Nutritional status, nutrient requirements and gastro intestinal development of scavenging village chickens in the Vhembe District Municipality, Limpopo Province

by

Thomas Raphulu

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SUPERVISORY COMITEE

C. Jansen van Rensburg

Department of Animal and Wildlife Sciences

Faculty of Natural and Agricultural Sciences

University of Pretoria
Private bag x 20
Pretoria
0028
South Africa

DECLARATION

I declare that the thesis, which I hereby submit for the degree P.hD (Animal Science) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution

Signed …………………………………………………………..

Raphulu Thomas

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Only the Lord alone knew the plans He had for me, plans to bring me prosperity and not disaster, plans to bring about the future I had hoped for. AMEN.

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NDI A LIVHUWA

LIST OF ABBREVIATIONS

%, percentage

Al, aluminum

AME, apparent metabolisable energy

AOAC, Association of Official Analytical Chemist

AW, absolute weight

Ca, calcium

Calc, calculated

Cd, cadmium

CF, crude fibre

Co, cobalt

CP, crude protein

Cr, chromium

Cu, copper

DM, dry matter

E, East

EE, ether extract

FAO, Food and Agriculture Organization

FCR, feed conversion ratio

Fe, iron

FRIS, free range indigenous scavenging

g, gram

GIT, gastro intestinal tract

GLM, General Linear Models

HH, household

I, iodine

Kcal, kilocalories

Kg, kilogram

LS, least squares

LSD, least significance difference

AME, apparent metabolisable energy

Mg, milligram

MJ, mega joule

Mn, manganese

MTL, maximum tolerance level

NFE, nitrogen free extract

NRC, National Research Council

P, phosphorus

Pb, lead

RW, relative weight

S, South

SAS, Statistical Analysis System

SEM, standard error of the mean

TME, True metabolisable energy

V, vanadium

VIS, Venda indigenous scavenging

Zn, zinc

ABSTRACT

In rural communities of the Vhembe District, South Africa, poultry production is based on traditional scavenging systems at household level and chickens are kept for religious, cultural considerations, supply of negligible income and high quality food protein in the form of meat and eggs. Four experiments were conducted with the aim to improve FRIS chickens in rural communities. In the first experiment, 288 FRIS chickens were randomly purchased from six rural villages over three seasons (autumn, winter and spring) and sacrificed for crop content analysis. The FRIS chickens consumed grains, kitchen wastes, seeds from the environment, plant materials, worms and insects and some undistinguishable materials. The CP of the crop contents of grower and adult chickens were 123 g\kg DM and 118 g\kg DM, respectively. Concentrations of Al, Cu, Fe, Mn, Zn and Co were above the requirements of poultry and might pose risks to FRIS chickens health. For the second experiment, 117 FRIS chicks, 13 per age class (day 1, 4, 7, 10, 14, 17, 21, 24, 28) were randomly purchased from six rural villages in the Vhembe District, to evaluate development of the digestive tract and to determine the growth performance up to 20 weeks of age. The relative weight of the storage organs (crop, proventriculus and gizzard) and liver peaked at day 4 while small intestine and duodenum peaked at day 10. The FRIS chickens under village management were characterised by slow digestive tract development, growth performance and high mortalities. In the subsequent experiment, four FRIS chickens (1 young male and 1 young female of 10-16 weeks of age; a mature cockerel and a mature hen) were randomly purchased from each of six adjacent rural villages during three different seasons (autumn, winter and spring) to determine the meat yield and carcass chemical composition. The carcass weight, dressing %, mass of the breast, mass of the thighs, mass of the drumsticks, breast yield, thighs yield and drumsticks

yield of both grower and adult FRIS chickens were not influenced by season. The meat from FRIS chickens provided a constant nutrient supply throughout the year to the rural communities. Lastly, freshly laid eggs of FRIS chickens purchased in rural villages of the Vhembe District, were hatched and randomly distributed to 27 floor pens, to determine the nutrient requirements in terms of dietary protein and metabolisable energy for growth of the indigenous chickens. During the starter and grower phases, unsexed FRIS chickens would require a dietary combinations of 170 g/kg CP and 11.0 AME MJ/kg and 150 g/kg CP and 12 AME MJ/kg in their diets to optimise weight gain and FCR and 150 g/kg and 11.3 MJ/kg to optimise ash content of muscles, protein content of the breast and fat content of the leg muscle. Protein deficit of 27 g/kg for growers between feed resource base for scavenging chickens in the rural villages and the required nutrients has to be compensated with supplemental feed. It can be recommended that supplementation of 27 g/kg to grower scavenging chickens, respectively, would be enough to improve chicken production in the rural villages. Locally available feed resources high in protein like groundnuts, beans, meat and bone scraps and insects should be used as supplement to compensate nutrient deficit intake and also to reduce input costs.

THESIS OUTPUTS

Publications for thesis

1. **Chapter 3**

   Raphulu, T., Jansen van Rensburg, C & van Ryssen, J.B.J., 2015. Assessing nutrient adequacy from the crop contents of free-ranging indigenous chickens in rural villages of the Venda region of South Africa. S. Afr. J. Anim. Sci. 45, 143-152.

2. **Chapter 4**

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1. Van Ryssen, J.B.J, **Raphulu, T.** &. Jansen van Rensburg, C., 2014. Heavy metal concentration of the crop contents of free-ranging fowls kept under subsistence farming conditions in Venda. Proc. 47th SASAS Congress, 6-8th July 2014, University of Pretoria, Pretoria. **(Oral,** J.B.J. van Ryssen**)**
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CHAPTER 1

General Introduction

Indigenous chickens are the most common types of poultry raised in the rural communities of South Africa. According to the Oxford Dictionary (1990) the term indigenous referred to living naturally in an area, not introduced. These indigenous chickens are raised in a free range system wherein they scavenge for food during the day around the household. The scavenging mode makes these chickens an efficient waste disposal system converting leftovers grains, human foods and insects into valuable protein foods, such as eggs and meat (Minh, 2005). It is estimated that about 80% of the Africa`s poultry population is found in traditional production systems (Branckaet *et al.,* 2000) and the system is characterised by a low input/low production system. The birds are not regularly provided with water and other inputs such as supplementary feeds, houses, vaccination and medication. As a consequence, many birds die during pre-weaning periods due to starvation, diseases and predators. Little care is taken with regard to housing, feeding, parasites or disease control (Minga *et al*., 1989) and chickens are well adapted to the environment they scavenge in.

Nutrition is a major importance in raising chicken, as feeds accounts 60-70% of the total production cost (Smith, 1990; Gunaratne *et al*., 1993). Energy and protein are two main nutrients that can affect all production parameters in broiler chickens (Kamran *et al*., 2008). Information on nutrient requirements of the free ranging indigenous chickens is very limited, particularly protein and energy. Few studies were conducted to determine the nutrient requirements of indigenous chickens (Ndegwa *et al*., 2001; Kingori *et al*., 2003; Mbajiorgu, 2010; Alabi *et al*. 2013). It is difficult to formulate diets that require knowledge of nutrient requirements as well as of the nutrient composition of the feed ingredients, when that information is not available (Roberts & Gunaratne, 1992).

Poultry meat forms part of the staple diet of rural communities and economic source of protein (Qureshi, 1990) and proteins are good sources of essential amino acids (Wattanuchant *et al*., 2004) and also excellent sources of water soluble vitamins and minerals such as iron and zinc (van Heerden *et al*., 2002). Smith (1982) reported that white meat obtained from poultry carcass is always low in fat, with high caloric values and low levels of cholesterol, which makes it a healthy food for children and aged adults. It is known that human diets in the rural communities are deficient in protein both qualitatively and quantitatively (FAO, 1997). High production of indigenous chickens in the rural communities can result in constant supply of good quality protein to the rural community, and that will result in alleviating malnutrition. However, the meat yield and carcass composition of the indigenous chickens in the rural communities are not yet defined.

Safalaoh (1997) reported that indigenous chickens take long to reach maturity and lay fewer clutches of eggs per year compared to modern breeds. The reasons for slower growth in indigenous scavenging chickens have not yet been fully explored. Several studies were conducted in broilers (Lilja, 1983; Nitsan *et al*., 1991a,b; Katanbaf *et al*., 1998; Noy & Sklan, 1998; Ravindran *et al*., 2006) and in Yangzhou goslings (Liu *et al*., 2010). The information on post hatch development of the digestive system and growth in general of the indigenous scavenging chickens in the rural communities is very scarce. There is a need to define the development of the digestive system and the growth performance of the scavenging chickens under village management.

The justification of this study was that the nutritional status and nutrients requirements, growth and development of the digestive tract, meat yields and carcass composition of the free range indigenous scavenging (FRIS) and growth potential of the Venda indigenous chickens have never been covered. More in-depth knowledge on these important factors and traits could form the foundation of improving scavenging village chicken production, specifically in the Venda region. The improvement strategies need to be put in place without changing the low-input system of the scavenging chickens in the rural villages. The overall aim of the study was to provide guidelines for optimising feed supplementation and improve production of the scavenging indigenous chicken. An increase in the supply of high quality dietary protein to people living in the poverty-restricted rural villages of the Vhembe District, Limpopo Province, South Africa will contribute towards generating sustainable livelihoods and reducing poverty in the South African society.

The objectives of this study were:

- to assess the nutritional status of the feed consumed by scavenging chickens in different seasons, by assessing physical and chemical composition of the crop contents.
- to evaluate changes in the development of the gastro intestinal tract of free range indigenous scavenging chickens up to 28 days age under village management.
- to determine the growth performance of the free range indigenous scavenging chickens under village management up to 20 weeks of age.
- to determine the meat yield and carcass composition of the scavenging chickens.
- to determine the influence of seasons in the meat yield and carcass composition of the free range indigenous scavenging chickens
- to determine the nutrient requirements in terms of dietary protein and metabolisable energy of the indigenous chickens
- to determine the growth potential of the free range indigenous scavenging

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CHAPTER 2

Literature Review

The literature review that follows discusses the South African indigenous breeds, production systems, the role of indigenous chickens, feed resource base for scavenging chickens, crop content nutrients, post hatch development in chickens, growth performance in chickens, nutrients requirements and finally carcass yields and composition in scavenging chickens.

2.1. South African indigenous breeds

All species of poultry are used by rural small holders throughout the world. The most important species in the tropics are chickens, guinea fowl, ducks, pigeons, turkey and geese (Sonaiya & Swan, 2004). In South Africa, four phenotypically different lines exist, originating from rural areas in the northern and southern parts of South Africa, namely; Naked Neck, Ovambo, Potchestroom Koekoek and Venda (Joubert, 1996). All these South African lines have received little scientific attention and the research projects have been directed primarily towards commercial production systems (Van Marle-Koster & Nel, 2000). A summary of indigenous breeds' performance is presented in Table 2.1

2.1.1. Naked Neck

The Dutch East India Company introduced the Naked Neck chickens in the 17th century to the Cape of Good Hope in South Africa (Fourie & Grobbelaar, 2003). The Naked Neck is recognised as an indigenous breed to South Africa. The Naked Neck is an adaptable breed and can be found in all South African regions even under diverse environmental conditions. Chickens have very colourful white, red and black feather combinations (Joubert, 1996) (Figure 2.1.A). The Naked Neck chickens have 30% less feathers than the fully feathered birds and can therefore produce the same body weight with less feed.

