	0.111	65	9	-	74	0.170
Egg yolk	84	62	19	165	0.070	46	4	-	50	0.120	70	7	-	77	0.178
Meat quality	98	42	12	152	0.069	47	2	-	49	0.119	75	5	-	80	0.187

Rank1= Good; Rank2= Average; Rank 3= Poor; Rank4= No opinion. FCE: Feed Conversion Efficiency alongside other quantitative traits related to body size, growth rate and egg yield Dana *et al.* (2010), Okeno *et al.* (2011) and Hailu *et al.* (2014).

IC were ranked to have superior qualities with regard to traits such as heat and cold tolerance, disease resistance, ability to fight and escape from predators, broody behaviour, high hatchability of eggs and scavenging for food which are important in adaptation to the village conditions; and those traits, such as taste of egg and meat, affect consumers' preference and the market value (Dana *et al.,* 2010).

The spearman's non-parametric rank correlations were calculated independently for the traits perceived important by farmers, marketers and consumers and are presented in Table 13. For the traits perceived to be important by farmers, there was a positive and significant correlation ($P < 0.01$) between BW and growth rate (GR) and FER. This implies that farmers wanted chickens with high growth rate and high egg fertility rate and larger body size to increase their flock size.

Correlation were moderate between body weight and prolificacy (PRL), drought tolerance (DRTOL), disease tolerance (DTOL) and egg yolk colour (EYC). Preference of body weight was negatively correlated with temperament (TEMP), heat tolerance (HTOL), plumage colour (Pcol) and ESC. There was a significant negative correlation ($P < 0.01$) between meat quality (MQ) and BW, GR and FER. DRTOL and HTOL were positively correlated with Fer and PRL. Preference of Prl was positively correlated with FER indicating that farmers prefer hens with high egg fertility thus producing more chicks. Disease tolerance was moderately correlated with BW, GR and PRL but negatively correlated with FER. A moderate correlation was between FCE and BW, GR and PRL but negatively correlated to egg fertility. This indicates that poor feeding IC affects their egg fertility. In general, disease tolerance, egg fertility, growth rate and prolificacy were the most important reproductive, productive and functional traits.

Regarding marketer and consumers' preferences ranks correlation, positively and significant correlation ($P < 0.01, P < 0.05$) were obtained between BW and GR and MQ. Preference for BW was positively correlated with PRL, ESC, PCOL and EYC for both marketers and consumers. A moderate positive correlation was observed between GR and Pcol, ESC, EYC and MQ. Correlations of FER, PRL, DRTOL, TEMP, HTOL, DTOL, FCE and other traits in the consumers' preference were not calculated due to the low ranking these traits obtained (Table 13).

Consideration of farmers' genotypes or breed and trait preferences is important in design of sustainable improvement programs (Mbuthia *et al.,* 2015). This is because it ensures

Table 13. Correlation of farmer, marketer and consumer rankings for traits of economic importance

Category	Traits	BW	GR	FER	PRL	DRTOL	TEMP	HTOL	DTOL	FCE	PCOL	ESC	EYC
Farmers	GR	0.528**											
	FER	0.362**	0.492**										
	PRL	0.053	0.113	0.333**									
	DRTOL	0.079	0.108	0.178*	0.505**								
	TEMP	-0.012	0.013	-0.021	0.049	-0.004							
	HTOL	-0.015	-0.060	0.028	0.146*	0.260	0.194						
	DTOL	0.032**	0.036	0.026	0.088**	-0.045	0.281	0.030					
	FCE	0.012	0.048	-0.011	0.014	-0.045	-0.038	0.062	0.0120				
	PCOL	-0.131	-0.040	-0.025	0.038	-0.025	0.068	0.051	0.013	0.214			
	ESC	-0.098	-0.107	-0.014	-0.06	0.045	0.044	-0.003	-0.009	0.106	0.148		
	EYC	0.081	0.005	-0.02	0.012	0.006	0.005	0.08	-0.094	-0.029	0.021	-	
	MQ	-0.213**	-0.333**	-0.201**	0.093	0.045	0.09	0.093	0.053	-0.03	-0.084	-0.063	0.009
Marketers	GR	0.085**											
	PRL	0.058	0.072*	-									
	TEMP	0.040	0.149	-	0.472	-	-						
	DTOL	-0.015	-0.106	-	0.238	-	-	0.062					
	PCOL	0.123	-0.114	-	0.056	-	-	0.039	-0.012	-			
	ESC	0.124	-0.203	-	-0.264	-	-	-0.056	0.072	-	-0.145		
	EYC	0.174	0.249	-	-0.021	-	-	0.093	0.226	-	0.232	0.094	
	MQ	0.064*	0.015	-	0.040	-	-	0.007	0.326	-	-0.016	0.060	0.100
Consumers	GR	0.029											
	PCOL	0.093	0.029	-	-	-	-	-	-	-			
	ESC	0.097	0.109	-	-	-	-	-	-	-	-0.098		
	EYC	0.003	0.033	-	-	-	-	-	-	-	0.024	0.071	
	MQ	0.146*	0.044	-	-	-	-	-	-	-	0.135	-0.016	-0.035

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

[a] *BW body weight, GR growth rate, FER egg fertility, PRL prolificacy, DRTOL drought tolerance, TEMP temperament, HTOL heat tolerance, DTOL disease tolerance, FCE food conversion efficiency, PCOL plumage colour, ESC egg shell colour, EYC egg yolk colour, MQ meat quality.*

that animal selection is based on traits that farmers understand, measures and records easily and derives direct economic value (Tada *et al.*, 2013). However, it might be difficult to combine both productive, reproductive and functional traits as some are negatively correlated (Table 13). When the traits of interest are numerous and/or some of them are antagonistic, different lines may be created, and maintained by within-line selection. Therefore, intervention measures where some traits can be improved through management while others through selection are needed (Okeno *et al.,* 2011). This can be achieved through consideration of appropriate genotypes that can efficiently utilize available resources and are adapted to the environment conditions.

4.4 Conclusion

Results from this study revealed that prolificacy, mature weight, disease tolerance, egg number, and heat tolerance were the most preferred attributes across different IC genotypes. Selection of breeding cocks and hens was mainly based on disease tolerance, body weight at sexual maturity, body size, growth rate and high egg fertility were the highly-preferred traits for breeding cocks. Egg yield, mothering ability, growth rate, body size, body weight at sexual maturity and disease resistance were the most important traits preferred for hens.

In general, farmers wanted chicken which combined productive, reproductive, functional and aesthetic traits. However, egg yield, disease tolerance, high growth rate, prolificacy, high body weight and egg fertility were highly preferred by farmers. For the traits perceived to be important by farmers, there was a positive and significant correlation between body weight and GR and FER. There was a significant negative correlation between meat quality (MQ) and BW, GR and FER Regarding marketer and consumer' preferences rank correlation, positively and significant correlation were obtained between BW and GR and MQ. The trait preferences perceived by marketer and consumers were meat quality, egg yolk colour, plumage colour, disease tolerance, and growth rate and body weight. As such, appropriate genotypes which suit these characteristics need to be identified and utilized based on their performance and adaption to the environment conditions to ensure efficient resource utilisation. The study has clearly showed there is need to consider the stakeholders' preferences in the future development of improvement programs for IC.

CHAPTER FIVE

BIO-ECONOMIC MODEL DEVELOPMENT AND ESTIMATION OF ECONOMIC VALUES FOR TRAITS

5.1 Introduction

Poultry, particularly chicken are the most widely raised livestock species in the world and also the most numerous (Mengesha and Tsega, 2011; FAO, 2013; Gabanakgosi *et al.,* 2013). More than 80% of the total poultry are kept in rural and peri-urban areas of developing countries (Gabanakgosi *et al.,* 2013). They significantly contribute to improving human nutrition, provision of much needed source of nutrients and micronutrients and generate income and savings, especially in disadvantaged groups and low income food-deficit countries (Guèye, 2002; Akinola and Essien, 2011; FAO, 2013). In Africa, IC make up over 70% of the total chicken population (Kingori, *et al.,* 2010).

Over 80% of the small-scale farmers in Rwanda rear chicken, majority of which are IC (FAO, 2009; NISR, 2011). In Rwanda, they contribute 3000 tonnes of eggs and 2144 tonnes of chicken produced annually (FAOSTAT, 2014). Their popularity among resource poor rural households in developing countries is attributed to their low cost of production, adaptability to harsh scavenging conditions, resistance to disease outbreaks and adjustment to the fluctuations of feed availability (Menge *et al.,* 2005; Akinola and Essien, 2011; Dana *et al.,* 2010; Kingori *et al.,* 2010; Mengesha and Tsega, 2011). Compared to other livestock species, chicken production has the advantages of having quick returns to investment and relatively simple management practices with numerous market outlets for products (Kingori *et al.,* 2010). Chicken production has less detrimental impact on the environment than other livestock, and uses less water (FAO, 2013). IC are extremely important in providing income and high-quality protein in the diets of rural people whose traditional foods are typically rich in carbohydrate but low in protein (FAO, 2013). Their contribution goes beyond provision of food, cash income and employment as they also serve as a means of wealth accumulation and are valued in religious and sociocultural lives of most communities (Mack *et al.,* 2005; Grobbelaar *et al.,* 2010; Kingori *et al.,* 2010; Okeno *et al.,* 2012).

Despite playing these important roles, production constraints such as high disease incidences, inadequate nutrition, low genetic ability for eggs and meat production, poor housing, healthcare, marketing channels and lack of appropriate breeding objectives, reduce their contribution to rural development (Mengesha and Tsega, 2011; Magothe *et al.,* 2012; Okeno *et* *al.*, 2013). However, IC possess high genetic diversity for many traits which can be improved through selection (Okeno *et al.*, 2013).

Definition of breeding objectives is the first step in genetic improvement as it describes the direction of selection and genetic merits of performance traits (Åby *et al.*, 2012; Wolc *et al.*, 2011). Breeding objectives are linear combinations of the traits that have an impact on the profitability of a given production system, weighted with their respective economic values (Menge *et al.*, 2005; Henning *et al.*, 2013). The breeding objective should reflect the production and economic environment under which the animals are raised (Okeno *et al.*, 2013; Mbuthia *et al.*, 2015a). In chicken production, different production environment, management and marketing exist, further complicating the process of developing a general breeding objective. Under such situations, a general bio-economic model becomes an important tool as a larger number of factors and their complex interactions in the production systems are considered concurrently (Kahi and Nitter, 2004; Åby *et al.*, 2012).

In developing countries, bio-economic models have been developed and utilised to estimate the profitability and economic values for pigs (Mbuthia *et al.*, 2015a), dual purpose goats (Bett, *et al.*, 2007), Boran beef breed and dairy cattle (Rewe *et al.*, 2006; Åby *et al.*, 2012), and indigenous chicken (Menge *et al.*, 2005; Henning *et al.*, 2013; Okeno *et al.*, 2013). Such highlighted studies are non-existent in Rwanda. There is a need to develop a bio-economic model integrating the productive and functional traits, and deriving their economic values under the production circumstances of Rwanda. The present study aimed to develop a bio-economic model incorporating biological and functional traits and estimate their economic values to support smallholder chicken production systems.

5.2 Material and methods

5.2.1 Model description

In this study, a deterministic model was developed and used to evaluate the biological and economic aspects of IC production systems in Rwanda. A deterministic model is one in which every set of variable states is uniquely determined by parameters in the model and by sets of previous states of these variables; therefore, a deterministic model always performs the same way for a given set of initial conditions. The model involves description of typical production systems practised and modelling their profitability taking into account traits that have influence on revenues and costs (Mbuthia *et al.,* 2015b). The production systems have been characterised and categorized into extensive or free range, semi-intensive and intensive systems (Chapter 3). In extensive/free-range/scavenging system (FRS), both the chicks and the mature chicken are mostly left to scavenge for feeds during the day and confined at night. Occasionally the birds are supplemented with household crop leftovers. Housing under free scavenging system is not developed and where it exists it is mainly for birds' protection against predators and extreme weather. It is characterised by low outputs-egg and meat production per bird. Replacement stocks are obtained from own hatching chicks or purchased from the local market, neighbours or given as gift (Chapter 3). Marketing channels for products and live birds are undefined. During the time when there is urgent need of money or when birds are sick or when hatching is not required, live birds and eggs are sold at the gate or in the local market (MINAGRI, 2012).

In the semi-intensive or semi-scavenging system (SIS), chickens are partly confined, especially in relation to the prevailing activities in arable agriculture, e.g., when crops are at stage where foraging chickens could destroy them (Moges *et al.,* 2010). Chickens are confined to avoid conflicts among neighbours, but get crop residues, grains and kitchen leftovers as supplement for their daily feed requirements. It was assumed that the growers and breeding stock derived equally (50%) of their feed intake from scavenging feed resources and supplementation. Water and sometimes veterinary or ethno-veterinary care is provided though not adequately and mortality is 40-60% in young chicks (Dana *et al.,*2010; Moges *et al.,* 2010; Kingori *et al.,* 2010; Okeno *et al.,* 2012).

The intensive system or Confined full-ration system (IS), is the production system where flock is confined all the time and supplied with a rationed feed (Moges *et al.,* 2010). Chicks are fed on chick mash for 6 weeks, from 7 to 21 weeks on grower mash and layers mash thereafter (Menge *et al.,* 2005; Okeno *et al.,* 2013). Ecto- and endoparasites control and vaccination against endemic diseases are carried out under this system.