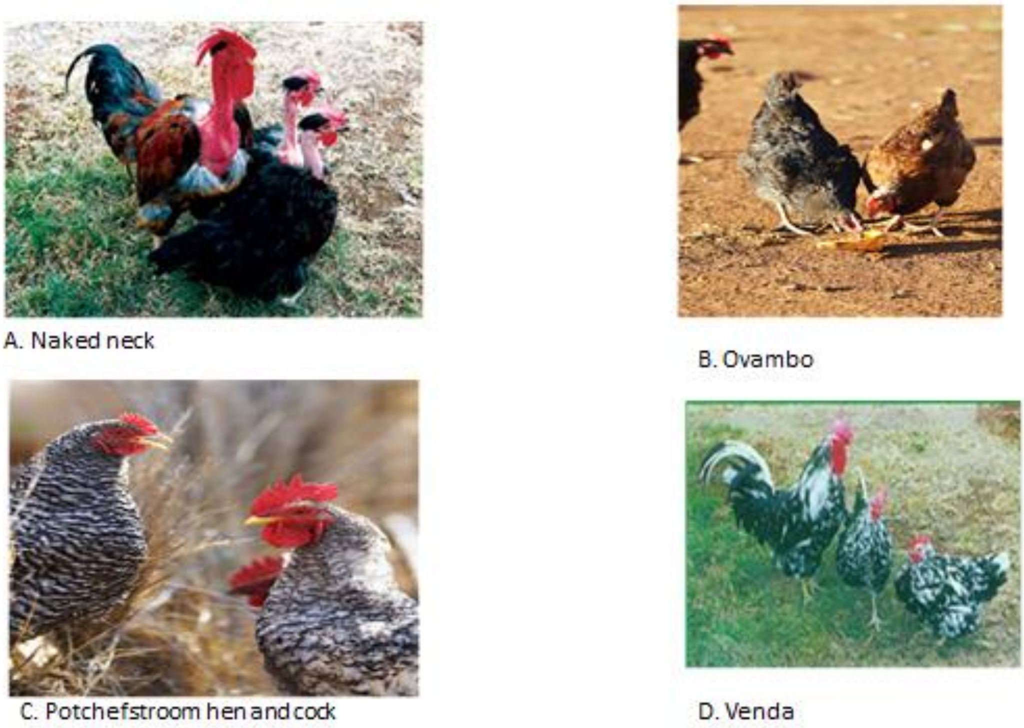

Figure 2. 1 South African indigenous breeds (Joubert, 1996)

2.1.2. Ovambo

The Ovambo is generally very aggressive and agile (Figure 2.1.B). They are predominantly dark coloured and are capable of flying and roosting in trees to avoid predators (Joubert, 1996). They are aggressive and will attack and kill mice and small rats. These chickens are characterised as layers and survive under harsh conditions.

2.1.3. Potchefstroom Koekoek

The Potchefstroom Koekoek was bred from crosses between the Black Australorp and the White Leghorn and is recognised as a locally South African developed breed (Joubert, 1996) (Figure 2.1.C). It is classified as a heavy breed while also characterised by relative high egg production and adaptability for household production.

2.1.4. Venda

In 1979 a veterinarian, dr. Naas Coetzee, noticed a distinctive new breed in Venda and named it after the region (Figure 2.1.D). The Venda chicken is a multi-coloured bird with white, black and red as the predominant colours. In contrast to other indigenous breeds, the Venda is fairly large and lays tinted eggs of a generous size. The hens are broody and are very good mothers. The current study focused on the Venda indigenous chickens found in the Vhembe District, Limpopo province. Venda region was a bantustan in northern South Africa, now part of Limpopo province, Vhembe District. It was founded as a homeland for the Venda people, speakers of the Venda language. Vhembe District is the most northern district of the Limpopo Province and it shares borders with Botswana, Zimbabwe and Mozambique.

Table 2.1 Summary of the breed performance of poultry breeds in South Africa (Joubert, 1996)

		Performance				
Breeds	Gender	Weight at 16 weeks (kg)	Weight at 20 weeks (kg)	Sexual maturity (days)	Average egg weight (g)	Egg production (eggs/year)
Naked Neck	Male	1.5	1.95	155	55.1	-
	Female	1.1	1.4			
Venda	Male	1.57	2.01	143	52.7	-
	Female	1.24	1.4			
Ovambo	Male	1.74	2.16	143	52.5	129
	Female	1.32	1.54			
Potchefstroom Koekoek	Male	1.84	2.4	130	55.7	198
	Female	1.4	1.7			

2.2. Production systems

There are four poultry production systems in developing countries, namely free range extensive, backyard extensive, semi intensive and small scale intensive system (Sonaiya & Swan, 2004). Free-range and the backyard systems are the main types of poultry husbandry systems practiced in the traditional poultry production in Africa (Guèye, 1998; Sonaiya & Swan, 2004).

2.2.1. Free range extensive system

In this system, birds are not confined and can scavenge for food over a wide area. Shelters may be provided and these may or may not be used. The most notable characteristic of this system is low feed investment costs, with chickens allowed to scavenge, finding their feed and multiplying themselves (Ly, 2000). Part of the diet consumed by poultry is obtained through scavenging on available feed resources such as food left overs or kitchen wastes, garden vegetables, crop, grains, orchards, harvest residues and environmental materials such as insects, worms, snails, slugs, forage leaves/flowers, forage seeds, sand and grits (Goromela *et al*., 2007). The birds are not regularly provided with water and other inputs such as supplementary feeds, houses, vaccination and medication. As a consequence, many birds die during pre-weaning periods due to starvation, diseases and predators. Birds roost outside usually on trees and nest in the bush. Flock sizes may vary from an average of 1-10 birds of indigenous poultry per rural household. The birds are owned mostly by women and children for home consumption, small cash income and social and cultural activities (Goromela *et al.*, 2006). The level of productivity in terms of number of eggs produced (30-50 eggs hen^{-1} $year^{-1}$) and growth rate (5-10 g day^{-1}) is very low compared to improved free-range or backyard systems.

2.2.2. Backyard system

In the backyard system, birds are semi-confined either within an enclosure made from local materials, overnight shelters or within a fenced yard (Sonaiya *et al*., 1999). Birds are housed at night and allowed to scavenge during the day. Farmers usually provide grains, grain by-products and kitchen waste in the morning and/or evening to supplement scavenging. This is the system widely followed by the farmers of Africa, Asia and Latin America. They keep about 5-50 birds, which mostly are owned by women and family members. There is a regular provision of water, grains and household waste, improved night shelters, vaccination and little medication to control diseases and parasites and to some extent exchange of cockerels between farms (Goromela *et al*., 2006).

2.2.3. Intensive system

This system is used at the household level but also by medium to large scale commercial enterprises. Birds are totally confined. Capital outlay and production costs are higher and birds are totally dependent on their keepers for all their requirements. The number of birds to be raised (flock sizes) varies depending on perception and priorities, financial capacity and facilities of the poultry producers (Singh *et al*., 2011). This system is uncommon for rearing indigenous chickens in the rural communities.

2.2.4. Semi intensive systems

These are the combination of the extensive and intensive systems where birds are confined to a certain area with access to shelter. Feed and water are available in the house to avoid wastage by rain, wind and wild animals. Birds are allowed 6-8 hours during the day for scavenging and supplementary feeding is a must which is usually carried out with home grown grains, grain by-products and kitchen wastes (Sonaiya & Swan, 2004)

2.3. The role of indigenous chickens in the rural communities

The reasons for keeping chickens in the rural communities are for religious and cultural considerations and a supply of negligible income and high quality food protein in the form of meat and eggs (Swatson *et al*., 2001). Poultry meat forms part of the staple diet of rural communities and economic source of protein (Qureshi, 1990) and proteins are good sources of essential amino acids (Wattanuchant *et al.,* 2004) and also excellent sources of water soluble vitamins and minerals such as iron and zinc (Van Heerden *et al*., 2002). It is known that human diets in the rural communities are deficient in protein both qualitatively and quantitatively (FAO, 1997). Consumption of indigenous chickens' meat supplement protein deficient diets in the rural communities. Smith (1982) reported that white meat obtained from poultry carcass is always low in fat, with high caloric values and has low levels of cholesterol, which makes it a healthy food for children and aged adults.

Scavenging chickens serve as an efficient waste disposal system converting leftovers grains and human foods and insects into valuable protein foods, such as eggs and meat (Minh, 2005). They are also useful for insects and weed control and supplying organic fertiliser for crops. Indigenous chickens contribute significantly to household food security in developing countries (Branckaert *et al*., 2000). In order to sustain reliable supply of protein and job opportunities, productivity of indigenous chickens in the rural communities need to be improved.

2.4. Feed resource base for scavenging chickens

Researchers have classified the feed resources available for scavenging poultry in South East Asia and Africa and named it the Scavengeable Feed Resource Base (SFRB) (Gunaratne *et al*., 1993; Roberts, 1999; Sonaiya, 2004). The SFRB is defined as the total amount of food products available to all scavenging animals in a given area, which is the total sum of:

- household materials i.e. food left over, kitchen wastes, gardens, crop grains, orchards and harvest residues
- environment materials such as plant leaves and seeds, worms, insects, snails, stones grits and sand

Keeping poultry under free range and backyard systems depends to a large degree on the quality of the feed available from the scavenging environment. If the available SFRB is exceeded, then the production falls (birds die and hens lay fewer eggs). However, if there is a surplus of SFRB such as good harvest then the production increases (more chicks and growers survive and more eggs are laid) (Gunaratne *et al*., 1994). If the nutrient requirement exceeds SFRB, the SRFB is inadequate to support growth of scavenging chickens. Protein deficiency in feed reduces growth rates as a consequence of depressed appetite and thus intake of nutrients (Kingori *et al.,* 2003)

Under normal conditions the proportion of the SFRB supplied by household materials as determined by crop contents of scavenging birds usually forms a greater part of total SFRB consumed per day (Roberts, 1999). It was found by Gunaratne *et al*. (1993) that in Sri Lanka 72 % of the crop contents of the 15 hens slaughtered consisted of household materials and the remaining of the crop contents came from environment.

Sonaiya (2004) observed similar results in Nigeria while the household refuse made up 64 % of the crop content.