In this study, the production, management and nutritional variables used were obtained through the field survey at farm level conducted in five districts of Rwanda namely, Rwamagana, Rulindo, Ruhango, Muhanga and Kicukiro. Where information could not be obtained, previous studies conducted elsewhere in the tropics were consulted (Dana *et al.,* 2010; Fisseha *et al.,* 2010; Kingori *et al.,* 2010; Magothe *et al.,* 2012; Menge e*t al.,* 2005; Moges *et al.,* 2010; Okeno *et al.,* 2013). The profitability of each production systems was described as a function of annual revenues and costs per hen per year and was dependent on the input and output parameters. The main inputs were feeds, husbandry (i.e. vaccinations, disease treatments, labour etc.) and marketing costs. Sales of surplus eggs, growers not selected for replacement and culled breeding stock were the main sources of revenues. These input parameters reflect the actual performances of IC reared under the three production systems in Rwanda. To simplify the calculations some parameters were assumed to be the same for all production systems, although this might not be practical because management and production may differ between the systems. The economic variables were based on the actual average input and output prices. The prices were in Rwandan Francs (Frw) where US$ 1= Frw 772.7 and Ksh1= Frw 7.64.

5.2.2 Breeding, production and marketing

Flock composition and replacement

The composition by sex of the chicks at day old was assumed to be 1:1. The mating ratio was assumed to be 1 cock to 5 hens for all production systems, and hens were used to incubate eggs and brood chicks to weaning. The hens were able to lay 18, 30, 40 eggs per clutch in the FRS, SIS and IS, respectively. The average number of incubated eggs per hen per clutch was 12 with a laying cycle of 15 weeks translating to 3 clutches per year (Okeno *et al.,* 2013). In all systems, the hatching weight was assumed to be 30g. The replacement policy was such that 50% of old stocks were culled each year and the expected mature weights were 1.87 and 2.22kg for females and males, respectively (Moges *et al.,* 2010; Magothe *et al.*, 2012; Okeno *et al.,* 2013). The replacement pullets and cockerels were selected at 21 weeks and surplus cockerels and pullets were sold off when they reached sexual maturity. Table 14 shows the realistic estimated level of production variables considered in the model for all production systems.

Table 14. The level of production variables considered in the model

Variables	Units	Production system		
		FRS	SIS	IS
Production variables				
Egg yield per clutch	eggs	18.00	30.00	40.00
Egg weight	g	42.00	42.00	42.00
Egg fertility	%	87.00	87.00	87.00
Hatchability	%	94.00	94.00	94.00
Number of clutches per year		3.00	3.00	3.00
Hatching weight	g	30.00	30.00	30.00
Setting percentage	%	66.00	50.00	40.00
Number of setting		3.00	3.00	3.00
Chicks survival rate	%	50.00	67.00	82.00
Grower survival rate	%	75.00	80.00	98.00
Breeding stock survival rate	%	70.00	75.00	95.00
Expected mature live weight at 21 weeks (cocks)	kg	1.87	2.00	2.22
Expected mature live weight at 21 weeks (hens)	kg	1.60	1.75	1.99
Age at first egg	weeks	24.00	24.00	24.00
Productive lifetime	weeks	52.00	52.00	52.00
Management variables				
Mothering period	weeks	15.00	15.00	15.00
Sale age of surplus birds	weeks	21.00	21.00	21.00
Nutritional variables				
Metabolisable energy of chick's mash	Kcal/kgDM	-	2784	2784
Metabolisable energy of growers 'mash	Kcal/kgDM	-	2417	2920
Metabolisable energy of layers 'mash	Kcal/kgDM	-	2417	2500
Metabolisable energy of scavenged feed	Kcal/kgDM	2417	2417	-

FRS: free range production system; SIS: semi-intensive system; IS: intensive system

Source: (Field data; Dana *et al.*, 2010; Kingori *et al.*, 2010; Magothe *et al.*, 2012; Menge *et al.*, 2005; Okeno *et al.*, 2013).

Marketing and prices

Unselected growers were sold on per animal and not based on weight. Farmers sold birds and eggs through two main channels: directly to consumers (at farm gate) and through village level primary collectors who in turn sell the products through the village level primary markets. Farmers ferried live birds and eggs to primary markets using hand baskets while collectors used bicycles. Primary collectors sell live birds to retailers who operated in secondary market in urban centres.

The secondary collectors in turn sold directly to consumers or to other traders or to hotels or restaurants (Chapter 3; MINAGRI, 2012,). One kilogram of slaughtered IC was being sold at Frw 2500 while the mature live cock and hen were being sold at Frw 5000 and FRW3500, respectively. The marketing costs (levies) were assumed to be Frw 250 irrespective of the size of birds. No levies were charged on eggs. Table 15 present the unit prices and costs considered in the model.

Table 15. Unit prices and costs considered in the model

Economic variables	Symbols	Units	Production systems		
			FRS	SIS	IS
Prices (Frw)					
Eggs	PEgg	Frw/egg	100	100	100
Live chickens	Pl_{ch}	Frw/kg	2500	2500	2500
Mature culled cock	Pmcock	Frw/cock	5000	5000	5000
Mature culled hen	Pmhen	Frw/hen	3500	3500	3500
Costs (Frw)					
Chick mash	Chmash	Frw/kg	0.00	155	310
Grower mash	CGmash	Frw/kg	0.00	150	300
Layer mash	Clmash	Frw/kg	0.00	150	300
Scavenging feed	Psf	Frw/kg	30	30	0.00
Labour	LabW	Frw/day	1000	1000	1000
Marketing	Markc	Frw/bird	250	250	250
Veterinary	Vetcost	Frw/bird	0.00	120	120
Fixed	Fcost	Frw/system	0.00	1000	3000

FRS: free range production system; SIS: semi-intensive system; IS: intensive system

5.3 Estimation of revenues, costs and profitability

Revenues

The total revenues were calculated as below:

$$\boldsymbol{R} = R_{eggs} + R_{growers} + R_{cull}$$

where R_{eggs} is the revenue from the sale of surplus eggs (Frw), $R_{growers}$ is revenue from the sale of excess pullets and cockerels not selected as replacement stock, R_{cull} is revenue from the sale of culled cocks and hens.

The revenues from surplus eggs, growers (pullets and cockerels) not selected for replacement and culled breeding stock were computed as below:

Surplus eggs (R_{eggs}):

$$R_{eggs} = EN \times \left(1 - S_{perc}\right) \times N_{cluc} \times P_{egg}$$

where *EN* is eggs number per hen per clutch, S_{perc} setting percentage, *Ncluc* number of clutches per year and P_{egg} price per egg (Frw)

Growers not selected as replacement stock ($R_{growers=} + R_{pullets} + R_{cokls}$)

$R_{growers} = \{(N_{pcul} \times LW_p) + (N_{ckcul} \times LW_{crl})\} \times P_{meat}$

where N_{pcul} and N_{ckcul} are the number of pullets and cockerels not selected for replacement respectively, LW_p and LW_{crl} are live weights of pullets and cockerels respectively at 21 weeks of age and P_{meat} is the price per kg of IC meat at the market. N_{pcul} was estimated as:

$N_{pcul} = N_p - N_{psel}$

where N_P and N_{psel} are the number of available and selected pullets, respectively. N_P was calculated as:

$N_p = 0.5 \times N_{chicks} \times CSR \times GSR$

where N_{chicks} are the number of chicks hatched, *CSR* chicks' survival rate to 6 weeks and *GSR* grower survival rate. N_{psel} was computed as:

$$N_{psel} = (N_p \times H_{rt})$$

where H_{rt} is the hens' replacement rate. N_{ckcul} was calculated as:

$N_{ckcul} = (N_p \times H_{rt})/5$

where N_{ckcul} is the of the cockerels not selected for replacement

Revenues from culled breeding stock

$R_{cull} = (N_{coccul} \times LW_{cock} \times P_{mcock}) + (N_{hencul} \times LW_{hen} \times P_{mhen})$

where: N_{cocul} and N_{hencul} are the number of culled breeding cocks and hens respectively and LW_{cock} and LW_{hen} are their corresponding live weights. P_{mcock} and P_{mhen} are price of mature culled cock and hen, respectively. N_{coccul} and N_{hencul} were estimated as:

$N_{hencul} = (365 \times BSR)/PLT$

$N_{coccul} = \frac{N_{hencul}}{5}$

where *BSR* is the breeding stocks survival rate and *PLT* is productive life time in days.

Costs

The costs of feeds, health care, labour, marketing and brooding were computed as follow:

The total costs were derived as:

$\boldsymbol{C} = CF_{chicks} + CF_{growers} + CF_{cull} + C_{lab} + Mrt_c + C_{vet} + C_{brood} + C_{fixed}$

where FC_{chicks} is the feed costs for chicks, $FC_{growers}$ is the feed costs for pullets and cockerels, $FC_{breedstock}$ is feed costs for laying hens also includes the feed costs for cocks, C_{vet} is the cost of health care, C_{lab} is the cost of labour, C_{brood} is the brooding cost and C_{fixed} is fixed costs associated with shelter and equipment.

Chicks feed cost were computed as:

$$CF_{chicks} = N_{chicks} \times CFI_{chicks} \times PC_{hmash}$$

where CFI_{chicks} is the cumulative feed intake for chicks and PC_{hmash} is the price of chicks's mash. For extensive system, PC_{hmash} was replaced by P_{sf} is the scavenging feed cost.

Growers feed cost were computed as:

$$CF_{pullets} = \{(N_p \times CFI_p) + (N_{psel} \times CFI_p)\} \times P_{Gmash}$$

$$CF_{cockerels} = \{(N_{ckcul} \times CFI_{cklrs}) + (N_{psel} \times CFI_p)\} \times P_{Gmash}$$

$$CF_{growers} = CF_{pullets} + CF_{cockerels}$$

$CF_{pullets}$ and $CF_{cockerels}$ are the feed cost for pullets and cockerels. P_{Gmash} is the price of growers' mash. For the extensive system, P_{Gmash} was replaced by $P_{sf.}$

Feed cost for breeding stock were calculated as:

$$CF_{cull} = CF_{cock} + CF_{hen}$$

$$CF_{cock} = (CFI_{cock} \times BSR)/5 \times Pl_{mash}$$

$$CF_{hen} = CFI_{hen} \times BSR \times Pl_{mash}$$

where CF_{cock} and CF_{hen} are the feeding cost for cock and hen. Pl_{mash} is the price of layers's mash. In the extensive system. Pl_{mash} was replaced by P_{sf}.

Labour cost (C_{lab})

This was derived based on the time the farmer spent to attend to the chickens per day. This time has been estimated by Menge *et al* (2005) to be 10 minutes per bird per day.

$$C_{lab} = 0.17 \times t \times 365 \times 0.125 \times Lab_w$$

where Lab_W is the cost of labour per day for eight working hours in a day and t is the proportion of time spent in different production systems (i.e. FRS= 10%, SIS= 50% and IS= 100%); 0.17, number of hours spent to attend to each bird per day.

Marketing cost ($Cmkt_c$)

This was based on the levies charged per bird at the village market and was computed as:

$C_{mktc} = (N_{hencul} \times N_{coccul} + N_{pcul} \times N_{ckul}) \times Mark_c$

where $Mark_c$ is the cost levy charge in the village market.

Veterinary costs (C_{vet})

$C_{vet} = C_{vetchks} + C_{vetgrowers} + C_{vetbrs}$

$C_{vetchks} = N_{chicks} \times CSR \times V_{etcost}$

$C_{vetgrowers} = N_p \times GSR \times V_{etcost}$

$C_{vetbrs} = (N_{psel} + N_{cksel}) \times BSR \times V_{etcost}$

where $C_{vetchks}$, $C_{vetgrowers}$ and C_{vetbrs} are the costs of health care for chicks, growers and breeding stock, respectively and V_{etcost} is the cost of health care per bird. In FRS, this cost was assumed to be zero.

Brooding cost (C_{brood})

This was defined as the opportunity cost incurred because the hen was not in lay due to incubation and brooding, the eggs did not hatch due to infertility and because of low hatchability (Okeno *et al.*, 2013). Hens were assumed to take 15 weeks to incubate eggs and brood chicks to weaning. The cost was therefore computed as:

$$C_{brood} = [(EN \times S_{perc}) \times (1 - (FER \times HA)] + [(\frac{EN \times 105}{365})] \times P_{egg}$$

where *FER* and *HA* are egg fertility and hatchability, respectively.

Profitability

The annual profitability of the flock for each production system was estimated as:

$P = R - C$

Where P is the profit per flock per year, R is the revenue per flock per year and C is the cost per flock per year.

5.4 Derivation of economic values (EVs)

Economic values from profit functions can be derived by partial differentiation of the profit function with respect to the trait of interest and by accounting for unit change in returns (marginal returns) and costs (marginal costs) arising from improvement of a trait, also referred to as partial budgeting method (Kahi and Niter, 2004; Mbuthia *et al.*, 2015b). In this study, *EVs* for traits in the breeding objectives were estimated using the partial budgeting approach. The profitability of the flock was compared before and after genetic improvement. The biological traits affecting revenues and cost are presented in Table 16.

Table 16. The biological traits influencing revenues and costs

Traits	Units	Abbreviation
Egg yield per clutch	eggs	EN
Egg weight	g	EW
Egg fertility	%	FER
Hatchability	%	HA
Number of clutches per year		Ncluc
Hatching weight	g	HW
Setting percentage	%	Sperc
Number of setting		Nsett
Chicks survival rate	%	CSR
Grower survival rate	%	GSR
Breeding stock survival rate	%	BSR
Expected mature live weight at 21 weeks (cockerels)	kg	EWcock
Expected mature live weight at 21 weeks (growers)	kg	EWhen
Age at first egg	weeks	AFE
Productive lifetime	days	PLT

Economic values for the breeding objective traits were estimated using a bio-economical model developed above considering the fixed-flock size scenario to facilitate calculation of *EVs* in relation to the different production systems which may lead to a diversification of the breeding objective. The EVs were analysed to assess the impact of improving a certain trait weighted with its economic values on. The changes were performed one at time, keeping all other parameters constant.

The EVs were computed as described previously (Kosgey *et al.,* 2004; Kahi and Nitter, 2004; Rewe *et al.,* 2006; Bett *et al.,* 2007; Mbuthia *et al.,* 2015b):

$$EV_{flock-size} = \left[\frac{\delta R - \delta c}{\delta_t}\right]$$

where δR and δC are the marginal changes in revenue and cost after 1% change in traits of interest and δ_t is the marginal change in the traits after 1% increase.

5.5 Assessment of the effect of economic values on genetic gain

5.5.1 Phenotypic and genetic parameters

The genetic and phenotypic parameters are some of the most important input variables when evaluating breeding objectives/ programs as they play an important role in computation of accuracy of the index (Okeno *et al.,* 2015). Selection requires that certain measurements be done on candidates for specific characters which are targeted or related to those targeted for improvement. The traits targeted for improvement have to be heritable, possess some variation within the animal population and be phenotypically and genetically correlated (Menge, 2008). In this study, it was necessary to consult a wide variety of sources because estimates of genetic and phenotypic parameters for local chicken are scarce. The phenotypic standard deviations, heritability and genetic and phenotypic correlations between traits in the breeding objective used in this study are presented in Table 17 and were based on averages from previous studies on IC in the tropics (Iraqi *et al.,* 2002; Norris and Ngambi, 2006; Menge, 2008; Bahmanimehr, 2012; Dana *et al.,* 2011; Dessie *et al.,* 2011; Niknafs *et al.,* 2012; Okeno, 2012; Osei-Amponsah *et al.,* 2013).

Table 17. The phenotypic standard deviation (σp), heritability (along diagonal, in bold), genetic (above diagonal) and phenotypic (below diagonal) correlations for traits in breeding objective and selection criteria

Traits	σ_p	EW	LW	EN	FER	HA	ADG	CSR	AFE	GSR	EYC
EW	0.70	**0.56**	0.10	-0.19	-0.17	-0.49	0.00	0.00	0.12	0.00	0.25
LW	540.04	0.20	**0.54**	0.81	0.24	0.00	0.65	0.00	0.19	0.00	0.00
EN	11.43	-0.13	0.73	**0.35**	0.23	0.20	0.00	0.00	0.95	0.00	0.00
FER	16.70	0.07	0.24	0.23	**0.25**	0.43	0.00	0.00	0.59	0.00	0.00
HA	18.10	-0.49	0.00	0.20	0.02	**0.6**	0.00	0.00	0.00	0.00	0.00
ADG	2.98	0.00	0.65	0.00	0.00	0.00	**0.44**	0.00	0.43	0.00	0.00
CSR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.40**	0.00	0.00	0.00
AFE	12.01	0.32	0.41	-0.32	0.10	0.00	0.00	0.00	**0.55**	0.00	0.00
GSR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.45**	0.00
EYC	0.13	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**

[a] see Table 16 for description of traits

5.5.2 Selection indices and criteria

Selection indexes are used by livestock breeders of many species around the world and are considered an essential part of any modern livestock breeding program. Selection indexes aid in the selection of animals for use within a breeding programme where there are several traits of economic or functional importance by providing an overall score of an animal's genetic value. Selection indexes are calculated for a specific breeding purpose and are calculated based on weightings placed on individual traits that are deemed to be important for that purpose.

In the current study, the breeding objective based on marketable end products was therefore considered. The breeding objective was to produce dual-purpose IC for both egg and meat production. The breeding goal traits consisted of EN, FER, HA, CSR, GSR, BSR, LWg, LWcock and LWhen. The traits considered in selection index were egg number (EN) after the first clutch, live weight at end of first clutch (LWhen), age at first egg (AFE) and average daily gain (ADG). Selection for females was assumed to occur at the end of first clutch. Males were selected at 8 weeks. Hens were selected based on individual information on EN, LW, AFE and ADG and information on their dams. The males were selected based on their LW at 8 weeks and on information on EN, LW, AFE and ADG on their dams and sisters.

One major advantage of selection indexes is that genetic values of the traits can be weighted by their relative economic value. In the current study where selection is for several traits at a time, the economic values are used as weights (Hazel *et al.*, 1994). The genetic response (GR) for traits in the breeding objective was defined as genetic superiority for each trait (j) achieved after one round of selection assuming selection intensity of one. It was estimated as:

$$GR_j = \left(\frac{ib'G}{\sigma_t}\right)$$

where *i* is the selection intensity, *b* the index weights, *G* variance-covariance matrix between traits in the index and the breeding objective and σ_t the standard deviation of the index.

The *b* was derived as follows:

$$b = P^{-1}Ga$$

where b is a vector of the selection coefficients of the index traits, P^{-1} is inverse of the phenotypic variance-covariance matrix of the characters in the selection index and *a* the vector of economic values of the traits in the breeding objective in Rwandese francs (Frw).

The economic response (*ER*, Frw) for traits in the breeding goal was defined as the sum of *GR* for all traits in the breeding goal, each weighted by its economic value. The ER after one round of selection was calculated using the equation:

$$ER_j = \sum_{i=1}^{j}(GR_j \, X \, EV_j)$$

where EV_j is the economic values for trait j.

5.6 Results and discussion

5.6.1 General bio-economic model

The model developed simulated the revenues, costs and profitability of different classes of IC under the different production systems evaluated which may be very difficult to collect in field conditions. It was not possible to validate the profit models by comparing estimated values with actual observations from experimental results but the simulated outputs were checked to determine whether they were reasonable or not. The values obtained for each production system depended on the flock structure used since the three production systems had different flock composition. The revenues, costs and profit are presented in Table 18. Generally, the revenues and costs were higher in IS than in both SIS and FRS production systems. The results show that the sales of surplus growers (pullets and cockerels), culled hens and surplus eggs had a positive impact on profitability of the three production systems.

The sales of surplus growers accounted for 83.7, 83.23 and 82.57% of the total revenues in IS, FRS and SIS operations, respectively. The simulated revenues obtained in this study were in agreement with those reported by Okeno *et al.* (2013) in Kenya where surplus growers accounted for 74.45, 67.00 and 58.32 % of the total revenues in FRS, SIS and IS, respectively. Sales of culled hens and cocks contributed to revenues in all production systems (9.85% in FRS, 6.95% in SIS and 6.14% in IS) indicating that culled hens and cocks are important sources of revenue in all production systems. Eggs contributed 10.48, 10.13 and 6.92 % of the total revenues in SIS, IS and FRS indicating that egg production traits are also important in these production systems. This could be due to the fact that the number of setting and eggs setting percentage used as input in the model was higher indicating the need for chicks by farmers. The revenues from sales of surplus eggs obtained from the model were comparable to those reported by Menge *et al.* (2005).

Table 18. Estimated revenues, costs and profitability (Frw, US$1=Frw 772.7) for indigenous chicken in the FRS, SIS and IS production systems

Variables	Production systems		
	FRS	SIS	IS
***Revenues* (Frw)**			
Eggs	1836.00	4500.00	7200.00
Growers	22068.68	35433.84	59510.31
Culled hens and cocks	2614.50	2981.25	4362.88
Total revenue (a)	26519.18	42915.09	71073.18
***Costs* (Frw)**			
Feed costs for chicks	998.04	6154.60	9217.91
Feed costs for growers	4058.93	30561.98	79891.66
Feed cost for breeding stock	811.52	5497.47	15245.79
Labour	775.63	3878.13	7756.25
Veterinary	0.00	3209.07	4619.61
Marketing	1975.23	2817.37	3179.61
Brooding cost	734.26	1136.31	1442.20
Total variable costs (b)	9353.61	53254.93	122628.27
Fixed cost (c)	0.00	1000.00	3000.00
Total costs (b+c)	9353.61	54254.93	125628.27
Profit (a-(b+c)) (Frw)	17165.57	-10339.83	-51555.09

The prices were in Rwandan Francs (Frw) where US$ 1= Frw 772.7 and Ksh1= Frw 7.64.

The overall costs were higher in IS than in both SIS and FRS. Table 18 illustrates the variable cost comprising of feeds, labour, health care (veterinary), brooding and marketing in the production systems. Feed costs contributed the major part of the total costs accounting for 78.33 and 79.27% of the total cost in SIS and IS, respectively. Similarly, Okeno *et al.* (2013) reported that feeds were the important costs accounting over 55.87 and 78.51% of the total costs in SIS and IS production operations, respectively. In various studies (Kahi and Nitter, 2004; Bett *et al.*, 2007; Rewe *et al.*, 2011; Okeno *et al.*, 2013; Mbuthia *et al.*, 2015b) conducted on different livestock species in different production systems revealed that feeds were the major part of the total production costs. Husbandry cost (labour and veterinary costs) contributed 13.31, 10.1 and 8.29%

of the total production cost in SIS, IS and FRS operation systems, respectively, followed by marketing and brooding costs. The levy cost was fixed at the village market irrespective of the size of the chicken. The opportunity cost for using broody hens to incubate eggs and brooding chicks to weaning contributed the least to total production costs (Table 18). This is in contrast to what was reported by Okeno *et al.* (2013) that the marketing costs contributed the least to total production costs. The simulated results also agrees with those reported in Kenya by Menge *et al.* (2005) that labour contributed significantly to the total costs in all systems (34.91% in IS, 52.92% in SIS and 28.12% in FRS).

The brooding cost can be minimised by allowing the hens to incubate the eggs up to hatching then raising the chicks artificially because such practices have been found to increase egg production and number of clutches per hen per year and reduce chick's mortality Kugonza *et al.* (2012) and Okeno *et al.* (2013). The inclusions of family labour and marketing costs in bio-economical models in this study resulted to increased cost of production. This is in agreement with previous studies (Bett *et al.*, 2011; Okeno *et al.*, 2013; Mbuthia *et al.*, 2015b) who reported that inclusions of family labour costs in the models results to inflate costs.

Profits were simulated by subtracting the total production cost including fixed costs from total revenues. The use of IC was the most profitable in FRS and not in SIS and IS operation systems (Table 18). The profitability of FRS could be explained by low input costs as feeds. Even though, it is difficult to quantify the cost of scavenging feed resources, ignoring such costs leads to overestimation of profitability (Menge *et al.*, 2005; Okeno *et al.*, 2013). The other major sources of variation may be due to fixed and veterinary costs which were set to zero in FRS. The profitability of FRS over other production systems agrees with the reports by Menge *et al.* (2005) but contradicts the negative profitability for SIS reported by (Okeno *et al.*, 2013). This might be attributed to the difference in terms of parameters used in the model as in SIS commercial feeds and scavenging feeds accounted equally 50% of feeds used in this system.

The profitability obtained in this study revealed that chicken can be utilised in FRS and can lead to increased smallholder poultry production income. Although SIS and IS showed negative profitability, they cannot be overlooked as transition from subsistence to commercial production requires that management levels get better as the genetic potential of the birds is also improved. The FRS has been described as a low input system compared to the SIS and IS which require high capital investment in terms of feeds, healthcare, housing and labour (Dana *et al.,* 2010; Kingori *et al.,* 2010; Akinola and Essien, 2011; Magothe *et al.,* 2012).

The cost of feeds observed in IS and SIS systems can be reduced by exploring other locally available feed sources for chicken such as drought-tolerant cereals or the possibility of harnessing insects such as termites which are abundantly available during dry seasons when cereals are scarce. This will not only reduce the cost of production but also will improve productivity hence increased profitability (Okeno *et al.,* 2012).

In Rwanda, like other developing countries with increased population and less acreage of land, there is need of shifting from substance to commercial production systems. This requires utilisation of IC under SIS and IS systems. This calls for developing the simple, applicable and affordable technologies such as use of hand woven baskets to protect birds against predators, constructions of simple chickens' house, vaccination programs and formulation of chicken feeds using the locally available feed stuffs. Such practices will result to increased flock size, reduction of conflicts between households due to crop destruction by chickens and increased profitability. However, these strategies should not only focus on increasing IC productivity but there is, also a need to consider marketers and consumer preferences.

5.6.2 Estimation of economic values (EVs)

The economic values were estimated using traditional bio-economic model. The EVs for traits in the breeding objectives for the three production systems under fixed flock size production conditions are presented in Table 19. Generally, economic values were higher under FRS than in both SIS and IS (Table 19). Economic values for traits such as egg yield, fertility rate, hatchability rate, chicks' survival rate, growers' survival rate, brooding stock survival rate, live weight for pullets, cocks and hens in FRS were all positive. There was a decrease in EVs as level intensification increased (Table 19).

Table 19. Economic values in Frw (1US$=Frw 772.7) for traits under fixed flock size

Traits	Production system		
	FRS	SIS	IS
	EVs	EVs	EVs
EN	+61.21	+112.12	+143.95
FER	+ 185.21	-68.16	-427.10
HA	+171.42	-63.08	-395.29
CSR	+293.45	-14.31	-324.98
GSR	+244.54	+10.26	-295.24
BSR	+24.26	-36.14	-117.43
LWg	+187.02	+270.49	+431.23
LWcock	+350.00	+375.00	+475.00
LWhen	+1225.00	+1312.50	+1662.50

[a] see Table 16 for description of traits

The economic values for productive traits (EN, LWg, LWcock and LWhen) were positive in all three production systems. The EVs for functional traits (FER, HA, CSR,) were positive in FRS but negative in both SIS and IS. The EVs for growers' survival rate were positive in both FRS and SIS and negative in IS production system. This indicates that a unit increase in genetic merit of the productive and functional traits had bigger influence on the revenues than costs. Focus on genetic improvement of these traits would result in positive profitability in all three production systems.