Much of the lower performance under scavenging system has been attributed to a poor SFRB. It is essential to know what feed resources are available in the rural communities, the nutritional composition of the SFRB and also how it varies with season. It is impossible to formulate diets without accurate values for nutrient requirements as well as of the nutrient composition of feed ingredients (Roberts & Gunaratne, 1992). Availability of such information, will make it easier to develop feed supplementary strategies in the rural communities.

2.4.1. Factors affecting Scavengeable Feed Resource Base

The size of the household materials in scavenging systems always varies depending on factors such as population density (Roberts, 1992), food crops grown, their processing methods, decomposition due to climatic conditions, the number of scavenging animals which may compete with the rural poultry (Kitalyi, 1998; Sonaiya & Swan 2004), season and altitude (Goromela *et al*., 2006).

2.4.1.1. Season

Season is the most important factor affecting availability of SFRB depending on the rainfall versus dryness in a particular season of the year. It determines the rainfall pattern, planting and harvesting time. During the rainy season there is an abundant supply of insects, worms and green forage materials while in the dry or harvesting season there is high supply of cereals grains, cereal by-products and low supply of green forage and insects or worms (Goromela *et al*., 2006). Mwalusanya *et al*. (2002a) observed that in Tanzania during the wet season there were less amounts of grains and kitchen waste with high amount of insects, worms and green forages. Tadelle & Ogle (2000) reported that during short rainy season the mean percentage of plant materials were lower and highest during the long rainy season as a result of the increased availability of plant materials and in particular abundance of green shoots which are palatable to the birds.

Goromela *et al.* (2008) reported that the food leftover portion of the SFRB is more or less constant throughout the year but the portion from the environment and grain supplement varied with seasonal conditions and with activities such as cultivating, harvesting and grain processing. Harvesting time, livestock habits (Goromela *et al*., 2007) and local horticulture (Mwalusanya *et al.,* 2002a) has previously been reported to influence crop contents of the scavenging chickens. Mwalusanya *et al*. (2002a) reported that in Tanzania chickens from the cool zone and wet zone had higher content of bran in crops which was scavenged from the pigs kept in open pens.

The influence of season on the nutritional status of scavenging chickens in the rural communities of South Africa has not yet been fully explored. It is clear that differences in occurrence and availability of plant materials, worms and insects in different countries are due to differences in climatic conditions (rainfall patterns) which determines availability or growth of plant.

Most of the plant materials available for scavenging are not concentrated enough in terms of energy because they contain a lot of crude fibre (Sonaiya *et al.,* 1999). Thus a bird kept in free-range and backyard systems can certainly not find all the nutrients it needs for optimal production all the year round. The protein content of SFRB tends to fall considerably during the short rainy season and dry season, which could be due to the comparatively lower population of insects and worms (Mwalusanya *et al.*, 2002a). Insects, snails, maggot larvae and earthworms are the potential feedstuffs with reasonably high protein content (Smith, 1990; Sonaiya *et al*., 1999). Memon *et al*. (2009) observed higher consumption of chicken meat in winter due to a need for warmth and extra energy. Studies in Ethiopia have indicated that energy supply is deficient in the diet of scavenging birds for most of the periods throughout the year (Tadelle & Ogle, 1996) and the supply of energy is even more critically low during dry periods. Momoh *et al.* (2010) reported that grains have high values of total digestible nutrients (TDN) and NFE. Green forages have been reported to have higher values of CF and CP content than grains (Ali, 1995). Goromela *et al*. (2007) reported differences in slaughter and carcass weight due to season, with higher weights being recorded in dry season compared to the rainy season. Authors attributed differences to higher intakes of cereals and their by-products spilled on the ground during harvesting, threshing and winnowing activities in dry season.

Goromela *et al*. (2007) reported higher mean crop content weights in the dry season than rainy season due to large consumption of cereal grains and their by-products as well as oil seeds and their by-products, which were more abundantly available during the dry season. Goromela *et al*. (2008) reported 18.1 and 14.9 g during dry and rainy seasons in Tanzania, whereas Mwalusanya *et al*. (2002a) reported 20.5 and 14.5 g for adult and growers, respectively. Differences in chemical composition of crop contents between localities are due to differences in climate which determines the type of vegetation and availability of feeds in the environment (Ologhobo, 1990). Studies of this nature are scarce in South Africa, especially in the rural communities. Nutrient status of scavenging chickens in different seasons can assists in formulating supplementation strategy in the rural communities.

2.4.1.2. Flock biomass

Flock biomass is defined as the total live weight or the number in the flock times the mean live weight (Goromela *et al*., 2006). If village flock biomass exceeds the carrying capacity of the SFRB, then there will be strong competition pressure among chickens of different sex and ages on the available household refuse and environmental feed (Goromela *et al.,* 2006). Under this competition, chicks and growers, because they are the weakest members of the village flock, cannot compete with adult chickens for SFRB. Therefore, chicks and growers grow slowly and the weaker birds may die due to starvation when there is strong competition for SFRB (Roberts, 1999). Thus, growth and survival of chicks and growers can be greatly improved if they are given preferential access to household refuse supplements.

2.5. Determination of SFRB available for scavenging birds

Scavenging is the main feeding system for small holder poultry units in the rural communities. One of the major production constraints to the development and growth of the rural family poultry in most developing countries is the estimation of feed intake and feed utilisation under scavenging conditions. To determine feed utilisation by the village chicken, crop content analysis is used by determining the chemical composition of the crop contents (Gunarante *et al*., 1993; Mwalusanya *et al*., 2002a; Rashid *et al*., 2004). Ajuyah (1999) suggested that determination of the chemical composition of crop content only is a poor indicator of nutrient utilisation or digestibility. It was further suggested to include an indirect or pairing of techniques for the quantitative and qualitative estimation of feed utilisation and digestibility by village chicken, based on physical and chemical analysis of crop content in addition to the chemical analysis of faecal excretion and ileum digesta content.

To determine the digestibility of the diet the chemical composition of both crop contents and ilea/excretal digesta should be used. It was reported that lower weights of crop contents could be found in the chickens slaughtered in the morning compared to those slaughtered in later periods of the day (Goromela *et al*., 2008). This was also supported by Feltwell & Fox, (1978) who reported that birds filled their crops in four-hour cycles of eating, although some of the feeds may completely bypass the crop.

2.6. Post hatch development in chickens

Several studies in post hatch development were conducted in broilers (Lilja 1983, Nitsan *et al*., 1991a,b; Katanbaf *et al*., 1998; Noy & Sklan, 1998; Ravindran *et al*., 2006), in Yangzhou goslings (Liu *et al*., 2010) and ducks (King *et al*., 2000). All reported that digestive organs grow more rapidly in weight than the whole body mass. The relative weights of these organs are maximal from 6-8 days of age in turkey poults (Sell *et al*., 1991; Noy & Sklan, 1998) and 6-10 days of age in chicks (Katanbaf *et al*., 1998). Kadhim *et al*. (2010) reported that the pattern of organ weight relative to body weight for all organs of both breeds (Malaysian fowl and broilers) reached the optimum value at day 10 post hatch and after that declined sharply, except for proventriculus and gizzard of broiler breeds, which declined sharply after day one post hatch and then gradually decreased from day 20-120 post hatch. Noy *et al*. (2001) reported that the mass of the small intestine increased by nearly 600 % within the first 7 days. Dror *et al*. (1977) showed that the relative weight of the duodenum, jejunum, pancreas and liver were smaller in broiler than lighter chicks closely after hatch. The information on post hatch development of the digestive system and growth performance in general of the local chickens under village management is very scarce.

It has been reported that access to nutrients initiates growth about 24 hours after ingestion of exogenous food to which early access results in the more rapid development of the intestine during the immediate post hatch period (Sklan, 2001). This was echoed by Batal & Parsons (2002) who reported that the reduced amount or undigested feed reaching the small intestine may possibly impair or limit the need for intestinal development, while Moran (1985) reported that the presence of feed is the major stimulus for mucosal growth in chickens and mammals.

Feeding behaviour, rather than differences in individual body weight, accounted for gross anatomical differences in the intestine (Yamauchi & Zhou, 1998). Noy & Sklan (1999) reported that the early growth of the small intestine occurs both in the presence and absence of feed, although in the absence of exogenous feed both absolute and relative growth is lower. Murakami *et al*. (1992) and Uni *et al.* (1998) indicated that withholding feed and water from birds resulted in reduced growth of all segments of the intestinal tract. It is known that little care is taken with regard to housing, feeding, breeding or parasite and disease control (Minga *et al*., 1989). It may be assumed that lack of quality feeds to young chicks might be responsible for high mortalities in indigenous chickens in the rural communities and surviving chickens might not achieve full growth potential due to lack of regular availability of feeds. The relative weight of the duodenum, jejunum and pancreas but not ileum was found to be higher in light breeds than heavy breeds (Dror *et al*., 1977). Breed effect on the development of the digestive tract post-hatch, however, was not noticeable when chickens had full access to feed.

2.7. Growth performance of indigenous chickens

Growth is a compound trait influenced by genetic and management, especially nutrition and health. While it is important to know how chickens perform under scavenging conditions, knowledge of their production potential is also essential (Pedersen, 2002). Aini (1990) stated that the productivity of local birds in Malaysia is characteristically very low, but there is a much variation in production performance in different localities. Safalaoh (1997) reported that indigenous chickens take long to reach maturity and lay fewer clutches of eggs per year compared to modern breeds. There are many ecotypes, breeds and strains of indigenous poultry that are well adapted to their production environment (Tadelle & Ogle, 2001). The growth rate of indigenous chickens under 16 weeks old were 10.6, 8.5 and 8.7 g/bird/day on a supplementary feeding with 10,12 and 14% dietary protein besides their natural scavenging (Thammabood & Choprakan, 1982). Kingori *et al*. (2003) reported a growth rate of 11.5 g/bird/day in 14-21 weeks growth phase in indigenous chickens that were fed 160 g CP/kg. Many studies were conducted to determine performance of indigenous chickens, however they are not comparable as the way in which the data was gathered varied from study to study. The growth performance of local chicken is summarised in Table 2.2.

Table 2.2 Summary of the growth performance of the indigenous chickens

Adult body weight (g)			References	Country
Female	Male	Mixed		
1538	1884		Minga *et al*. (1989)	Tanzania
1827	2708		Lawrence (1998)	Tanzania
	2819		Norris *et al*. (2007)	South Africa
1348	1948		Mwalusanya *et al*. (2002b)	Tanzania
1100			Rashid *et al*. (2004)	Bangladesh
1300			Mekonnen *et al*. (2010)	Ethiopia
		1300	Demeke (2003)	Ethiopia
20 weeks				
1135	1240		Lwelamira *et al*. (2008)	Tanzania
		985	Gondwe & Wollny (2005)	Malawi
12 weeks				
631	739		Lwelamira *et al*. (2008)	Tanzania
		349-479	Tadelle *et al*. (2003)	Ethiopia
		371	Omeje & Nwosu (1984)	Nigeria
		538	Mafeni (1995)	Cameron
8 weeks				
		157	Tadelle & Ogle (2001)	Ethiopia
197	374		Lwelamira *et al*. (2008)	Tanzania

Males are consistently heavier than females (Melo *et al*., 1996; Santos *et al*., 2004; Rahayu *et al*., 2008). Shahin & Elazeem (2005) did not establish sex and genotype influences on any proportion of total meat weight found in various cuts. Young *et al*. (2001) and Rondelli *et al*. (2003) reported that female carcass had significant bigger breasts and fillet yield and lower thigh and drumstick yield compared to male carcass.