An increase of 1% in egg yield trait resulted in an increase in surplus eggs' revenue by Frw 61.208, 112.123 and 143.945 in FRS, SIS and IS production systems, respectively. Improving egg yield would result in more surplus eggs for sale after selecting for incubation. The revenues from live weight hens increased by Frw 1225, 1312.5 and 1662.5, while that for live weight cocks increased by Frw 350, 375 and 475 of the total profits in the respective production systems. Economic values for live weight of hens were higher than for the cocks in all systems. This is because an improvement in this trait affects several hens as half of productive hens are culled each year and cocks are low in number compared to the hens according to the flock composition. The other reason of high economic values can be attributed to the fact that the chickens in this category are taken to the market and bought based on the heavy chicken size resulting to the high revenues compared to grower chickens which have moderate body size. Okeno *et al.* (2012) reported that these traits had direct impact on the profitability of the production systems and indicated that their improvement would be economically beneficial to the producers. However, improving live weight would result in increased costs as a result of increased feed consumption by mature chickens in SIS and IS systems.

In the current study, grower chickens are the major contributor to revenue. From the bio-economic model, an increase of 1% in LWg resulted in a profit of Frw 187.023, 270.487 and 431.234 in free range, semi-intensive and intensive systems, respectively. This implies that increase LWg not selected for replacement have great effect on the revenues. The economic values for fertility and hatchability rate were positive for FRS and negative for both SIS and IS production systems. By increasing the Fer and HA by 1%, profit increased by Frw 185.207 and 171.415 in FRS, respectively. The negative economic values observed in SIS and IS implies that an increase 1% in FER and HA will result in an increase in the number of chicks which will directly increase the cost of feeds for chicks in SIS and IS production systems. The positive economic values for FER and HA obtained in this study agree with those reported by Okeno *et al.* (2013). Positive economic values for fertility has also been reported in pigs (Mbuthia *et al.,* 2015a) and in goats (Bett *et al.,* 2011).

An increase in profit for both CSR, GSR and BSR traits were observed in FRS production system. These traits influenced profit negatively in SIS and IS. This might be due to the fact that the improvement in survival traits exerts changes in flock composition rather than in individual performance. Therefore, the larger the flock size, the more production costs thus low profitability of these systems. However, survival traits are important in the tropics where prevailing conditions are characterized by disease challenges, poor nutrition and heat stress (Mbuthia *et al.,* 2015b).

In general, the positive economic values obtained in FRS compared to SIS and IS production systems could be explained by the low cost of production (Table 19). The findings concur with studies by Menge *et al.* (2005) and Okeno *et al.* (2012) which reported that economic values were large in FRS compared to SIS and IS. This implies also that improved indigenous chicken would be more profitable if raised under free range production systems. Meat quality, egg size, combo colour, egg yolk drought tolerance and diseases resistance perceived by farmers were not included in the model because it was difficult to measure these attributes.

5.6.3 Effect of economic values on genetic gain

The influence of economic values on genetic improvement was assessed by comparing the genetic gain achieved in the breeding objective. The economic values, economic response and accuracy to selection assuming different production systems when EN, LW, AFE, FER and HA were considered are presented in Table 20. Generally, the economic response for reproduction traits (AFE, FER and HA) where lower compared to the economic response for production traits (EN, and LW) in all production systems. The selection accuracy was almost uniform and high across all traits selection in all production systems. The increase of inbreeding rate was 0.152% per generation. This might be attributed to the chicken population size (1000 females and 200 males), intensity of selection of males and female candidates (10% of male and 25 % of females) and relationship information used when simulating the genetic gain and economic response. There was a slight difference in overall response between FRS, SIS and IS production systems. However, the economic response for production traits in IS was highest compared to economic response for FRS and SIS (Table 20). This might be due to the better management practices applied in IS production system. Therefore, the large positive economic values obtained in IS should be assumed. Improvement in genetic merit should be advantageous for the improved IC (Menge, 2008).

In FRS and SIS, FER and HA had a smaller economic impact than production traits. The negative economic response obtained when selection was focused on FER could be due to large negative economic value for FER obtained in this study which resulted in loss in economic response (ER) (Table 20). This in agreement with the results reported by Menge (2008) that CSR, HA and FER contributed minimally to economic response in all the production systems. Selection targeting improvement of LW resulted in economic response of Frw 23416.85, Frw 2495.06 and Frw 3106.44 for FRS, SIS and IS production systems, respectively. On the other hand, selection relative to EN resulted in positive economic values for Frw 96.87, Frw 179.78 and Frw 229.96 in FRS, SIS and IS, respectively. The economic response obtained for LW and EN imply that genetic improvement targeting selection of the production traits will have a positive impact on profitability of the IC kept in all three production systems. The predicted genetic superiority for LW and EN traits showed that farmers whose emphasis is to increase LW for meat production will have more profit than farmers emphasizing on eggs production (Table 20). Although the IC birds are kept in a dual-purpose role, more is to be gained from meat than eggs. Therefore, the study suggests that the structure of the breeding for IC should be modeled to develop the specialized lines for meat and egg production. Menge (2008) reported that, in economic terms, an improvement in meat production traits would be expected to have a greater positive impact on the livelihoods of the farmers than a similar improvement in egg traits.

Table 20. Genetic superiority in the breeding objective and economic response to selection for production systems

Traits	Genetic Superiority								
	Production systems	Ev_s (Frw)	EN(n)	LW(g)	AFE (days)	FER (%)	HA (%)	r_{IH}	ER (Frw)
	FRS	61.21	1.58	-	-	-	-	0.724	96.87
EN	SIS	112.12	1.60	-	-	-	-	0.72	179.79
	IS	143.95	1.59	-	-	-	-	0.72	229.95
	FRS	350.00	-	15.63	-	-	-	0.72	2316.85
LW	SIS	375.00	-	15.72	-	-	-	0.72	2495.05
	IS	457.00	-	15.52	-	-	-	0.71	3106.44
	FRS	187.02	-	-	0.52	-	-	0.72	97.75
AFE	SIS	270.49	-	-	0.49	-	-	0.72	132.26
	IS	431.23	-	-	0.43	-	-	0.71	186.49
	FRS	185.21	-	-	-	0.56	-	0.72	104.51
FER	SIS	-68.08	-	-	-	0.46	-	0.72	-31.34
	IS	-427.10	-	-	-	0.35	-	0.71	-148.99
	FRS	171.42	-	-	-	-	46.85	0.72	46.85
HA	SIS	-63.08	-	-	-	-	-0.09	0.72	5.77
	IS	-395.29	-	-	-	-	-0.47	0.71	185.05

[a] see Table 16 for description of traits

The positive economic responses were realized for selection aimed at genetic improvement of AFE in all production systems (Table 20). Therefore, inclusion of AFE in the breeding objectives is justified. This indicates that if selection could be done for chicken which attain the AFE earlier, it will have a positive influence on live weight and egg production during the entire chicken production cycle. This will further lead to profitability of IC in all three production systems. The results of this study are not in agreement with the previous study by Menge (2008) who reported that genetic improvement of AFE will have a negative impact on profitability in all production systems.

In general, the study demonstrated the feasibility of incorporating productive and reproductive traits in the breeding goals. There were relationships between the economic values and genetic gain in the breeding goals traits, which is an indicator of positive impact of the magnitude of economic values of traits of IC. Even though traits like FER and HA had lower to negative genetic superiority than LW and EN, they should be considered in the breeding program because it has been shown that intense selection for high body weight alone introduces infertility problems among chicken. The breeding objectives defined in this study need to be converted into actual material and monetary gain for smallholder formers who rear IC. Therefore, there is need to identify IC with the best genetic merit relative to the breeding objective. Further research is also needed to identify the genetic and phenotypic parameters for IC and identify the optimum breeding strategies that can be used to achieve these breeding objectives.

5.7 Conclusion

This study focused on development of a bio-economic model and assessment of the economic values for the traits of economic importance perceived by farmers. The bio-economic model was used to estimate the revenues, costs and profitability of IC in different smallholder production in the breeding objective. The results from the model show that IC can be utilised profitably under FRS. However, negative profits were observed in SIS and IS. The results show that genetic improvement of the production (EN, LWg, LWcock and LWhen) and functional (FER, HA, CSR,) traits would give the highest economic values hence increase profitability of IC production systems. Traits considered in this study could probably be combined with other traits in the breeding objectives. However, it might be difficult to genetically change them as they might have antagonistic relationships. It is important to note that further studies on bio-economic model incorporating risk-rated economic values are needed as it will prevent over-estimation of profits for the IC production systems. This will help farmers to select IC based on traits that suit their production system.

CHAPTER SIX

GENERAL DISCUSSION AND CONCLUSIONS

6.1 Aim of the study

The role of IC to rural households in developing countries is well known. This is evident from the fact that indigenous genotypes are widely distributed in rural and peri-urban area of developing countries, frequently in excess of 80 percent (Gabanakgosi *et al.*, 2013; Pym, 2010). For the last several decades, IC have been recognized as important tools to wealth creation, poverty and food insecurity alleviation in developing countries (Dana, 2011; MINAGRI, 2012). In many developing countries, several projects had been initiated to improve the IC productivity through crossbreeding with exotic commercial breeds. However, most of these projects have been unsuccessful due to several factors such as poor understanding of IC production systems, lack of clear breeding objectives and operational breeding programs. Therefore, there is need to establish the socio-economic contribution of chicken in the overall effort to alleviate poverty and food insecurity. The current study focused on generating information on IC production systems, identifying the traits of economic importance and developing the breeding objectives for IC genetic improvement in Rwanda. The study had three objectives. Firstly, to understand the socio-economic characteristics, management of IC, production parameters, feed resources and constraints faced by farmers rearing IC in Rwanda. Secondly, to determine farmers breeding practices and identify traits of economic importance for IC genetic resources from the perspective of stakeholders along the IC value chain in Rwanda. Thirdly, to develop a bio-economic model and estimate economic values for production and functional traits for IC in Rwanda.

This thesis addressed three major research questions namely: 1) what are the characteristics of the production and marketing systems of IC in Rwanda? 2) what are the breeding practices and traits of economic importance in the selection of IC genetic resources? and 3) what are the economic value of the traits in the breeding objectives under different IC production systems?

6.2 Study methodology

Information on IC production systems characteristics was achieved through direct observations and interviews with the farmers selected in five districts with high IC population in Rwanda. They included Kicukiro, Rwamagana, Muhanga, Ruhango and Rulindo districts (NISR, 2011). Qualitative and quantitative data were obtained through interviews using pre-tested structured questionnaires, farmers group discussions and observations made by enumerators and researcher. The main information covered were farmers' characteristics (including age, level of education, occupation, household size, household status), farms' characteristics (farm size, land ownership, livestock species, number and reason of keeping IC) and IC management characteristics (production systems, housing, nutrition, extension services and challenges to IC production). A total of 206 farmers were interviewed. Results of the first objective are presented in Chapter 3 of this thesis. The analysis employed PROC FREQ and PROC MEANS procedures of SAS (version 9.00, 2002) to determine the frequency and descriptive statistics.

Information on farmers' breeding practices and traits of economic importance were obtained from the farmers, marketers and consumers using three set questionnaires. Data on flock composition, IC ecotypes, traits preferences as well as selection criteria were captured. A total of 206 farmers, 56 marketers and 80 consumers were interviewed. Ranking and index methodology was applied to provide the overall ranking for the traits preferences perceived by farmers, marketers and consumers. The use of ranking and index have been extensively used to identify the most important traits or issues which need to be addressed (Kosgey *et al.,* 2004; Bett *et al.,* 2011; Mbuthia *et al.,* 2015a). The breeding practices and traits of economic importance are covered in Chapter 4 of this thesis.

The required information on development of breeding objectives was obtained by reviewing the literature, performance records from various studies and field survey. A bio-economic modeling approach was then used to estimate profitability and marginal returns of the production systems. The production variables used in the model were representative of the production circumstances in Rwanda and many are applicable in others tropical regions. Partial budgeting was applied to assess the effect of profitability of increasing specific traits by a unit to derive the economic values (Ponzoni and Newman, 2010).

6.3 Indigenous chicken production systems

Characterization of the existing IC production systems is an important step for making decision on conservation and sustainable utilization of IC genetic resources. This study was initiated to provide a clear picture of socio-economic contribution of the IC, production circumstances and constraints and opportunities for IC production (Chapter 3). Such information are critical in developing appropriate breeding objectives (Dana *et al.,* 2010; Okeno *et al.,* 2012;

Mbuthia *et al.,* 2014), but were lacking in the literature, since there were no studies conducted on IC production systems in Rwanda. This study indicated that chicken in Rwanda are raised for eggs and meat production and income generation. The production environment is mainly extensive characterized by inadequate feeding, uncontrolled mating, high diseases prevalence, lack of initial capital and predation risks (Chapter 3). This call for a combined effort from government, higher learning institutions and non-government organizations to develop and research on alterative feed resources using non-conventional feed stuffs such as insects. This will not only generate feeds for chickens but also will reduce the food competition problem between human and livestock on use of cereals and legumes. It has been reported that feeding termites to chicken provides a mechanism for converting cellulose into food for human consumption with benefits to the ecosystem (Okeno *et al.,* 2012). There is a need to sensitize and train poultry farmers on importance of housing birds in separate chicken houses to reduce the spread of diseases and predator's problem. Poultry need good housing. It should be locked up at night to protect chicken from bad weather, predators, and thieves.

A poultry house allows for inspection of birds and handling for normal management practices. It also allows collection of eggs from the same place. Therefore, to access training and other extension services on poultry housing and management, farmers must be organized into groups. However, this study indicated that the extension services are limited. The limited extension services can be supplemented by high learning institutions and non-governmental organizations (NGOs) as it has been demonstrated that most farmers, especially women who are the custodians of IC prefer to work with NGOs (Ochieng *et al.,* 2011; Okeno, 2012). Okeno *et al.* (2012) reported that government extension officers should be trained through refresher or short courses to equip them with modern technologies on poultry management and participation of NGOs in farmers training and organization is critical. He concluded that such approaches have been found to be successful in improving the IC production environment and productivity. There is need to focus on farmer's education and training in the areas of chicken breeding, feeding, diseases and parasite control and treatment and marketing. Training and education should be tailored to both sexes but the major focus should be on women as they play a major role in IC production systems (Halima *et al.,* 2007; Magothe *et al.,* 2012).

The high prevalence of Newcastle disease observed in this study (Chapter 3) has also been reported elsewhere in the tropics (Gondwe *et al.,* 2007; Fisseha *et al.,* 2010; Moges *et al.,* 2010;

Akinola and Essien, 2011; Okeno *et al.*, 2012). This led to the necessity of anticipating implementation of efficient poultry health management system. A country vaccination program for chickens will be an ideal strategy to enable chickens to develop immunity and prevent them from disease outbreaks. This can be supported by the Rwanda Agricultural Board (RAB) and NGOs which can provide human resources, vaccines and facilities to the farmers.

Small flock size, uncontrolled mating and lack of recording scheme are the characteristic features of IC production systems also observed in this study (Chapter 3). Under such circumstances, multiplication centers for poultry breeds with separate tier operating on profit basis should be established by the government (Ministry of Agriculture) across the country. The multiplication centers can further provide various services to the surrounding farmers such as extension services, farm recording systems training and selling of fertile eggs for hatching using broody hens or 3 months old chickens. To achieve this, appropriate mechanisms for multiplication and dissemination of improved poultry management technologies and improved breeds are required. Therefore, financial support from NGOs and private sectors will help to ensure the sustainability of this multiplier centers. This will result to increased flock size among smallholders.

6.4 Breeding practices and traits of economic importance

6.4.1 Chicken genotypes and their attributes

In this study, majority of farmers reported preference of dwarf and normal feathered genotypes over others (i.e. Frizzled feathers, naked neck, crossbreds) because of their prolificacy, disease tolerance and fighting ability against predators (Chapter 4). The dwarf gene is known to increase feed efficiency and mass egg production (Magothe *et al.*, 2012a). Utilizing dwarf and normal feathered or dwarf-normal feathered genotypes for dual purpose production would be expected to increase live bird offtake and egg yield and evade predators without additional cost increases. The crosses were preferred for their high eggs yield, mature weight and moderate growth rate over IC. Introducing the exotic genes into dwarf and normal feathered genotypes would be expected to improve egg production under all production systems. However, management and husbandry measures should be considered because the crossbreds (hybrids) are not resistant to diseases compared to the pure indigenous IC. A well planned crossbreeding program would not only result to conservation of the pure lines and improved productivity of crossbreds due to heterosis and breed complementarity, but could also lead to development of a synthetic breed which would carry valuable genes from the original indigenous breeds to future generations (Scholtz and Theunissen, 2010). However, evaluating the potential of different breeds under village conditions in relation to the overall breeding objectives is important for deciding on the type of breeding scheme (Dana, 2011).

In general, gaining a better understanding of farmers' preferred chicken ecotypes and their attributes (traits) might be used by government or NGOs in planning of appropriate breeding program.

6.4.2 Traits of economic importance

As presented in Chapter 4, selection of breeding stocks was based on combination of productive, reproductive, functional and aesthetics traits. Egg yield, disease tolerance, high growth rate, prolificacy, high body weight and egg fertility were highly preferred by farmers. The traits perceived by marketer and consumers were meat quality, egg yolk colour, plumage colour, disease tolerance and body weight. These traits proposed by farmer, marketer and consumers should be included in the development of IC breeding program to capture the expected future market dynamics. A critical economic consideration is: who will pay for the development of IC breeding program (IC genetic improvement)? This question is not particularly important when breeding nuclei, multipliers and commercial flocks are fully integrated. Therefore, creation of breeding nuclei and multipliers for IC genetic resources in different part of Rwanda will be justifiable. This commonly provides justification for public and private sectors, and NGOs involvement in facets of IC genetic improvement. An alternative model to improve village poultry is the Bangladesh model *(http://stud.epsilon.slu.se/6336/1/Tan_D_131220.pdf)*. The Bangladesh model is a macro-credit based model emphasizing on the entire supply chain. The beneficiaries are specialized in different activities ranging from vaccination and medication supply, rearing of chicks of different age classes, fertile egg production, hatching or feed supply. Some of the reasons for the success of the program are that the different activities of the beneficiaries are tightly integrated and inter-dependent and the actors at all levels profit from their activity. Challenge of this model is the insufficient numbers of high quality chickens produced that are able to withstand the local environments (Permin *et al.*, 1998; Dana, 2011).

6.5 Bio-economic model

A country's development objectives for agricultural production traditionally include economic variables, but should be extended to accommodate ethics, and other social aspects of human well-being (FAO, 2007). Different tools are available for this. The most common is bio-economic model or the profit function.

In this study, a deterministic approach to capture the features of production systems was applied and used to estimate the economic values for production and functional traits (Chapter 5). The result show that IC can be utilized profitably under FRS. The SIS and IS system resulted to a negative profit. This might be attributed to the facts that the flock-size was fixed. Bett *et al (*2007) noted that the assumption of the fixed flock-size may not always be true because the animals are kept in small flocks with fluctuating numbers in the smallholder systems. In addition, unpredictable dates of animal disposal and seasonal variation of prices of chicken and feeds on markets may also affect the profitability production systems. The positive economic values for EN, LWg, LWcock and LWhen in all production systems indicate that genetic improvement of these traits would have positive effect on the profitability in these smallholder production systems (Chapter 6). The positive economic values for functional traits (FER, HA and CSR) under these systems indicated that breeding for increased FER, HA and CSR would be beneficial in influencing the number of animals available for replacement and markets hence increasing profitability of production systems. The inclusion of these traits in the breeding objectives would increase the flock size and offtake, which is a tool with which to change the product output levels of the flock and replacement rates.

6.6 General conclusions

This study has generated vital information on the IC sub-sector in Rwanda, identified the traits of economic importance and developed the breeding objectives.

i. The nutritional, income and employment roles played by IC demonstrates their importance in the households' livelihood. However, their productivity is low due to the associated constraints mentioned such as disease outbreaks, predators, lack of investment capital, price fluctuation and lack of breeding stock.
ii. The trait perceived by farmers were prolificacy, mature weight, disease tolerance, egg number, and heat tolerance were the most preferred attributes across different IC genotypes.

iii. The trait preferences perceived by marketer and consumers were meat quality, egg yolk colour, plumage colour, disease tolerance, and growth rate and body weight.
iv. The results from the model show that IC can be utilised profitably under FRS. However, negative profits were observed in SIS and IS. The economic values for traits such as EN, FER, HA, CSR, GSR, BSR, LW_g, LW_{hen} and LW_{cock} in FRS were all positive. There was a decrease in EVs as level intensification increased. The economic response for reproduction traits (AFE, FER and HA) where lower compared to the economic response for production traits (EN, and LW) in all production systems.

6.7. General recommendations

i. The production constraints mentioned in this study need urgent mitigation measures to sustain utilisation of IC against the changing climatic and economic conditions. Studies on the locally used feeds and medications should be considered. There is a need to sensitize farmers to construct separate chicken houses to reduce the spread of diseases and predators. Therefore, individual, public institutions and non-governmental organisations efforts are required to develop a sustainable IC breeding objectives that account for whole production circumstances and farmer’s need.
ii. Further studies on phenotypic and genotypic characterization should be considered to evaluate the uniqueness of the present genotypes and generate more information on the breeds for the future utilization and conservation of these IC genetic resources.
iii. The Identified traits of economic importance by farmers, marketers and consumers should be considered in development of breeding objectives or other IC genetic improvement interventions. There is need to identify IC genotypes which are superior in traits in the breeding goals and develop breeding strategies to be used in dissemination of improved genes. This can be achieved if trait recording, performance testing and breeding value estimation are undertaken. With the right policies and investment, there is ample evidence that well designed and participative development program will help to overcome the constraints faced by the smallholder poultry producer with significant economic and social benefits.
iv. The results of this study showed that genetic improvement of the production (EN, LWg, LWcock and LWhen) and functional (FER, HA, CSR,) traits would give the highest economic values hence increase profitability of IC production systems.

References

Abeykoon, M. N. D. F., Weerahewa, J., and Silva, G. L. L. P. (2013). Determinants of Market Participation by Indigenous Poultry Farmers : A Case Study in Anuradhapura District in Sri Lanka. *Tropical Agricultural Research*, *24*(4), 347–361.

Åby, B. A., Aass, L., Sehested, E., and Vangen, O. (2012). A bio-economic model for calculating economic values of traits for intensive and extensive beef cattle breeds. *Livestock Science*, *143*(2–3), 259–269.

Addisu, H., Zewdu, W., and Hailu, M. (2014). Breeding practice and objective of indigenous chicken in North Wollo, Amhara regional State, Ethiopia. *International Journal of Livestock Production*, *5*(1), 15–22.

Adeleke, M. A., Peters, S. O., Ozoje, M. O., Ikeobi, C. O. N., Bamgbose, A. M., and Adebambo, O. A. (2011). Growth performance of Nigerian local chickens in crosses involving an exotic broiler breeder. *Tropical Animal Health and Production*, *43*(3), 643–650.

Akinola, L. A. F., and Essien, A. (2011). Relevance of rural poultry production in developing countries with special reference to Africa. *Worlds Poultry Science Journal*, *67*, 697–705.

Alewi, M., Melesse, A, and Teklegiorgis, Y. (2012). Crossbreeding Effect on Egg Quality Traits of Local Chickens and Their F 1 Crosses With Rhode Island Red and Fayoumi Chicken Breeds Under Farmers ' Management Conditions Crossbreeding Effect on Egg Quality Traits of Local Chickens and Their F 1 Crosses Wi. *Journal of Animal Production Advances*, *2*(8), 697–705.

Alipanah, M., Deljo, J., Rokouie, M., and Mohammadnia, R. (2013). Heritabilities and Genetic and Phenotypic Correlations of Egg Quality Traits in Khazak Layers. *Trakia Journal of Sciences*, *11*(2), 175–180.

Asmara, I. Y. (2014). Risk status of selected indigenous chicken breeds in Java , Indonesia : Challenges and opportunities for conservation Master of Biology Environment. MSc Thesis, Charles Darwin University.

Asresie, Aleme; Mitiku, E. (2015). Traditional Chicken Production System and Marketing in Ethiopia : A review. *Journal of Marketing and Consumer Research*, *8*(2422–8451), 27–35.

Bahmanimehr, A. (2012a). Inheritance of Important Economic Traits in Chickens Under Short Term Selection. *International Journal of Animal and Veterinary Advances*, *4*(2), 109–112.

Bahmanimehr, A. (2012b). Selection for economic traits in chickens breeding program according to genetic parameters and correlation between traits. *World Applied Sciences Journal*, *20*(10), 1332–1335.

Bekele, F., AdnoØy, T., GjoØen, H. M., Kathle, J., and Abebe, G. (2010). Production performance of dual purpose crosses of two indigenous with two exotic chicken breeds in sub-tropical environment. *International Journal of Poultry Science*, *9*(7), 702–710.

Bett, H. K., Bett, R. C., Peters, K. J., Kahi, A. K., and Bokelmann, W. (2011). Estimating farmers ' preferences in selection of indigenous chicken genetic resources using non-market attributes. *Animal Genetic Resources*, *49*, 51–63.

Bett, H. K., Bett, R. C., Peters, K. J., Kahi, A. K., and Bokelmann, W. (2012). Linking Utilisation and Conservation of Indigenous Chicken Genetic Resources to Value Chains Linking Utilisation and Conservation of Indigenous Chicken Genetic Resources to Value Chains. *Journal of Animal Production Advances*, *2*(1), 33–51.

Bett, R. C., Gicheha, M. G., Kosgey, I. S., Kahi, A. K., and Peters, K. J. (2012). Economic values for disease resistance traits in dairy goat production systems in Kenya. *Small Ruminant Research*, *102*(2–3), 135–141.

Bett, R. C., Kosgey, I. S., Bebe, B. O., and Kahi, A. K. (2007). Breeding goals for the Kenya Dual Purpose goat. II. Estimation of economic values for production and functional traits. *Tropical Animal Health and Production*, *39*(7), 467–475.

Bett, R. C., Kosgey, I. S., Kahi, A. K., and Peters, K. J. (2011). Definition of breeding objectives and optimum crossbreeding levels for goats in the smallholder production systems. *Small Ruminant Research*, *96*(1), 16–24.

Bwalya, R. (2014). An Analysis of the Value Chain for Indigenous Chickens in Zambia ' s Lusaka and Central Provinces. *Journal of Agricultural Studies*, *2*(2), 32–51.

Cabarles, J. C. (2013). Production potentials of native chickens (Gallus gallus domesticus L.) of Western Visayas, Philippines. *Tropical Animal Health and Production*, *45*(2), 405–410.

Chimonyo, M., and Dzama, K. (2007). Estimation of genetic parameters for growth performance and carcass traits in Mukota pigs. *Animal*, *1*(3), 317–323.

Dana, N. (2011). Breeding programs for indigenous chicken in Ethiopia: analysis of diversity in production systems and chicken populations. Wageningen University. Retrieved on 14th July, 2016 from http://library.wur.nl/WebQuery/wda/lang/1955246

Dana, N., Dessie, T., van der Waaij, L. H., and van Arendonk, J. A. M. (2010). Morphological features of indigenous chicken populations of Ethiopia. *Animal Genetic Resources*, *46*, 11–23.