2.8. Mortality

Chick mortality is considered to be a major problem facing rural producers (Minh, 2005). Minga *et al*. (1989) reported predation and exposure to extreme weather conditions as important causes of mortality up to 50 % among the youngest group of scavenging chickens. Mapiye & Sibanda (2005) found that about over 40% of mortalities in scavenging chickens were attributed to predation, while disease accounted for 30 % of deaths over a 12-month observation period in Zimbabwe. This was supported by Afred *et al*. (2012) who found predation to be the leading cause of losses in free range chickens in Tanzania. Mwalusanya *et al*. (2002b) reported a survival rate of 59.7 % (mortality 40.3 %) up to 10 weeks of age and predation to be an important cause of losses from chicken flocks. Mortality was reported to be 47 % for young birds in traditional scavenging chickens without vaccination in Vietnam (Vang & Son, 2000). The high mortality in chicks could be attributed to poor quality feeds. Chicks only survive few days post-hatch mainly from nutrients supplied by the yolk. Sell *et al*. (1991) reported that nutrients from the yolk are depleted in broiler chicks and poults within 4-5 days. Anthony *et al*. (1989) reported that the yolk is used for maintenance, while exogenous energy is utilised for growth.

2.9. Feed supplementation

Feed supplementation is a major problem in rural poultry production and it has been calculated that scavenging birds are usually able to find feed for their maintenance, but that higher levels of production require supplementation (Dessie, 1996). Energy and protein are two main nutrients that can affect all production parameters in broiler chickens (Kamran *et al*., 2008). Minh (2005) indicated that supplementation of both energy and protein is necessary to improve the productivity of scavenging local and improved hens in Vietnam. It was reported that protein supplementation is usually more important than energy supplements in scavenging poultry production systems in Bangladesh (Rashid, 2003). Swatson *et al*. (2001) observed that mopani worms, termites and stink bugs could be used as a protein source in Venda chickens. The provision of supplementary feed and improved husbandry conditions would lead to improvement in indigenous chicken production and in turn will improve food security in the rural communities. Van Ryssen *et al*. (2014) demonstrated that wood ash is a good source of calcium and can replace feed lime in the diets of broilers. However, Van Ryssen & Ndlovu (2003) expressed caution against the use of home stead ash because of the impurities in it. Campbell and Taverner (1988) reported that in a stress-free environment, given adequate intake of essential nutrients, growth will increase until a genetically determined upper limit is reached. It is easy to supplement where it is known that there is a deficiency in certain nutrients, however under scavenging environment that information is scarce.

2.9.1. Energy requirements of scavenging chickens

Metabolisable energy (ME) is the gross energy of the feed consumed minus the gross energy contained in the faeces, urine, and gaseous products of digestion. For poultry the gaseous products are usually negligible, so ME represents the gross energy of the feed minus the gross energy of the excreta (NRC, 1994). Scavenging birds require ME in varying amounts for all metabolic purposes, including scavenging activities (Minh, 2005). The use of published equations to predict the apparent metabolisable (AME) needs of scavenging hens are inappropriate because they are based on caged, high producing birds (Farrell, 2000). Rashid *et al*. (2005) observed ME intakes from scavenging feed resource to be below the requirements of growers and layers for optimum performance and vary during the rainy season. Studies in Ethiopia have indicated that energy supply is deficient in the diet of scavenging birds for most of the periods throughout the year (Tadelle & Ogle, 1996) and the supply of energy is even more critically low during dry periods.

It is a widely accepted principle in poultry nutrition that dietary energy and the essential nutrients must be considered as an entity. A change in the energy content of the diet will normally result in an inverse change in the total amount of feed consumed and will therefore influence the intake of essential nutrients (Slagter & Waldroup, 1990). Nawaz *et al*. (2006) and Onwudike (1983) observed that feed consumption in broilers was lower with high energy diets than with low energy diets. It has been demonstrated that chickens eat to satisfy their energy requirements (Scott *et al*., 1982; Leeson *et al*.,1996) or chickens eat less of feed higher in energy content that one having a lower value (Velkamp *et al*.,2005; Nahashon *et al*.,2006). Leeson *et al*. (1991) reported that body weight and growth rate were unaffected by levels of the energy in the diet of broilers. Other authors observed that body weight was elevated with increase in CP and ME (Kamran *et al*., 2008; Hossein-Vasham *et al*., 2010). NRC (1994) recommended 12.14 MJ ME/kg DM of feed, whereas Tadelle & Ogle (2000) recommended 11.99 MJ ME/kg DM of feed determined from the chemical analysis of crop contents. Nawaz *et al*. (2006) and Holsheimer and Veerkamp (1992) reported that feed efficiency was affected significantly by energy content of the diet. Kingori *et al*. (2003) and Jackson *et al*. (1982) observed improved feed efficiency with increasing levels of dietary CP and ME.

2.9.2. Protein requirements

Dietary requirements for protein are actually requirements for the amino acids contained in the dietary protein. Amino acids obtained from dietary protein are used by poultry to fulfill a diversity of functions (NRC, 1994). For example, amino acids are primary constituents of structural and protective tissues, such as skin, feathers, bone matrix, and ligaments, as well as of the soft tissues, including organs and muscles. Also, amino acids and small peptides resulting from digestion-absorption may serve a variety of metabolic functions and as precursors of many important non-protein body constituents. Because body proteins are in a dynamic state, with synthesis and degradation occurring continuously, an adequate intake of dietary amino acids is required.

The amino acids profiles of the crop contents will give information on the intake of these nutrients, which is the basis for supplement policy of scavenging chickens (Mwalusanya *et al*., 2002a). The protein of the SFRB was reported to be below the requirements of growers and layers for optimum performance in Bangladesh (Rashid *et al*., 2005) and was critical particularly during drier months in Ethiopia (Dessie, 1996). Cereals such as sorghum and millet, commonly fed to indigenous chickens, are deficient in essential amino acids, and supplementation with protein source is required. However, the amount of protein required for supplementation to scavenging chickens in the rural communities is not yet known. Kingori *et al*. (2003) and Ndegwa *et al*. (2001) reported 160 g/kg DM and 170 g/kg as the recommended dietary protein requirement in indigenous chickens, respectively, whereas, Chemjor (1998) observed that a dietary protein of 130 g/kg during the 14-21 weeks growth phase was adequate for indigenous chickens. Schiere & De Wit (1993) suggested that feeding standards based on the data sets and concepts for one system cannot blindly be applied in another system.

It is known that if dietary protein (amino acids) is inadequate, there is a reduction or cessation of growth or productivity and a withdrawal of protein from less vital body tissues to maintain the functions of more vital tissues. Nguyen and Bunchasak (2005) and Han *et al*. (1992) reported no differences in feed intake of broilers when offered different levels of dietary CP. In support, Ndegwa *et al*. (2001) reported that indigenous growing chickens fed diets containing 170-230 g CP/kg had similar feed intake. In contrary, Buyse *et al*. (1992) and Horniakova and Abas (2009) found that broilers increased their feed intake in an attempt to meet their protein and amino acid requirements. Increased dietary protein content resulted in improved growth performance (Jackson *et al*., 1982; Nguyen and Bunchasak, 2005). Bikker *et al*. (1994) reported that feeding above the protein requirements does not result in an increase in protein deposition, but nitrogen excretion through the urine increases. There are reports that dietary protein did not affect carcass yield (Leeson *et al*., 1996; Kerr and Kidd, 1999; Rezaei *et al*., 2004; Nguyen and Bunchasak, 2005). More research is needed to determine the effect of CP supplementation on the performance of scavenging chickens in order to improve village chickens production.

Furlan *et al*. (2004) reported that carcass protein was affected by the level of protein in the diet. It was found that reduced protein level in the feeding ration does not influence the chemical composition of meat chickens (Jamroz *et al*., 1984). Higher protein diets induce higher meat protein content, while reducing the fat content of muscles (Bogosavljević-Bošković, 2010b). The decrease in dietary CP caused an increase in carcass fat and decrease in carcass protein content (Si *et al.,* 2001). It was found that decrease in total body lipid content or abdominal fat was often observed when dietary protein concentration was increased (Waldroup *et al*., 1980). Kamran *et al*. (2004) observed non-significant differences in abdominal fat of the broilers fed low protein diets supplemented with essential amino acids.

Significant interaction between dietary CP and AME showed the importance of balanced protein to energy ratio to achieve optimum performance (Wang & Liu, 2002). The physiological and practical implications of the interaction between energy intake and protein metabolism and between protein intake and energy metabolism must then be considered when dietary requirements for either nutrient is assessed (Sompie *et al*., 2015). Mbajiorgu (2010) observed that dietary CP level of 178 g/kg and energy level of 14 MJ/kg allowed for optimal nutrient utilisation for growth in Venda chickens between one and six weeks of age. Alabi *et al*. (2013) found that 12.42 MJ ME/kg DM and 12.66 MJ ME/kg DM at CP of 180 g/kg DM supported optimum growth rate. Whereas Nakkazi *et al*. (2015) reported that CP of 180 g/kg and ME of 11.7 MJ/kg were sufficient for rearing indigenous chickens during the early growth phase (0-6 weeks). Differences in responses to dietary CP and AME combinations by indigenous chickens might be attributed to different dietary protein and energy levels in the diet used during experimentation. Although information on nutrient requirements of the indigenous chickens is minimal, estimates of energy and protein requirements for broilers could not be used to estimate requirements of indigenous chickens due to the vast differences in body weight and growth rate between broilers and indigenous chickens.

2.9.3. Crude fibre requirements

Fibre is composed of cellulose, lignin and hemi-cellulose that cannot be digested efficiently by monogastric endogenous enzymes, the increase in crude fibre means the digestibility of the diet diminishes progressively (Mekonnen *et al*., 2010). It has been reported that green forages have a higher value of crude fibre than cereal grains (Ali, 1995). High crude fibre content in scavenged feed has adverse effects on feed digestibility and the nutrient intake of indigenous chickens (Longe & Ogedegbe, 1989). In most studies, the scavenging feed resource base has been found to contain high amounts of crude fibre as Mekonnen *et al*. (2010), Rashid *et al*. (2005) and (Mwalusanya *et al*. (2002a) found significantly higher crude fibre content in chickens crop contents than maximum levels (5%) recommended for commercial layer rations (Feltwell and Fox, 1978).

2.9.4. Mineral requirements in poultry

Minerals are the inorganic part of feeds or tissues. There are twenty nine elements known which are required by at least one animal species. Seven elements are macro-minerals whose requirements or concentrations in organism are expressed by over 100 mg/kg, and 22 elements are micro-minerals in traces whose requirements are below 100 mg/kg, and even can be expressed in µg/kg values (McDowel, 2003).

2.9.4.1 Macro elements

Macro elements are essential dietary nutrients for poultry and livestock. Macro mineral elements include calcium, phosphorus, sodium, chlorine, magnesium and sulphur. Calcium and phosphorus are mainly required for the growth and development of the chicken skeletal system. In Ethiopia, Tadelle &Ogle (2000) and Mekonnen *et al*. (2010) reported that calcium content varied from 0.2-0.9 % and 0.43 to 0.90% of dry matter, respectively. Rashid *et al.* (2004) observed higher calcium content (1.32%) than the latter findings. The phosphorus content reported by Mekonnen *et al*. (2010) (0.24%-0.38%) was lower than that of Tadelle & Ogle (2000) (0.6%). McDonald *et al*. (2002) recommended minimum phosphorus requirement of 0.5% and stated that the calcium level must be much higher for eggshell formation. Most scavenging feed resources of village chickens in developing countries are deficient in calcium and phosphorus, which are both required for optimum egg production and growth (Mekonnen *et al*., 2010). Supplementing calcium-phosphorus rich feeds would probably result in increased optimum growth of scavenging village chickens in developing countries.

2.9.4.2 Micro minerals requirements

Trace minerals like cobalt, copper, iron, manganese, molybdenum, selenium, zinc, iodine, chromium, fluorine, vanadium, nickel, silicon, lead, boron and arsenic are required for the normal functioning of basically all biochemical processes in the body (López-Alonso, 2012). The requirements for trace minerals are hard to establish and most estimates are based on the minimum level required to overcome deficiency symptom and not to necessarily promote productivity (Close, 2006).

Heavy metals are included in the group of trace elements that have negative influence on human health, even at very low concentrations. Heavy metals are defined as that group of elements that has specific weights higher than 5 g/cm^3 (Holleman and Wiberg, 1985). Heavy metals of great concern include cadmium, lead, arsenic, mercury, selenium and chromium. Other mineral elements of nutritional significance which also fit into this category include vanadium, manganese, iron, cobalt, copper, zinc and molybdenum (Henry & Miles, 2001). Heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as trace (<1000 mg\kg) (Kabata-Pendias and Pendias, 2001). Soil acts as a long term sink for heavy metals which can have residence times ranging from hundreds to thousands of years depending on the element and the properties of soil (Alloway, 1995). Heavy contamination of soil may pose risks and hazards to humans and ecosystem through direct ingestion or contact with contaminated soil, food chain (soil-plant- human or soil-plant-animal-human), drinking water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity and land tenure problems (Ling *et al*., 2007). The presence of toxic metals in soil can severely inhibits the biodegradation of organic contaminants (Maslin and Maier, 2000).

All mineral elements whether considered to be essential or potentially toxic, can have an adverse effect upon the humans and animals if included in the diet at excessively high concentrations (Okoye, 2011). Toxicity of aluminium (Al) has no practical relevance to animals (EU, 2003), as it does not accumulate in edible animal tissues and products. Cadmium and lead are non-essential nutrients that are of direct concern to human and livestock health and may accumulate in the body, particularly in the kidney, liver, and to a lesser extent in the muscle (Li *et al*., 2005). It has been reported that Cu, Zn, Co, Cr, Mn and Fe are toxic when taken in excess of the requirements (Monni *et al*., 2000). Cadmium and lead are cumulative poison, persistence and not metabolised in other intermediate compounds and do not easily breakdown in the environment (Mukesh *et al*., 2008). Lead levels in all seasons exceeded the permissible limit of <1 mg/kg DM in the United Kingdom (Nicholson, 1999). Dietary requirements and maximum tolerable levels (mg/kg DM) of trace mineral elements for poultry are presented in Table 2.3.

Indigenous chickens are one of the main sources of protein for rural communities, chickens scavenge around the household for food which may result in consuming heavy metals from the soil which might be detrimental to the health of the humans that consume the scavenging chickens. There is lack of data on the nutritive values (trace minerals) of feeds consumed by scavenging chickens and also possible contamination of SFRB by trace elements. Background knowledge of potentially risks of toxic elements in consumed by scavenging chickens in the rural communities is necessary for appropriate remedial options.

Table 2.3 Dietary requirements and maximum tolerable levels (mg/kg DM) of trace mineral elements for poultry (NRC, 1994, 2005**)**

Element	Broiler	Leghorn 12-18 weeks	Maximum tolerance
Aluminum	NG	NG	200
Cadmium	NG	NG	0.5
Chromium	NG	NG	1000
Cobalt	NG	NG	10
Copper	8	4	300
Iron	80	60	1000
Lead	NG	NG	<1
Manganese	60	30	2000
Vanadium	NG	NG	10
Zinc	40	35	1000

NG: not given

2.10. Feed efficiency

Feed efficiency is described as units of feed consumed per unit of weight gained and is a useful measure of performance as long as all other factors affecting both growth and feed intake are either minor or do not vary from flock to flock. Feed is used by the bird for two basic reasons, namely for growth and for maintenance. In young birds most feed is used for growth and little is used for maintenance, and so efficiency is very good. It is very difficult to determine feed efficiency in scavenging chickens. Few researchers determined feed efficiency in fed indigenous chickens. Kingori *et al*. (2003) and Chemjor, (1998) reported feed efficiency of 5.8 and 5.2, respectively.

2.11. Carcass yields and composition

The shares of major basic carcass parts (breast, drumsticks and thighs) and the presence of certain tissues in them, as well as the chemical composition of the muscular tissue are regarded as vital parameters determining broiler meat quality (Holcman *et al*., 2003). The breast, thigh and drumsticks are the components yielding most of the meat and portions that are mostly consumed (Broadbent *et al*., 1981). The literature on the major carcass parts of the native chickens in different seasons in rural communities is very limited. Many studies were conducted to determine the percentage yield of major basic carcass parts (breast, thigh and drumstick) in broilers. Bogosavljević-Bošković *et al*. (2010a) reported 31.69, 13.40 and 16.11 % of the breast, thigh and drumstick in free range broilers, respectively. Nikolova & Pavlovski (2009) observed 20.43, 9.73 and 10.63 % of the breast, thigh and drumstick in Cobb 500 broilers. Castellin *et al*. (2002) found that percentages of breast and thigh meat increased when birds had outdoor access and kept at lower stocking density in free-range production systems.

The influence of gender on carcass weight, dressing percentage, mass of the breast, thighs, drumsticks, breast yield, thighs yield drumstick yield and fat yield has been reported and males are consistently heavier than females due to large differences in body weight (Ristic, 1995; Melo *et al*., 1996; Santos *et al*., 2004; Rahayu *et al*., 2008). It was reported that female carcasses had significant bigger breasts and fillet yield and less thighs and drumstick yield compared to male carcasses (Young *et al*., 2001; Rondeli *et al*., 2003).

Dressing percentage is defined as the percentage of the live animal weight that becomes the carcass weight at slaughter and is determined by dividing the carcass weight by the live weight, then multiplying by 100. Pousga *et al*. (2005) observed 60.6 % for scavenging pullets in Bukina Faso. Tadelle (1996) and Goromela *et al*. (2008) reported dressing percentage of 63-64 % and 65.6 % in scavenging chickens, respectively. These authors suggested that differences in dressing percentage could probably be due to heavier weights of the gastro intestinal tract (GIT) and its contents. Poltowicz & Doktor (2011) reported an average dressing percentage of 68.47 % and 69.04 % for indoor and free-range broilers, respectively. According to Van Marle-Koster & Webb (2000) lower dressing percentage in native chickens than broilers is due to slower growth of the native chickens. Waldroup *et al*. (1990) observed no significant effect on ME on dressing % of male broilers.

Žlender *et al*. (1995) reported that the protein content of leg muscles and breast muscle-plus-skin ranged from 15.8 to 17.9% and 21.9 to 23.5%, respectively. Perreauit and Leeson (1992) calculated protein leg meat at 21, 35 and 56 days of age of 83.9, 83.6 and 86.3 %, respectively. Van Marle-Koster and Webb (2000) observed 31.4 % dry matter, 4.7 % ash, 49.6 % crude protein and 28.8% crude fat in the carcasses of Lebowa-Venda indigenous chickens. Demby & Cunningham (1980) reported that raw chicken meat contained 60.4 to 75.4 % water, 17.0 to 23.3 % protein, 1.0 to 17.4 % fat, and 0.7 to 3.6 % ash.

There are reports that diet is one of the factors that determines the chemical composition, particularly fat and protein, of poultry meat (Leenstra, 1986; Liu *et al*., 2006). Protein and fat of muscle tissue are important meat quality parameters and contribute substantially to the nutritional characteristics of meat. van Marle-Koster and Webb (2000); Wattanachant *et al*. (2002); Meluzzi *et al*. (2009) reported that indigenous chickens contain higher protein and less fat than broilers and emphasized the differences in chemical composition of poultry meat due to genotype.

Animal age has been known to affect chemical composition, properties and structure of muscle which contribute to the quality of the meat (Lawrie, 1991). Wattanachant and Wattanachant (2007) reported that during growth of the indigenous chickens, moisture content in muscles decreased from 77.8 to 71%, whereas protein CP and fat increased from 21.5 to 24% and 1.35 to 3.90%.

Generally, females are fatter than males (Haro, 2005; Nir *et al*., 1988). Tumova and Teimouri (2010) suggested that differences could be attributed to metabolic differences, higher competitiveness among males, different fat accumulation capacity, different nutritional requirements and higher hormonal effect in males. Fat is responsible for reproduction process, when birds matured the production of egg yolk is influenced by lipid metabolism (Rahayu *et al*., 2008). Carcasses of male chickens contain higher protein content than that of females (De Marchi *et al*., 2005; Bogosavljević-Bošković*et al*. (2010a,b). Grey *et al*. (1983) observed that gender effect at various ages was significant only for the thigh muscles which had the highest lipid concentration. Simeonovová (1999) observed that leg muscle had higher fat and lower protein than breast. The differences in breast and leg muscle could be attributed to the very structure of these organs, breast being mostly composed of white fibres, as opposed to drumstick made up of muscles that contain red fibres having different metabolic functions (Diaz, 2010).