Dana, N., van der 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*, *42*(7), 1519–1529.

Dana, N., vander Waaij, E. H., and van Arendonk, J. A. M. (2011). Genetic and phenotypic parameter estimates for body weights and egg production in Horro chicken of Ethiopia. *Tropical Animal Health and Production*, *43*(1), 21–28.

Dessie, T., Taye, T., Dana, N., Ayalew, W., and Hanotte, O. (2011). Current state of knowledge on phenotypic characteristics of indigenous chickens in the tropics. *World's Poultry Science Journal*, *67*(3), 507–516.

EACS. (2014). Promote agricultural investments: An opportunity to enhance food security in the East Africa countries. *EAC Geneva Forum*, 1–8.

Ebrahimzadeh-Allahabad, A., Mahmodian, Z., Pezeshkian, Z., and Mollaei, A. (2015). Estimation of genetic and phenotypic parameters of some important economic traits in Khazak native hen in Iran. *Animal Genetic Resources*, *57*, 99–103.

Essien, A., Harcourt, P., State, R., and State, C. R. (2011). Small-Scale Family Poultry Production Relevance of rural poultry production in developing countries with special reference to Africa. *World's Poultry Science Journal*, *67*, 697–705.

FAO. (2007). Genetic improvement methods to support sustainable utilization. In the state of the world's commission on genetic resources for food and agriculture food and agriculture organization of the united nations rome, 2007 animal genetic resources for food and agriculture – *in brief* (pp. 381–427). Rome, Italy. Retrieved on 3rd March, 2016 from http://www.fao.org/3/a-a1250e/a1250e18.pdf

FAO. (2009). Revue du secteur avicole Revue, Rwanda. In division de la production et de la sante animales de la fao. Retrieved on 4th March, 2016 from http://www.fao.org/avianflu/en/poultryproduction.html

FAO. (2013). *Poultry Development Review*. Retrieved on 4th March, 2016 from http://www.fao.org/avianflu/en/poultryreview.html

Fisseha, M., Abera, M., 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 Agricultural Research*, *5*(13), 1739–1748.

Fisseha, Moges, Azage, Tegegne and Tadelle, D. (2010). Indigenous chicken production and marketing systems in ethiopia : characteristics and opportunities for market-oriented development indigenous chicken production and marketing. *International Livestok Research Institute*, 24, 8-45.

Gabanakgosi, K., Moreki, J. C., Tsopito, C. M., and Nsoso, S. J. (2013). Impact of family chickens on the livelihoods of people living with HIV and AIDS in four villages of Botswana. *Journal of World's Poultry Research*, *3*, 43–53.

Gebre, K. T., Fuerst-Waltl, B., Wurzinger, M., Philipsson, J., Duguma, G., Mirkena, T., and Sölkner, J. (2012). Estimates of economic values for important traits of two indigenous Ethiopian sheep breeds. *Small Ruminant Research*, *105*(1–3), 154–160.

Gondwe, T. N., and Wollny, C. B. A. (2007). Local chicken production system in Malawi: Household flock structure, dynamics, management and health. *Tropical Animal Health and Production*, *39*(2), 103–113.

Grobbelaar, J. A. N., Sutherland, B., and Molalakgotla, N. M. (2010). Egg production potentials of certain indigenous chicken breeds from South Africa. *Animal Genetic Resources*, (46), 25–32.

Guèye, E. F. (1998). Village egg and fowl meat production in Africa. *World´s Poultry Science Journal*, *54*, 73–86.

Guèye, E. F. (2002). Employment and income generation through family poultry in low-income food-deficit countries. *World's Poultry Science Journal*, *58*(4), 541–557.

Hailu, A., Wuletaw, Z., and Mazengia, H. (2013). Breeding practice and objective of indigenous chicken in North Wollo , Amhara regional State , Ethiopia. *International Journal of Livestock Production*, *5*, 15–22.

Halima, H., Neser, F. W. C., Van Marle-Koster, E., and De Kock, A. (2007). Village-based indigenous chicken production system in north-west Ethiopia. *Tropical Animal Health and Production*, *39*(3), 189–197.

Harrison, J. L., and Alders, R. G. (2010). An assessment of chicken husbandry including Newcastle disease control in rural areas of Chibuto, Mozambique. *Tropical Animal Health and Production*, *42*(4), 729–736.

Hazel, L. N., Dickerson, G. E., and Freeman, A. E. (1994). The selection index--then, now, and for the future. *Journal of Dairy Science*, *77*(10), 3236–3251.

Henning, J., Morton, J., Pym, R., Hla, T., Sunn, K., and Meers, J. (2013). Economic analysis of interventions to improve village chicken production in Myanmar. *Preventive Veterinary Medicine*, *110*(3–4), 525–40.

Kahi, A. K., and Nitter, G. (2004). Developing breeding schemes for pasture based dairy production systems in Kenya: I. Derivation of economic values using profit functions. *Livestock Production Science*, *88*(1–2), 161–177.

Kahi, A. K., Nitter, G., and Gall, C. (2004). Developing breeding schemes for pasture based dairy production systems in Kenya. *Livestock Production Science*, *88*(1–2), 179–192.

Kaingu, F. B., Kibor, A. C., Shivairo, R., Kutima, H., Okeno, T., Waihenya, R., and Kahi, A. K. (2010). Prevalence of gastro-intestinal helminthes and coccidia in indigenous chicken from different agro-climatic zones in Kenya. *African Journal of Agricultural Research, 5*(6), 458–462.

Kingori, A. M., Wachira, A. M., and Tuitoek, J. K. (2010). Indigenous chicken production in Kenya: A review. *International Journal of Poultry Science, 9*(4), 309–316.

Kiplangat, N. (2011). Genetic Analysis of Growth Patterns of Different Ecotypes of Indigenous chicken in Kenya. MSc Thesis, Egerton University.

Kitalyi, A., and Kaudia, T. J. (2002). Commercializing rearing of village chicken in Kenya Thomas Junne Kaudia and Aichi Kitalyi. *International Network for Family Poultry Development*, (1998). Retrieved on 5th May, 2016 from http://www.infpd.net/econference/view/id/29

Kosgey, I. S., Van Arendonk, J. A. M., and Baker, R. L. (2004). Economic values for traits in breeding objectives for sheep in the tropics: Impact of tangible and intangible benefits. *Livestock Production Science*, *88*(1–2), 143–160.

Kugonza, D. R., Nabasirye, M., Hanotte, O., Mpairwe, D., and Okeyo, A. M. (2012). Pastoralists' indigenous selection criteria and other breeding practices of the long-horned Ankole cattle in Uganda. *Tropical Animal Health and Production, 44*(3), 557–565.

M.M, Iraqi, M.S, Hanafi, M.H, Khalill, A.F, El-Labban and M, E.-S. (2002). Genetic evaluation of growth traits in a crossbreeding experiment involving two local strains of chickens using multi-trait animal model. *Livestock Research for Rural Development., 1*(5).

Mack, S., Hoffmann, D., and Otte, J. (2005). The contribution of poultry to rural development.

World's Poultry Science Journal, *61*(1), 7–14.

Magothe, T. M., Muhuyi, W. B., and Kahi, A. K. (2010). Influence of major genes for crested-head, frizzle-feather and naked-neck on body weights and growth patterns of indigenous chickens reared intensively in Kenya. *Tropical Animal Health and Production*, *42*(2), 173–183.

Magothe, T. M., Okeno, T. O., Muhuyi, W. B., and Kahi, A. K. (2012a). Indigenous chicken production in Kenya : II . Prospects for research and development. *World's Poultry Science Journal*, *68*, 133–144.

Magothe, T. M., Okeno, T. O., Muhuyi, W. B., and Kahi, A. K. (2012b). Small-Scale Family Poultry Production Indigenous chicken production in Kenya : I . Current status. *World's Poultry Science Journal*, *68*, 119–132.

Mbuthia, J. M., Rewe, T. O., and Kahi, A. K. (2014). Breeding objectives for pigs in Kenya. II: economic values incorporating risks in different smallholder production systems. *Tropical Animal Health and Production*, *47*(2), 361–367.

Mbuthia, J. M., Rewe, T. O., and Kahi, A. K. (2015a). Analysis of pig breeding management and trait preferences in smallholder production systems in Kenya. *Animal Genetic Resources*, 1–7.

Mbuthia, J. M., Rewe, T. O., and Kahi, A. K. (2015b). Breeding objectives for pigs in Kenya. I: Bio-economic model development and application to smallholder production systems. *Tropical Animal Health and Production*, *47*(2), 299–309.

Mekonnen, H., Mulatu, D., Kelay, B., and Berhan, T. (2010). Assessment of the nutritional status of indigenous scavenging chickens in Ada'a district, Ethiopia. *Tropical Animal Health and Production*, *42*(1), 123–130.

Menge, E. O. (2008). Breeding Goals for Production Systems Utilising. MSc Thesis, Egerton University.

Menge, E. O., Kosgey, I. S., and Kahi, A. K. (2005). Bio-economic model to support breeding of indigenous chicken in different production systems. *International Journal of Poultry Science*, *4*(11), 827–839.

Mengesha, M., and Tsega, W. (2011). Phenotypic and genotypic characteristics of indigenous chickens in Ethiopia : A review. *Journal of Agricultural Research*, *6*(24), 5398–5404.

MINAGRI. (2012). Investment plan to strengthen meat industry in rwanda final report.

Missanjo, E., Imbayarwo-Chikosi, V., and Halimani, T. (2013). Estimation of genetic and phenotypic parameters for production traits and somatic cell count for jersey dairy cattle in zimbabwe. *ISRN Veterinary Science*, *2013*, 470585.

Moges, F., Mellesse, A., and Dessie, T. (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 Agricultural Research*, *5*(13), 1739–1748.

Msoffe, P. L. M., Bunn, D., Muhairwa, A. P., Mtambo, M. M. A., Mwamhehe, H., Msago, A., and Cardona, C. J. (2010). Implementing poultry vaccination and biosecurity at the village level in Tanzania: A social strategy to promote health in free-range poultry populations. *Tropical Animal Health and Production*, *42*(2), 253–263.

Mtileni, B. J., Muchadeyi, F. C., Maiwashe, A., Chimonyo, M., Mapiye, C., and Dzama, K. (2012). Influence of socioeconomic factors on production constraints faced by indigenous chicken producers in South Africa. *Tropical Animal Health and Production*, *45*(1), 67–74.

Musa A.A, Orunmuyi M., Akpa G.N, Olutunmogun A.K, Muhammad H., Adedibu, I. (2015). Diallel analysis for bodyweight involving three genotypes of Nigerian indigenous chickens. *South African Journal of Animal sciences*, *45*, 2221-4062.

Mwacharo, J. M., Bjørnstad, G., Han, J. L., and Hanotte, O. (2013). The History of African Village Chickens: An Archaeological and Molecular Perspective. *African Archaeological Review*, *30*(1), 97–114.

Natukunda, K., Kugonza, D. R., and Kyarisiima, C. C. (2011). Indigenous chickens of the Kamuli plains in Uganda: I. production system and flock dynamics. *Livestock Research for Rural Development*, *23*(10).

Niknafs, S., Nejati-Javaremi, A., Mehrabani-Yeganeh, H., and Fatemi, S. A. (2012). Estimation of genetic parameters for body weight and egg production traits in Mazandaran native chicken. *Tropical Animal Health and Production*, *44*(7), 1437–1443.

NISR. (2011). Integrated household living conditions survey .eicv3 thematic report Agriculture. Retrieved on 27th July, 2015 from http://microdata.statistics.gov.rw/index.php/catalog/36

NISR. (2012). Characteristics of households and housing characteristics. Retrieved on 27th July, 2015 from http://microdata.statistics.gov.rw/index.php/catalog/65

Njenga, S. K. (2005). Productivity and Socio-Cultural Aspects of Local Poultry Phenotypes in

Coastal Kenya. MSc Thesis, The Royal Veterinary and Agricultural University.

Norris, D., and Ngambi, J. W. (2006). Genetic parameter estimates for body weight in local Venda chickens. *Tropical Animal Health and Production*, *38*(7–8), 605–609.

Ochieng, J., Owuor, G., Bebe, B.O., Ochieng, D. (2011). Effect of Management Interventions on Productive Performance of Indigenous Chicken in Western Kenya. Retrieved on 12th August 2015 from http://www.lrrd.org/lrrd23/5/ochi23114.html

Okeno, T. O. (2012). Production Systems , Breeding Objectives and Selection Schemes for Indigenous Chicken Genetic Resources in Keny*a*. Humboldt University of Berlin. Retrieved on 13th August 2015 from http://pure.au.dk/portal/da/publications-research/production-systems-breeding-objectives-and-selection-schemes-for-indigenous-chicken-genetic-resources-in-kenya%28ce971fa9-6ec5-489c-b2d3-8fd961ab34fa%29.html

Okeno, T. O., Kahi, A. K., and Peters, K. J. (2011). Breed selection practices and traits of economic importance for indigenous chicken in Kenya. *Livestock Research for Rural Development*, *23*(10).

Okeno, T. O., Kahi, A. K., and Peters, K. J. (2012). Characterization of indigenous chicken production systems in Kenya. *Tropical Animal Health and Production*, *44*(3), 601–608.

Okeno, T. O., Kahi, A. K., and Peters, K. J. (2012). Genetic and economic evaluation of alternative breeding objectives for adoption in the smallholder Indigenous Chicken Improvement Program. In *Conference on International Research on Food security, Natural Resource Management and Rural Development* (Vol. 1, pp. 1–4).