2.12. Conclusion

Rural communities keep indigenous chickens for religious, cultural, negligible income, for consumption as they provide them with quality protein, as waste disposal, insects and weeds control and manure. Indigenous chickens contribute significantly to food security in the rural communities. Indigenous chickens rely on household materials like kitchen waste, food left overs and grains and materials from the environment like seeds, leaves as their SFRB. Much of the lower performance of the indigenous chickens in the rural communities has been attributed to poor quality SFRB. Accurate nutritive values of the SFRB and productivity (growth, carcass) of scavenging chickens in the rural communities have not yet been fully established. An improvement in the productivity of local chickens will contribute towards generating sustainable livelihoods and alleviation of poverty. To address the gaps identified, the following research studies have been conducted: assessed nutrient adequacy from the crop contents of free-ranging indigenous chickens in rural villages of the Venda region of South Africa, determined growth performance and digestive tract development of indigenous scavenging chickens under village management, carcass composition of Venda indigenous scavenging chickens under village management and the dietary protein and energy requirements of Venda indigenous chickens.

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CHAPTER 3

Assessing nutrient adequacy from the crop contents of free-ranging indigenous chickens in rural villages of the Venda region of South Africa

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Assessing nutrient adequacy from the crop contents of free-ranging indigenous chickens in rural villages of the Venda region of South Africa

T. Raphulu[1,2], C. Jansen van Rensburg[1#] & J.B.J. van Ryssen[1]
[1] Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria 0002, South Africa
[2] Department of Agriculture Limpopo, Mara Research Station, P/Bag X2467, Makhado 0920, South Africa

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Abstract

The aim of the study was to evaluate the nutritional status of scavenging chickens by assessing the composition of their crop contents. The study was conducted on 288 free-ranging indigenous chickens from six adjacent rural villages in Venda region of South Africa over three seasons (autumn, winter and spring). The chickens consumed grains, kitchen waste, seeds from the environment, plant materials, worms and insects, and some undistinguishable materials. Household waste accounted for 78.6%, 91.1% and 75.8% and materials of animal origin, including insects and worms, accounted for 7.4%, 10.4% and 16% of the crop content in autumn, winter and spring, respectively. Grains and kitchen waste consumption and macro- and micro-nutrient concentrations varied with season. The crude protein (CP) level of the crop contents of adult chickens in all seasons and the calcium and phosphorus levels in winter corresponded with the requirements of poultry for maintenance and growth, but not egg production. Supplementation of CP to young birds in all seasons and calcium and phosphorus in autumn and spring might be necessary to improve their growth. Concentrations of copper, manganese, zinc and cobalt were above the requirements of poultry, but below their maximum tolerance levels (MTL). Iron concentrations ranged from 2907 mg/kg DM to 6424 mg/kg DM, which are well above MTL, suggesting potential detrimental effects on the birds if the iron in the crop contents is bioavailable. Aluminium concentrations ranged from 2256 mg/kg DM to 4192 mg/kg DM, though aluminium is considered non-toxic. It was concluded that the birds would not suffer from micro-mineral deficiencies, and that a risk of toxicity would depend on the bioavailability of the consumed element.

Keywords: Chemical composition, heavy metals, household waste, nutritional status
[#] Corresponding author: christine.jansenvanrensburg@up.ac.za

Introduction

In rural communities of Vhembe district in Venda region of South Africa (hereafter Vhembe), poultry production is based on traditional scavenging systems at household level. A local eco-type, the Venda chicken, is the predominant type of chicken. It is adapted to the production system and is an efficient converter of scavengeable feed resources into eggs and meat (Fourie & Grobbelaar, 2003). An improvement in indigenous chicken production in the region could increase the access of rural communities to quality protein in the form of meat and eggs. This should contribute to their health and socio-economic wellbeing. However, any advances in the productivity of free-ranging indigenous chickens would require close attention to nutritional, breeding and health aspects.

In recent studies, the growth potential of the Venda chicken (Norris *et al*., 2007), and its protein (Mbajiorgu *et al*., 2011) and metabolizable energy (Alabi *et al*., 2013) requirements have been investigated under confined optimal management conditions. However, traditional scavenging systems are low input methods in which the production of the animal is usually adjusted to feed availability, implying that the producer has to rely on what is locally and seasonally obtainable (Schiere & De Wit, 1993). Rashid *et al.* (2004) pointed out that if the capacity of the scavenging feed resource base and seasonal variations are known, more efficient strategies for improved production of scavenging chickens could be developed, though it is impossible to formulate diets without reliable values for nutrient requirements, nutrient composition and daily intake of available feed (Roberts & Gunarantne, 1992).

In many studies worldwide, the physical and nutrient compositions of crop contents have been investigated to obtain information about the feed ingredients that scavenging chickens take in and the

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nutrient composition of what they consume (Sonaiya, 2004; Goromela *et al*., 2008; Mekonnen *et al*., 2010). From this information, the nutritional status of the birds can be estimated, based on the assumption that if the concentration of a nutrient in crop contents indicates a deficiency, the chickens are likely to consume insufficient quantities of that nutrient. It would therefore be possible to obtain reliable information about possible nutrient deficiencies and excesses in the diets. Based on this, recommendations could be made for supplementing nutrients to overcome apparent nutritional problems, which could be implemented if this is feasible under that subsistence husbandry condition.

From investigations of the crop contents of chickens under free-ranging management conditions in rural villages, the general conclusion is that the nutrient composition of crop contents varies widely with season, climatic conditions and locality (Rashid *et al*., 2004; Sonaiya, 2004; Goromela *et al*., 2008; Mekonnen *et al*., 2010). Results from one study cannot be extrapolated to another situation.

Few, if any, studies have been conducted in terms of evaluating the composition of the nutrient intake of free-ranging Venda-type chickens in the rural communities of Vhembe. Such information would assist in identifying possible constraints that inhibit the productivity of the chickens, and could lead to the addition of dietary supplements to meet the nutritional requirements of these chickens and improve their output. The objective of the present study was to establish the nutrient composition of the feed consumed by free-ranging indigenous chickens in Vhembe in various seasons to assess the nutrient adequacy of their diets. Special attention was given to the concentration of mineral elements in their feed, an aspect that has not been covered by similar studies in which the assessment of nutrient adequacy was based on the composition of crop contents.

Materials and Methods

The study was approved by the Animal Use and Care Committee of the University of Pretoria (EC008-08). Two hundred and eighty eight free-ranging indigenous chickens, predominantly of the Venda type (Grobbelaar *et al.* 2010), were randomly purchased from six adjacent rural villages, namely Tshifudi, Tshidzini, Tshamutshedzi, Tshivhilwi, Tshitereke and Makhuvha, which are situated at latitude S22º48 to S22º53 and longitude E30º28 to E30º42 in Thulamela Municipality, Vhembe, Limpopo, South Africa. Vhembe is regarded as a tropical (humid) region with an average annual rainfall of 820 mm. The peak rainfall occurs in January - February (an average of more than 184 mm per month), while less than 20 mm occur monthly in the winter period (Mpandeli, 2014). The birds were collected over three seasons (autumn: April; winter: July; and spring: October), 96 chickens per season. Eight young chickens (four males and four females), 10 - 16 weeks old, four mature cockerels and four mature hens that have had at least one laying cycle were purchased from each of the six villages. Summer was not included in the study as birds are kept indoors during this period to prevent them from scavenging newly planted crops. The main crops in the area are maize, groundnuts and vegetables.

The birds were caught while scavenging between 14:00 and 17:00, weighed and immediately killed humanely by cervical dislocation. They were eviscerated and the crop contents were collected. The crop contents were categorised visually into eight main components, as presented in Table 1, weighed and oven-dried for 48 h at 60 ºC. To measure the chemical composition, the dried crop contents were pooled according to class of bird (sex and age group) and season. Villages constituted the six replications. Dried crop contents were milled to pass through a 0.5 mm screen.

Dry matter (DM), ash, moisture and ether extract (EE) levels were obtained according to AOAC (2000) procedures. Crude protein (CP) was determined by the Dumas combustion procedure (Leco CNS 2000; Leco, St. Joseph, Mich, USA) and crude fibre (CF) with Fibre-Tech apparatus (Robertson & Van Soest, 1981). Calcium (Ca), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), cobalt (Co), vanadium (V), cadmium (Cd), lead (Pb), chromium (Cr) and aluminium (Al) analyses were done with a Perkin Elmer Atomic Spectrophotometer (Giron, 1973). Phosphorus (P) analysis was carried out with the Spekol 1300 apparatus using the spectrophotometric method (AOAC, 2000). Nitrogen-free extracts (NFE) was calculated by difference as: 1000 – (CP + CF + Ash + EE + moisture). An indirect method of Wiseman (1987) was used to calculate true metabolizable energy (TME) as TME (kcal/kg DM) = 3951 + 54.4 EE% - 88.7 CF% - 40.8 ash%. Apparent metabolizable energy (AME) was calculated by assuming that TME is 8% (Wiseman, 1987) higher than AME. The conversion factor of 238.85 kilocalorie (kcal) equivalents to 1 megajoule (MJ) was used to convert kcal to MJ.

Statistical significance between carcass weight and physical and chemical composition of dry crop contents between treatments (bird age group, sex and season) was determined by an analysis of variance with the GLM model of SAS Institute (SAS, 2010). The following model:

$$Y_{ijkl} = \mu + S_i + A_j + X_k + (SA)_{ij} + (SX)_{ik} + (AX)_{jk} + E_{ijkl}$$

was employed and a 5% significant level was used, where Y_{ijkl} is an observation for a given variable; µ is the general mean common to all observations; S_i is the effect due to ith season; A_j is the effect due to the jth age class of chicken; X_k is the effect due to the kth effect of the sex group of chickens; $(SA)_{ij}$ is the interaction effects between the ith season and jth age; $(SX)_{ik}$ is the effects between the jth age and kth sex class; $(AX)_{jk}$ is the effects between the jth age and kth sex group and E_{ijkl} is the random error. Differences among means were determined by the least significant difference (LSD) procedure of SAS (2010).

Results

The physical components of the crop contents of the chickens are presented in Table 1.

Table 1 Description of physical components of crop contents of free-ranging indigenous chickens in the Vhembe district in Limpopo, South Africa

Type of feed	Physical components
Grains and seeds (cultivated)	Maize, baked maize, groundnuts, beans and sorghum
Household (HH) waste: plant origin	Cooked cabbage, maize by-products, brewers' waste residues, porridge, pieces of bread, tomatoes, cooked rice, beetroot, vegetables and sweet potatoes
Household (HH) waste: animal origin	Chicken feet bones and scales and intestines, eggshells, meat and fish scraps, feathers
Seeds from the environment	Grasses and fruits
Other plant materials from the environment	Green leaves of vegetables and grasses
Worms and insects	Locusts, small ants and ant-like insects, termites, small millipedes, centipedes, ticks, earthworms, small snails, cockroaches, small crickets and flies
Undistinguishable and miscellaneous materials	Various feed particles, pieces of glass, plastic and battery paper
Grit	Small stones

The household (HH) waste of plant origin could be attributed to kitchen leftovers (porridge and its waste products), maize by-products (bran and maize meal) and brewers' waste from local traditional beer. Dry maize grains are processed at the nearest mill (threshing) or manually to produce maize meal for human consumption, while winnowing and drying are done at the homesteads. The major part of kitchen waste of plant origin was porridge, which is the staple meal of the community.