Okeno, T. O., Kahi, A. K., and Peters, K. J. (2015). Evaluation of breeding objectives for purebred and crossbred selection schemes for adoption in indigenous chicken breeding programmes. *British Poultry Science, 1668, 54, 62-75.*

Okeno, T. O., Magothe, T. M., Kahi, A. K., and Peters, K. J. (2012). Application of risk-rated profit model functions in estimation of economic values for indigenous chicken breeding. *Tropical Animal Health and Production*, 44, 1279–1287.

Okeno, T. O., Magothe, T. M., Kahi, A. K., and Peters, K. J. (2012). Breeding objectives for indigenous chicken : Model development and application to different production systems. *Tropical Animal Health and Production*, 45, 193–203.

Oleforuh-okoleh, V. U. (2011). Estimation of Genetic Parameters and Selection for Egg Production Traits in a Nigerian Local Chicken Ecotype. *ARPN Journal of Agricultural and*

Biological Science, 6(12), 2006–2009.

Olwande, P. O., Ogara, W. O., Okuthe, S. O., Muchemi, G., Okoth, E., Odindo, M. O., and Adhiambo, R. F. (2010). Assessing the productivity of indigenous chickens in an extensive management system in Southern Nyanza, Kenya. *Tropical Animal Health and Production*, *42*(2), 283–288.

Osei-Amponsah, R., Kayang, B. B., and Naazie, A. (2013). Phenotypic and genetic parameters for production traits of local chickens in Ghana. *Animal Genetic Resources*, *53*, 45–50.

Padhi, M. K. (2016). Importance of Indigenous Breeds of Chicken for Rural Economy. *Scientifica*, *2016*(Article ID 2604685), 9.

Permin, A., Pedersen, G., and Riise, J. C. (1998). Poultry as a Tool for Poverty Alleviation : Opportunities and Problems Related to Poultry Production at Village Level, (Pandey 1992), 143–147.

Ponzoni, R. W., and Newman, S. (2010). Developing breeding objectives for australian beef cattle production. *Animal Production*, *49*(1), 35–47.

Pym, R. A. E. (2010). The role of the world's poultry science association (WPSA) in support of poultry production in developing countries. *Proceedings of the 21st Annual Australian Poultry Science Sumposium, Sydney, New South Wales, 1-3rd February 2010*.

Rakhmanin, V. O., and Gennari, P. (2014). FAO Statistical Yearbook 2014, 130. Retrieved ofrom http://scholar.google.com/scholar?hl=enandbtnG=Searchandq=intitle:No+Title#0

Rewe, T. O., Herold, P., Kahi, A. K., and Zárate, A. V. (2011). Trait improvement and monetary returns in alternative closed and open nucleus breeding programmes for Boran cattle reared in semi-arid tropics. *Livestock Science*, *136*(2–3), 122–135.

Rewe, T. O., Indetie, D., Ojango, J. M. K., and Kahi, A. K. (2006). Breeding objectives for the Boran breed in Kenya: Model development and application to pasture-based production systems. *Animal sciences Journal*, *77*(2), 163–177.

Scholtz, M. M., and Theunissen, A. (2010). The use of indigenous cattle in terminal cross-breeding to improve beef cattle production in Sub-Saharan Africa. *Animal Genetic Resources*, *46*, 33–39.

Tada, O., Muchenje, V., and Dzama, K. (2013). Preferential traits for breeding Nguni cattle in low-input in-situ conservation production systems. *SpringerPlus*, *2*(1), 195.

Victor A.C, Subalini E., and T. S. (2014). Socio-economic role, farming system and productive performance of local chicken in the Eastern Province of Sri Lanka. In *International*

Conference of Agriculture Sciences (Aginsight 2014) (pp. 1–5).
Wolc, A., Stricker, C., Arango, J., and Fulton, J. E. (2011). Breeding Value Prediction for Production Traits in Layers Using High-density SNP Markers. *Animal Industry Report, 657*.

APPENDICES

Annex 1. FOR THE RESEARCH ON CHARACTERISATION OF PRODUCTION SYSTEMS AND DEVELOPMENT OF BREEDING OBJECTIVES FOR INDIGENOUS CHICKEN IN RWANDA

Introduction

I am conducting a survey on "***Characterisation of production systems and development of breeding objectives for indigenous chicken in Rwanda***". The results of the study will be used to improve Indigenous chicken (IC) production and marketing systems, identify the traits of economic importance and estimated their economic values and develop breeding objectives for IC for the genetic improvement of IC in Rwanda. All information will be treated confidential. We are kindly asking for your consent to be part of the study.

Household consent obtained [Yes] [No]

A. General information

1. Socio-economic profile of household/ Farmer's characteristics

1. Respondent's name………………………………………………. Province……………………

District……………………………………………. Sector……………………...

Enumerator's name…………………………………Date of interview…………

2. Age (years) of respondent………………………………3. Gender: Male (1), Female (2)

4. Major occupation……………………........................

5. Total number of people residing in the household…………......

6. Education level of the respondent (TICK): No formal education (1), Read and write (2), primary (3), Secondary (4), post-secondary (5)

B. Farm characteristics

7. Status of the family (TICK): 1. Poor 2. Medium 3. Rich

8. Land size/ ha…………

9. Land ownership (TICK): Own (1), Lease (2), other (3) specify…………….

10. System of production (TICK): Intensive (1), semi-intensive (2), extensive/ free range/backyard (3)

11. Livestock kept

Enter numbers in the first column	Numbers	Rank
Chicken		
Cattle		
Sheep		
Goats		
Rabbit		
Others (specify)….		

12. Sources of income to finance your poultry farming?

Tick first column as appropriate, rank (1-10) level of source of income in second column_ 1 highest 10 is least		
	Tick	Rank
Crop sales		
Poultry sales		
Egg sales		
Livestock and products*		
Salary/ wages		
Bank		
Money lender		
Cooperatives		
Family of friends		
Off-farm work		
**includes the value of non-cash outputs or products e.g. manure*		

C. HUSBANDRY PRACTICES

1. Management

13. State the number or members who care for poultry. (Based on sex and age group)

Age group	Male	Female
Under 14 years		
Ages between 15-30 years		
Ages between 30-60 years		
Above 60 years		

14. For how long has poultry been kept in this household? (Years)....................

15. What chicken types do you raise? (TICK in the table below).

Chicken types	Age group of the owner		No. of poultry species		No. of chicks	Source of breeding stock	Source of replacement stock
	Male	Female	Male	Female			
Starter (0-4wks)							
Finisher (5-8wks)							
Grower							
Layer/hen							
Breeder							

16. Source of foundation for replacement stock (TICK)

Purchase (1) Inherited (2) Custody (3) Hatched (4) Government (5) NGO's (6) Other (specify (7) ………………

17. For which of the following purposes do you spend money? (TICK)

Purchase of chicken (1) Purchase of feeds (2) Purchase of veterinary products (3) Labour (4) Others (specify (5) ………………………….

18. On average, how many days per week do you and your family spend to take care of the birds?............................

19. Do you feel the need to improve your poultry production? (TICK)

1. Yes.........2. No...........

2. Feeding

20. Do you give supplementary feed to your birds? (TICK)

1. Yes..........2. No............

21. If yes, what type of feed resources do you give to your poultry?

Type of feed	Specific name of the feed
Grains	
Multi-vitamins tree	
Concentrated	
Minerals	
Insects	
Vitamins	
Others by-products specify	

22. If you give feed, how frequently do you feed your birds daily? (TICK)

Once (1) ......Twice (2) ......Thrice (3) ....More specify (4) ....

23. If you give feed, how do you feed your birds?

Put feed in containers (1) ....Throw on the ground for collective feeding (2) ....

Other specify (3) ……………………...................

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

Lack of awareness about feed (1) ....Expensive (2) ....Lack of cash/credit (3) ....

Time shortage (4) ....Feed not available (5) ....Other, specify (6) …………………

25. Do your birds scavenge? Yes (1) ....No (2) ....

26. Are your birds watered? Yes (1) ....No (2) ....

27. If yes, how many times per day?...........................

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

29. If you give water to the chickens, where do you get the water from? (TICK)

1. Borehole...........2. Well ....3. Rain .... 4. River........5. Tap water........

6. Other, specify…………………………

3. Housing

30. Where do your birds rest at night? (TICK)

1. in the kitchen ....2. A room inside the house..........3. Perch on trees........4. Hand woven basket...........5. In the house purposely made for chicken ....6. Other, specify………………………

31. If they rest in chicken house or cage, how frequently do you clean per week?................

4. Health and disease control

32. Do you experience serious disease outbreaks? (TICK)Yes (1) ....No (2) ....

33. What do you do when birds fall sick? (TICK)

1. Treat them myself.........2. Call in the veterinarian........3. Let birds to cure them self.........4. Kill them immediately..........5. Consume them immediately ....6. Sell them immediately...........7. Other, specify…………

34. Describe the common diseases you have experienced in your flock. If none tick this box ☐

Local name or Symptoms of disease	English/ scientific name of diseases	Susceptible species (age)	Favorable seasons		Severity death (age)	Are chicken treated when sick?		Treatment given *(if known)*
			Dry	Wet		Yes	No	
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								

35. Have your flock been vaccinated against prevalent disease? (TICK) 1. Yes.......2. No.........

If yes, which type of disease?..

36. Ecto-parasite and endo-parasite control for chickens

Tick the most appropriate	Done routinely		Done when need arise		comments
	Dry	Wet	Dry	Wet	
Ecto-parasites					
Endo-parasites					

D. Production and Breeding

37. Which breeds of chicken do you keep and which traits are considered important in each?

Breed	**Traits:** (1) = prolificacy, (2) =mature weight, (3) = heat tolerance, (4) = disease tolerance, (5) = mothering ability, (6) = mature weight, (7) = growth rate, (8) =feed conversion efficiency, (9) = carcass weight, (10) = egg weight									
Dwarf	1	2	3	4	5	6	7	8	9	10
Frizzed feather										
Necked neck										
Long legs										
Improved breed										
Others										

38. Quality of traits perceived by owner as of primary importance (Rank 1- 4) *(tick inside)*

Trait	Rank	**Breed 1**				**Breed 2**			
Performance		Good	Average	Poor	No Opinion	Good	Average	Poor	No Opinion
High body weights									
Big size									
High growth rate									
Reproduction									
High fertility									
High prolificacy									
Functional									
Drought tolerance									
Heat tolerance									
Temperament									
Disease tolerance									

Residual feed conversion efficiency									
Aesthetic									
Colour									
Shape									
Meat quality									

39. Purpose of keeping chickens

Reasons	tick	Rank (1-6)	Which brings in more income
1. Eggs			
2. Meat			
3. Breeding stock			
4. Financing			
5. Manure			
6. social roles (*i.e. ceremonies)*			

40. Flock structure

1. Are performance records (e.g. live weights, eggs hatched, eggs laid) available?

1. Yes......2. No........

If yes, which records do you keep…………………………………..................................?

Give the reasons for recording the traits. 1………………………, 2. ……………………., 3.…………………………, 4…………………………., 5..........................……

If records are not available, do you wish to keep or do performance recording?

1. Yes......, 2. No................

41. Flock Dynamic

	Number of entries	Number of exits
Hatched / died	Class (1) ….	
Bought /sold	Class (1) …. (2) ….. (3)	
Exchanged / lent		
Slaughtered/ consumed		
Received as gifts / stolen		
Others		

42. Do you purposely cull your birds at any time? 1. Yes ....2. No........

For what purpose, do you cull the poultry? (TICK)

1. for consumption ......2. For sale......3. Poor performance ....4. Age........5. Sickness.........

6. Body condition 7. Others, specify…………………………

43. Give reasons for your preference on the trait ranked (for males)

Rank 1………………………………………………………………………………

Rank 2……………………………………………………………………………...

Rank 3………………………………………………………………………………

Rank 4………………………………………………………………………………

Rank 5………………………………………………………………………………

44. Give reasons for your preference on the trait ranked (for females)

Rank 1………………………………………………………………………………

Rank 2………………………………………………………………………………

Rank 3………………………………………………………………………………

Rank 4………………………………………………………………………………

Rank 5………………………………………………………………………………

45. State the productivity of your birds in the following table

Chicken Types	Age at sexual maturity (month)		No. of times the hen hatches in a year	Average No of egg per clutch	Average No of days per clutch	Average No of eggs per set	No of chicks hatched per clutch	No. chicks surviving to adulthood
	Hen	Cock						
Starter								
Finisher								
Layer								

After which clutch period the hen is supposed to set eggs for hatching chicks……………

Egg characteristics (TICK)

1. Colour: 1. White…… 2. Pale white………. 3. Pale……… 4. Pale brown............

5. Dark Brown………6. Others, specify…………….

Egg weight (in grams) ………………

What kind of bedding materials are used during incubation of eggs? ....

E. Extension

46. 1) did you actively seek advices on poultry farming in the last 12 months? (1) Yes......., (2) No...........*If yes go to 2 and if no go to 5.*

2). If yes whom did you approach for the advice?

(1) sector livestock officer..........., (2) District veterinary officer................, (3) RAB extension officer.................., (4) farmer co-operative...................., (5) Neighbour farmer....................., (6) Radio/Television......................, (7) Newspapers......................., (8) church......................., (9) Agricultural exhibition....................., (10) market......................, (11) friends.................., (12) others, specify………….

3) Did you succeed in contacting the extension agent? (1) Yes.............., (2) No..............

4) If the farmer meets with extension agent note the normal meeting place?............................

Distance to meeting place (Km)…………….

Cost of transport (Rfw)………………….

5) If no why did you not seek advice? TICK reasons.

(1) Long distance......, (2) Time consuming........, (2) extension agent not available............,

(3) Too expensive........, (4) not necessary........., (5) other, specify…………

47. Constraints to poultry production

What are the main constraints to poultry production according to you?

Constraints	**Rank**	**Comments**
Diseases		
Lack of breeding stock		
Feed shortage		
Lack of capital		
Marketing/ price fluctuation		
Theft		
Lack of housing		
Lack of information		
Others (specify)		

F. SECTION FOR ECONOMIC QUESTIONNAIRE

48. Marketing

1. Distance to the market (km)…….

2. Type of market? (1) Local market......, 2) Neighbours.........., (3) Bar and restaurants/hotels.........., (4) Middle men..........., (5) Neighbouring countries..............., (6) other, specify…………….............

3. Seasonal variation in sales? (1) More in wet season..........., 2) more in dry season............, (3) intermediate...................

4. Any variation in prices? (1) Yes.........*if yes specify……………………* (2) No..........,

5. Where do you normally get information on marketing? (TICK)

(1)	Local market	(5)	RAB livestock extensionist	(9)	Agro-vet shops
(2)	Bar and restaurants	(6)	Neighbour famer	(10)	friends
(3)	Sector livestock officer	(7)	Radio/TV	(11)	Middle men
(4)	District veterinary officer	(8)	Newspapers	(12)	Other (specify) ....

Which information do you usually get?...

Costs and Expenses

Input	**details**	**unit**	**Number of units**	**Unit cost/price**	**Total cost**
Feeds/Feeding	concentrates				
	containers				
Housing					
Labour					
Health management	vaccination				
	drugs				
	Vet. Costs				
Marketing	Egg trays				
overheads					

What is the price of: a) an egg

b) Pullet

c) Cockerel

d) Mature hen or cock

e) 1kg of body carcass

f) 1kg of manure

THANK YOU FOR YOUR RESPONSES

DATA ANALYSIS OUTPUTS

Annex 2. Percentage and number[a] (in parentheses) of households perceiving different traits for each IC ecotype to be important in five districts of Rwanda

Traits/ attributes	Ecotypes																	
	Dwarf					Total (%)	Frizzled feathers					Total (%)	Naked neck					Total (%)
	Rwamagana	Rulindo	Ruhango	Muhanga	Kicukiro		Rwamagana	Rulindo	Ruhango	Muhanga	Kicukiro		Rwamagana	Rulindo	Ruhango	Muhanga	Kicukiro	
Prolificacy	18	17	19	21	20	46.1 (95)	7	6	9	10	9	19.9 (41)	5	3	1	3	2	6.8 (14)
Mature weight	2	1	3	1	4	5.3 (11)	10	9	8	7	6	19.4 (40)	4	2	2	1	-	4.4 (9)
Heat tolerance	5	6	8	4	6	14.1 (29)	2	3	4	5	1	7.3 (15)	10	10	12	8	8	23.3 (48)
Disease tolerance	7	9	4	5	7	15.5 (32)	2	5	4	2	4	8.3 (17)	7	9	10	6	7	18.9 (39)
Mothering ability	3	1	2	1	1	3.9 (8)	3	3	1	3	1	5.3 (11)	2	1	3	4	1	5.3 (11)
Growth rate	1	1	-	-	-	1.0 (2)	5	3	2	1	1	5.8 (12)	1	2	1	4	2	4.9 (10)
Feed conversion efficiency	1	-	1	-	-	1.0 (2)	1	-	2	1	-	1.9 (4)	1	2	-	2	-	2.4 (5)
Carcass weight	2	3	3	2	1	5.3 (11)	4	3	1	2	1	5.3 (11)	4	3	2	1	2	5.8 (12)
Egg yield	2	1	-	1	2	12.9 (6)	4	3	2	2	3	6.8 (14)	3	1	1	2	3	4.9 (10)

Annex 2. continued…

Traits/ attributes	Ecotypes											
	Normal feathers					Total (%)	Crosses/modern breed					Total (%)
	Rwamagana	Rulindo	Ruhango	Muhanga	Kicukiro		Rwamagana	Rulindo	Ruhango	Muhanga	Kicukiro	
Prolificacy	2	3	3	5	4	8.3 (17)	1	1	2	1	2	3.4 (7)
Mature weight	8	5	8	7	6	16.5 (34)	7	6	9	5	5	15.5 (32)
Heat tolerance	9	10	7	7	8	19.9 (41)	3	4	2	1	3	6.3 (13)
Disease tolerance	4	4	5	6	6	12.1 (25)	1	3	-	-	2	2.9 (6)
Mothering ability	3	4	2	2	5	7.8 (16)	1	1	-	3	1	2.9 (6)
Growth rate	3	3	6	4	3	9.2 (19)	3	2	2	4	6	8.3 (17)
Feed conversion efficiency	2	1	-	-	2	2.4 (5)	-	1	-	1	2	1.9 (4)
Carcass weight	1	-	-	-	1	1.0 (2)	3	3	2	6	5	9.2 (19)
Egg yield	4	3	5	3	4	9.2 (19)	12	12	13	10	11	28.2 (58)

ANNEX 3. SPEARMAN CORRELATION OF TRAITS PERCEIVED BY FARMERS, MARKETERS AND CONSUMERS TO BE PRIMARY OF ECONOMIC IMPORTANCE

Correlations_FARMERS

			BW	GR	FER	Prl	Dtol	Temp	Htol	Dtol	FCE	Pcol	ESC	EYC	MQ
Spearman's rho	BW	Correlation Coefficient	1.000	.528**	.362**	.053	.079	-.012	-.015	.032	-.012	-.131	.081	-.098	-.213**
		Sig. (2-tailed)	.	.000	.000	.447	.257	.864	.834	.647	.868	.060	.246	.163	.002
		N	206	206	206	206	206	206	206	206	206	206	206	206	206
	GR	Correlation Coefficient	.528**	1.000	.492**	.113	.108	.013	-.060	.036	-.048	-.040	.005	-.107	-.333**
		Sig. (2-tailed)	.000	.	.000	.107	.121	.852	.389	.606	.490	.570	.948	.127	.000
		N	206	206	206	206	206	206	206	206	206	206	206	206	206
	FER	Correlation Coefficient	.362**	.492**	1.000	.333**	.178*	-.021	.028	-.026	-.011	-.025	-.020	-.014	-.201**
		Sig. (2-tailed)	.000	.000	.	.000	.010	.767	.685	.714	.880	.718	.772	.845	.004
		N	206	206	206	206	206	206	206	206	206	206	206	206	206
	Prl	Correlation Coefficient	.053	.113	.333**	1.000	.505**	.049	.146*	-.088	.014	.038	.012	-.060	.093
		Sig. (2-tailed)	.447	.107	.000	.	.000	.484	.036	.208	.841	.590	.864	.394	.182
		N	206	206	206	206	206	206	206	206	206	206	206	206	206
	Dtol	Correlation Coefficient	.079	.108	.178*	.505**	1.000	-.004	.260**	-.045	-.045	-.025	.006	.045	.045
		Sig. (2-tailed)	.257	.121	.010	.000	.	.956	.000	.519	.518	.722	.934	.520	.523
		N	206	206	206	206	206	206	206	206	206	206	206	206	206

TEMP	Correlation Coefficient	-.012	.013	-.021	.049	-.004	1.000	.194**	.281**	-.038	.068	.005	.044	.090
	Sig. (2-tailed)	.864	.852	.767	.484	.956	.	.005	.000	.583	.332	.947	.534	.199
	N	206	206	206	206	206	206	206	206	206	206	206	206	206
Dtol	Correlation Coefficient	-.015	-.060	.028	.146*	.260**	.194**	1.000	.030	.062	.051	.080	-.003	.093
	Sig. (2-tailed)	.834	.389	.685	.036	.000	.005	.	.672	.373	.468	.252	.970	.183
	N	206	206	206	206	206	206	206	206	206	206	206	206	206
Dtol	Correlation Coefficient	.032	.036	-.026	-.088	-.045	.281**	.030	1.000	.120	.130	-.094	-.009	.053
	Sig. (2-tailed)	.647	.606	.714	.208	.519	.000	.672	.	.085	.063	.178	.903	.453
	N	206	206	206	206	206	206	206	206	206	206	206	206	206
FCE	Correlation Coefficient	-.012	-.048	-.011	.014	-.045	-.038	.062	.120	1.000	.214**	-.029	.106	-.030
	Sig. (2-tailed)	.868	.490	.880	.841	.518	.583	.373	.085	.	.002	.683	.129	.667
	N	206	206	206	206	206	206	206	206	206	206	206	206	206
Pcol	Correlation Coefficient	-.131	-.040	-.025	.038	-.025	.068	.051	.130	.214**	1.000	.021	.148*	-.084
	Sig. (2-tailed)	.060	.570	.718	.590	.722	.332	.468	.063	.002	.	.765	.034	.229
	N	206	206	206	206	206	206	206	206	206	206	206	206	206
EYC	Correlation Coefficient	.081	.005	-.020	.012	.006	.005	.080	-.094	-.029	.021	1.000	.195**	-.063
	Sig. (2-tailed)	.246	.948	.772	.864	.934	.947	.252	.178	.683	.765	.	.005	.369
	N	206	206	206	206	206	206	206	206	206	206	206	206	206

ESC	Correlation Coefficient	-.098	-.107	-.014	-.060	.045	.044	-.003	-.009	.106	.148*	.195**	1.000	.009
	Sig. (2-tailed)	.163	.127	.845	.394	.520	.534	.970	.903	.129	.034	.005	.	.902
	N	206	206	206	206	206	206	206	206	206	206	206	206	206
MQ	Correlation Coefficient	-.213**	-.333**	-.201**	.093	.045	.090	.093	.053	-.030	-.084	-.063	.009	1.000
	Sig. (2-tailed)	.002	.000	.004	.182	.523	.199	.183	.453	.667	.229	.369	.902	.
	N	206	206	206	206	206	206	206	206	206	206	206	206	206

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

ANNEX 3. Example of how economic values for traits of economic importance were derived.

Obs	System	Eycl	EW	Fer	HA	Ncluc	Lpc	Sperc	Nsett	Neginc	FI	LWchicks	LWp	LWcock	LWhen	CFIchicks	CFIp	CFIcklrs	CFIhen
1	Extensive	18	42	0.87	0.94	3	0.75	0.66	3	12	1	1.3	1.18	1.40	1.30	1.13	8.70	8.80	30.10
2	Semi-intensive	30	42	0.87	0.94	3	0.75	0.50	3	12	1	1.4	1.31	1.66	1.39	1.13	7.61	7.50	32.72
3	intensive	40	42	0.87	0.94	3	0.75	0.40	3	12	1	1.3	1.38	1.53	1.43	1.01	7.63	7.06	44.21

Obs	CFIcock	HW	Csr	Gsr	Bsr	EWcoc	Ewhen	AFE	PLT	Mper	Ssbrs	MEchks	Meg	MElay	Mescav	Pegg	Pmcock	Pmhen	Pmeat	PChmash	PGmash
1	42.72	30	0.55	0.66	0.70	1.87	1.60	24	730	15	21	0	0	0	2417	100	5000	3500	2500	0	0
2	40.01	30	0.70	0.75	0.75	2.00	1.75	24	730	15	21	2784	2417	2417	2417	100	5000	3500	2500	310	300
3	46.42	30	0.90	0.93	0.95	2.22	1.99	24	730	15	21	2784	2920	2500	0	100	5000	3500	2500	310	300

Obs	Plmash	Psf	t	LabW	Markc	Vetcost	Fcost	F48	F49	Reggs	Nchicks	Np	Hrt	Npsel	Npcul	Ncksel	Nckcul	Rgrowers	Nhencul
1	0	80	0.1	1000	250	0	0			1836	29.4408	5.3435	0.5	2.67175	2.67175	0.53435	4.8092	22068.68	0.350
2	300	80	0.5	1000	250	120	1000			4500	29.4408	7.7282	0.5	3.86411	3.86411	0.77282	6.9554	35433.84	0.375
3	300	0	1.0	1000	250	120	3000			7200	29.4408	12.3210	0.5	6.16049	6.16049	1.23210	11.0889	59510.31	0.475

Obs	Ncoccul	Rbredcul	R	FCchicks I	FCchicks E	FCchks	FCpullets I	FCcockerels I	FCpullets E	FCcockerels E	FCgrowers	FCcockI	FChenI
1	0.070	2614.50	26519.18	0.00	2661.45	2661.45	0.00	0.00	5578.62	5245.18	10823.80	0.00	0.00
2	0.075	2981.25	42915.09	10313.11	2661.45	12974.56	26465.26	24471.38	7057.40	6525.70	64519.73	1800.45	7362.00
3	0.095	4362.88	71073.18	9217.91	0.00	9217.91	42304.07	37587.60	0.00	0.00	79891.66	2645.94	12599.85

Obs	FCcockE	FChenE	FCbreeding	LabC	MktC	Cvetchks	Cvetgrowers	Cvetbrs	Cvet	Bcost	C	Profit
1	478.464	1685.6	2164.06	775.63	1975.23	0.00	0.00	0.00	0.00	734.26	9353.61	17165.57
2	480.120	1963.2	11605.77	3878.13	2817.37	2473.03	695.54	40.50	3209.07	1136.31	54254.3	-10339.83
3	0.000	0.0	15245.79	7756.25	4454.84	3179.61	1375.02	64.98	4619.61	1442.20	125628.27	-51555.09

Obs	ProfitEV	HA	Profit	Trait_ change	pdiff	Economic_ Value_HA
1	6229.59	0.94	6152.75	.0094	76.847	81.753
2	-59059.80	0.94	-58592.73	.0094	-467.072	-496.885
3	-54228.04	0.94	-53856.46	.0094	-371.578	-395.295