Percentages of the components of dry crop contents for each season are indicated in Table 2. The main components of the crop contents varied (P <0.05) with season, except for seeds from the environment, grit and undistinguishable materials (P >0.05). There were good supplies of grains in autumn and HH waste of plant origin in spring and winter. The proportion of grains and HH waste of both animal and plant origin to total crop contents varied with season (P <0.05). The presence of grains differed (P <0.05) between seasons, constituting 54.5%, 22.5% and 10.7% of the total in autumn, winter and spring, respectively. The decrease in grains was accompanied by an increase in HH waste of plant origin. The HH waste of plant origin differed (P <0.05) between seasons. Kitchen waste was highest in spring (46.9% HH waste of plant origin), while maize by-products and brewers' waste were highest in winter. The proportion of HH waste of animal origin was highest in winter. Season by age interaction influenced HH waste of animal origin (P <0.05). Some sunflower seeds were observed in the crop contents of birds in autumn when sunflowers were harvested. There was no effect of age, sex and age x sex interaction (P >0.05) on the proportion of the main components of the crop contents. Season x age interaction (P <0.05) was observed for HH waste of animal origin. Adult chickens consumed more HH waste of animal origin (12.28% dry crop content) in winter than growers in autumn (1.42%) and spring (3.98%). Adult chickens tended to consume more HH waste of plant and animal origin and less grains, plant materials, worms and insects than growers. However, in general, differences between age and sex groups were negligible for type of crop component.

Bodyweight of the chickens at slaughter varied with season, age and sex (P <0.05). Adult males had a slaughter weight of 2067 g and adult females a slaughter weight of 1713 g. The heaviest chickens were recorded in winter and the lightest in spring. Weight at slaughter and chemical composition of the crop contents are summarised in Tables 3 and 4.

Table 2 Effect of season on physical composition of dry crop contents of free-ranging indigenous chickens

Components (% dry crop content)	Season			SEM	*P* values
	Autumn	Winter	Spring		
Grains	54.5^a	22.5^b	10.7^c	3.09	0.0001
HH waste of plant origin	22.8^b	60.4^a	61.6^a	3.65	0.0001
Kitchen waste*	19.1^c	31.2^b	46.9^a	3.80	0.0001
Maize by-products*	3.64^b	27.0^a	12.9^b	3.41	0.0001
Brewers' waste*	0.0^b	4.38^a	1.88^{ab}	1.30	0.0611
HH waste of animal origin	1.34^b	8.29^a	3.70^b	1.39	0.0016
Seeds	0.43	1.27	0.31	0.44	0.0544
Other plant materials	10.03^a	4.17^b	6.97^{ab}	1.50	0.0240
Worms and insects	6.07^b	2.06^b	12.0^a	1.84	0.0008
Grit	0.91	0.15	1.80	0.78	0.2618
Indistinguishable materials	3.98	1.20	3.01	1.40	0.7428

^{abc} Means with different superscripts within a row differed significantly at P <0.05.
HH: household waste.
*Subdivision of the HH waste material (expressed as percentages of HH waste plant origin).
SEM: standard error of mean.

Table 3 Slaughter weight of chickens, and dry matter (DM) and chemical composition of crop contents of free-ranging indigenous chickens, as influenced by season

Parameter	Season			SEM	*P* value
	Autumn	Winter	Spring		
Slaughter weight (g)	1854^{ab}	2033^a	1783^b	75.8	0.0544
DM in crop, % body weight	0.84	0.88	0.58	0.14	0.2225
Crude protein (g/kg DM)	113	130	118	4.80	0.1283
Crude fibre (g/kg DM)	36.9	34.2	32.9	1.82	0.4291
Ether extract (g/kg DM)	40.2	50.9	40.2	6.7	0.3234
NFE (g/kg DM)	649^a	592^b	590^b	17.9	0.0580
Ash (g/kg DM)	84^b	120^{ab}	139^a	7.7	0.0002
Calc. AME (MJ/kg DM)	13.47^a	13.2^a	12.68^b	0.24	0.0549

^{abc} Means with different superscripts within a row differed significantly at P <0.05.
NFE: nitrogen free extract; Calc. AME: calculate apparent metabolizable energy.
SEM: standard error of mean.

The NFE and ash levels of the crop contents varied with season (P <0.05) (Table 3). A CP level of 130 g/kg DM (P >0.05) of the crop contents was observed in winter, followed by 118 g CP/kg DM and 113 g CP/kg DM in spring and autumn, respectively. Ash content differed with season (P <0.05), with the lowest ash content being observed in autumn and the highest in spring. Season did not influence (P >0.05) CF and EE levels, but differences (P <0.05) between seasons were recorded for AME and NDF. No significant differences were observed on the effect of age and sex on the chemical composition of the crop contents, except that age (Table 4) had a significant effect on AME content (P <0.05). There was a tendency for the growing chickens to consume feed with a higher CP content and lower CF content than adults. Crop contents from adult birds had a higher (P <0.05) ash content than growers.

Table 4 Slaughter weight of chickens, dry matter (DM) and chemical composition of crop contents of free-ranging indigenous chickens, as influenced by age

Parameter	Adult	Grower	SEM	*P* values
Slaughter weight (g)	2788[a]	992[b]	62.0	0.0001
DM in crop, % body weight	0.59[a]	0.94[b]	1.09	0.0240
Crude protein (g/kg DM)	118	123	5.4	0.4940
Crude fibre (g/kg DM)	36.5	33.0	1.85	0.186
Ether extract (g/kg DM	41.4	46.1	5.47	0.5401
NFE (g/kg DM	608	614	14.8	0.5172
Ash (g/kg DM)	123	105	7.86	0.1186
Calc. AME (MJ/kg DM	12.81[b]	13.46[a]	0.19	0.0181

[abc] Means with different superscripts within a row differed significantly at *P* <0.05.
NFE: nitrogen-free extract; Calc. AME: calculate apparent metabolizable energy.

The Ca and P levels of the crop contents varied with season. In winter the Ca and P levels were higher (*P* <0.05) than in the other seasons (Table 5). Age by sex interaction had an effect on Ca in the crop contents (*P* <0.05). The crop contents of adult females, grower males, adult males and grower females had a Ca content of 11.7 g/kg DM, 7.47 g/kg DM, 6.52 g/kg DM and 3.90 g/kg DM, respectively.

Table 5 Mineral element composition of crop contents of free-ranging indigenous chickens as influenced by season

Elements	Season			SEM	*P* value
	Autumn	Winter	Spring		
Calcium (g/kg DM)	5.35[b]	10.87[a]	5.58[b]	1.66	0.0336
Phosphorus (g/kg DM)	3.11[b]	4.82[a]	3.06[b]	0.53	0.0327
Aluminium (mg/kg DM)	2256[b]	3901[a]	4192[a]	3.12	0.0001
Cadmium (mg/kg DM)	0.22[b]	0.35[a]	0.30[ab]	0.02	0.0019
Chromium (mg/kg DM)	18.8[b]	25.4[b]	47.5[a]	4.48	0.0065
Cobalt (mg/kg DM)	8.11[b]	9.35[ab]	9.53[a]	0.42	0.0951
Copper (mg/kg DM)	11.04	12.61	12.75	0.99	0.4469
Iron (mg/kg DM)	2907[b]	4624[a]	4617[a]	495	0.0697
Lead (mg/kg DM)	7.06[a]	6.54[a]	2.67[b]	1.09	0.0141
Manganese (mg/kg DM)	64.0[b]	93.9[ab]	99.0[a]	9.69	0.0763
Vanadium (mg/kg DM)	8.36[b]	15.52[a]	18.37[a]	1.45	0.001
Zinc (mg/kg DM)	55.2	60.0	67.1	5.38	0.3459

[abc] Means with different superscripts within a row differed significantly at *P* <0.05.
SEM: standard error of mean.

The trace element concentrations of the crop content of the chickens as influenced by season are summarized in Table 5. Aluminium, Pb, Cd, V and Cr concentrations varied with season (*P* <0.05). The crop contents of Al and V in spring and winter were significantly (*P* <0.01) higher than those in autumn. Season did not influence Cu, Zn and Co concentrations, but between seasons Fe and Mn concentrations were different (*P* <0.05). Mean concentrations of the elements over all seasons were (mg/kg DM): Al, 3491; Cd, 0.29; Cr, 30.5; Co, 9.0; Cu, 12.1; Fe, 4049; Pb, 5.4; Mn, 85.6; V, 14.3 and Zn 60.8. Season x age and season x sex interactions on Pb were observed (*P* <0.05). In autumn, crop contents of growers contained more Pb (10.47 mg/kg DM) than adults (3.65 mg/kg DM), while those obtained from females contained more Pb (10.46 mg/kg DM) than from males (3.65 mg/kg DM).

Discussion

The bodyweight of the adult birds of 2788 g ± 61.4 g compares well with the mature weight of 2819 g for male Venda chickens reported by Norris *et al.* (2007) in a growth study in which they were fed optimally to measure their growth curves. The birds in the present study might not all have been pure Venda chickens, but the comparison between adult weights suggests that they received sufficient nutrients to ensure that, at least, they did not suffer permanent stunting during the growth phase. In winter the birds were heavier than in the other seasons (Table 3). This could simply be because of variations in sampling, considering the limited numbers of birds per sex and age groups in each season.

Since the feed components in the crop at a specific time of day represent only a fraction of total DM intake per day, the concentrations of nutrients in the crop content can be used only as an indication of diet composition. In general, differences in chemical composition of crop contents between localities are the result of differences in climate, which are determined by type of vegetation and availability of feed in the environment (Ologbobo, 1990). However, in a review of studies in which the composition of crop contents was evaluated, Goromela *et al.* (2006) concluded that, on average, diets consumed by scavenging chickens were deficient in energy, protein, Ca and P. In the present study the amount of HH waste accounted for the major proportion of the total crop contents, with 78.6%, 91.1% and 75.8% in autumn, winter and spring, respectively. These results are in agreement with the findings of Goromela *et al.* (2008) and Rashid *et al.* (2005). An advantage of this high proportion of household waste is that the birds' owners can add supplements through this portion of the diet if deficiencies are identified.

Alabi *et al.* (2013) reported that diets containing 12.34 MJ ME/kg DM to 12.91 MJ ME/kg DM supported optimal feed intake, growth rate and feed conversion ratios during the starter and grower phase of Venda chicks under well-controlled management conditions. In the present study the high AME of 12.7 MJ/kg DM to 13.5 MJ/kg DM of crop contents suggests that the fowls had access to diets that were high in energy. These high energy levels are supported by the relatively low CF levels of <40 g CF/kg DM in the crop contents compared with 54 g CF/kg recommended by Gunaratne *et al.* (1993) for commercial hens. High NFE levels (590 to 649 g/kg), indicating soluble carbohydrates, were recorded (Table 3) and support the high ME levels in the crop content. However, since these high ME levels reflect the quality of the diet and not how much energy the birds consumed per day, it is not possible to conclude that these free-ranging chickens consumed sufficient energy to meet their requirements, especially since a large "activity increment" would probably have to be added to their energy requirements.

According to NRC (1994), the recommended levels of CP in diets for growing chickens (not broilers) range from 150 g/kg DM to 200 g/kg DM and for mature chickens from 100 g/kg DM to 160 g/kg DM. Mbajiorgu *et al.* (2011) raised Venda chickens in closed confinement from day old to 13 weeks old on diets containing 12.2 MJ ME/kg DM and varying levels of CP. The authors concluded that an energy : protein ratio of between 60 MJ ME/kg and 63 MJ ME/kg protein optimized feed intake, growth rate and feed conversion ratio for this type of chicken. In the present study, the CP levels of the crop contents ranged between 113 g/kg DM and 130 g/kg DM, and did not differ significantly between age groups, while the energy : protein ratio for both adults and growers was 109 MJ ME/kg DM crop contents. It appears therefore as if the birds did not receive adequate levels of dietary protein to support efficient production.

Although amino acid composition is a determining factor in assessing protein sufficiency of birds (Boisen *et al.*, 2000), 7.4%, 10.4% and 16% of the HH waste were from animal origin, plus insects and worms (Table 2), assumedly with a well-balanced amino acid content (Mlcek *et al.*, 2014). This could indicate that the mature birds received sufficient protein. Mwalusanya *et al.* (2002) recorded that the crop content of chickens in Tanzania contained 104 g CP/kg DM, and Mekonnen *et al.* (2010) reported a level of 129 - 150 g CP/kg in chickens in Ethiopia. In the present study the highest CP level was observed in winter, the driest season, when there is no abundance of insects and worms. This trend could be because of a higher consumption of household materials of animal origin in winter.

A problem with interpreting nutrient concentrations in crop contents is that the quantity of feed consumed is unknown. Total intake of a nutrient may be insufficient to meet the requirements of the birds, even if the concentration in the crop contents indicates adequacy. In addition, if insufficient quantities are ingested of a nutrient with the highest priority in the body, such as energy and protein, responses to the supplementation of other nutrients might be ineffective, except for those with antioxidant properties (Cronje *et al.*, 2006).

The ash content of the crop contents of 84, 120 and 139 for autumn, winter and spring, respectively, is well above recommended concentrations given in the NRC (1994). Since the percentage of grit in the crop contents was low, ranging from 0.15% to 1.8%, it is likely that dust and soil that could not be detected in the crop contents, contributed to this high ash content.

The crop contents of adult females, grower males, adult males and grower females had Ca levels of 11.7 g/kg DM, 7.57 g/kg DM, 6.5 g/kg DM and 3.9 g/kg DM, respectively. Total P levels of the crop contents were more constant (3.1 - 4.8 g/kg) and not affected by age, sex or season. Both Ca and total P contents in the crop were relatively low compared with NRC (1994) recommendations for layer- and meat-type poultry. A Ca concentration of approximately 8.8 g/kg DM for broilers and 35 g/kg DM for leghorn layers was recommended by Rama Rao *et al.* (2003) at low dietary phosphorus levels (3.5 g and 2.8 g of non-phytin P/kg feed, respectively). It is well documented that adult laying hens tend to select feedstuffs with higher levels of Ca than other chicken classes because of their higher Ca requirements to synthesize the eggshell (Payne, 1990; Mwalusanya *et al.*, 2002). Since about 0.50 - 0.80 total P in plant feedstuffs is bound as phytate P (Steiner *et al.*, 2007), which is poorly available to monogastric animals (Pointillart *et al.*, 1984) it can be concluded that the chickens in this study had a low intake of P. Supplementation of Ca and P seems to be necessary to improve the nutritional status of the local chickens, which in turn should improve their productivity.

Identifying deficiencies in the diets of free-ranging chickens in rural communities is valuable in planning a strategy to overcome nutritional problems. However, in most cases the owners of these birds do not have the financial means to purchase supplements for them. Van Ryssen *et al.* (2014) demonstrated that wood ash is a good source of Ca, and can replace feed lime in the diets of broilers. Calcium supplementation is therefore a possibility in Vhembe, because wood ash is available from homestead fires. However, it is unlikely that pure ash would be consumed by the chickens, and would have to be mixed with other HH waste. In addition, caution when feeding homestead ash was expressed by Van Ryssen & Ndlovu (2003) because of impurities in it. A further problem is that the ideal Ca to non-phytin P ratio in the diet could be disrupted with wood ash supplementation.

The concentration of the transition elements Cu, Fe, Mn, Zn and Co did not vary significantly between seasons. The concentrations of these elements were well above the requirements of meat and leghorn chickens as reported by NRC (1994), and, except for Fe, were within the maximum tolerance level (MTL) as suggested by NRC (2005). The only concern is that high concentrations of Cu, Mn, Zn or Co might be antagonistic to elements that are low in the crop content. It is well documented that soil ingestion by animals can have a significant effect on trace mineral ingestion, implying that the elements in soil are bioavailable. Judson & McFarlane (1998) pointed out that in ruminants under normal grazing conditions ingested soil can be a source of mineral elements such as Fe, iodine (I) and Mn. Neser *et al.* (1997) found that young calves with a pre-ruminant, that is, a monogastric, digestive system consuming soil high in Mn, developed Mn toxicity owing to the accumulation of Mn in their livers. Suttle *et al.* (1984) demonstrated that when sheep consumed soils that are high in Fe, Cu absorption was suppressed. It can be assumed that these elements in soil were available to the birds to a certain extent, supplying their requirements.

Iron concentration varied from 2907 mg/kg DM to 6424 mg/kg DM in the crop contents. Suttle (2010) pointed out that all species have high tolerance towards dietary Fe. However, high dietary levels of Fe are antagonistic to the absorption of Cu (Suttle *et al.*, 1984) and Mn (Suttle, 2010). The NRC (2005) concluded that Fe toxicity ranges from 500 mg/kg to 4500 mg/kg, depending on the bioavailability of the Fe source. According to Suttle (2010), tolerable Fe concentrations have been set for poultry at 1000 mg/kg. However, the author indicated that these levels depend on total available Fe intake. Where exogenous Fe sources have low relative biological values, such as in soil, tolerable levels would be much higher. Van Ryssen *et al.* (1993) recorded excessively high concentrations of Fe (16762 mg/kg DM) in the pure excreta of "backyard" chickens. These samples were collected in the Pietermaritzburg area of South Africa, but not from rural households. They concluded that the Fe must have originated mainly through the consumption of soil.

Prinsen Geerlings *et al.* (2003) suggested that food prepared in iron cooking pots could be used to overcome Fe deficiency in developing countries. However, in southern Africa there tends to be Fe overload in human beings in rural communities (Walker & Segal, 1999). In Vhembe three-legged cast iron pots are used extensively for cooking. Residues from food prepared in these pots could well be a major source of the high Fe concentration in the crop contents in the present study.

Aluminium concentrations in the crop contents varied from 2256 mg/kg DM to 4192 mg/kg DM. Aluminium is classified as non-toxic (Reilly, 1991), though in the summary of mineral tolerances in animals (NRC, 2005) studies are quoted in which the consumption of certain Al salts elicited toxic symptoms in chickens. A cautious maximum tolerance level of 1000 mg/kg DM was suggested by the NRC (2005). Van Ryssen *et al.* (1993) recorded a concentration of 9885 mg Al/kg in pure backyard excreta, and concluded that the Al originated from geophagia. Rao & Rao (1995) pointed out that Al contaminates food prepared in aluminium cooking pots, though in Vhembe the use of Al cooking pots is rare. The most likely source of Al in the crop contents is ingested soil, and it is probably not a health concern in free-ranging chickens because of an assumed low Al bioavailability.

The highest concentration of Pb (7.06 mg/kg) was obtained in autumn, but it was lower than the MTL of 10 mg/kg DM suggested by the NRC (2005). Vanadium concentration ranged between 8.36 mg/kg DM. and 18.37 mg/kg DM. Vanadium concentrations in winter and spring were higher than the MTL of 10 mg/kg DM in diets for poultry (NRC, 2005), which might affect egg quality. However, bioavailability of the V source often determines whether the V in the crop contents in winter and spring poses a risk to or a negative effect on the chickens. The mean concentration of Cd ranged between 0.22 mg/kg DM and 0.35 mg/kg DM, and the highest concentration was obtained in winter. Cadmium levels were found to be less than the permissible limit of 0.5 mg/kg DM (NRC, 2005), which indicates that Cd toxicity is not a risk to chickens in Vhembe.

Conclusions

Crop contents of chickens reflect not only the availability of nutrients in the environment, but also the selective feeding habits of birds, which are related to their nutritional requirements. However, crop nutrient contents at any time do not indicate total daily feed intake or utilization of nutrients. Therefore, any recommendation based on crop content of nutrients should take into consideration that crop content is only a guideline, because there are many other important factors such as scavenging area, foraging habit and density of the chickens.

From the concentration of nutrients in the crop contents of free-ranging chickens in Vhembe it could be concluded that the birds probably consume insufficient quantities of protein, Ca and P. It seems feasible to supplement Ca through adding wood ash to their diets, though caution should be taken not to upset the dietary Ca : available P ratio within a class of birds. Although the results suggest that supplementation of high-quality protein and available P would be beneficial to the birds, for practical and economic reasons it might be more difficult to achieve under these subsistence husbandry conditions.

The concentration of Al, Cu, Fe, Mn, Zn and Co in the crop contents were above the requirements of poultry, though below the MTL of the element, except for very high Fe and Al concentrations. It is suggested that most of these elements were obtained through ingesting soil and dust, and consequently would probably have a relatively low bioavailability in the bird, including Al, which is considered non-toxic. However, the high Fe concentrations might have also originated from cast iron pots used for cooking food in the region, and Fe from these pots could have accumulated in the feed consumed by the birds. There seems to be no need for the supplementation of trace minerals in the diets of the birds in the region, though further studies might be necessary to establish the bioavailability of the elements in the feed consumed by the birds.

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CHAPTER 4

Growth performance and digestive tract development of indigenous scavenging chickens under village management

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Growth performance and digestive tract development of indigenous scavenging chickens under village management

Thomas Raphulu [a,b,*], Christine Jansen van Rensburg [a]

[a]Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria 0002, South Africa
[b]Limpopo Department of Agriculture and Rural Development, Mara Research Station, P/bag x 2467, Makhado, 0920, South Africa

Abstract

The study was conducted on indigenous scavenging chickens under village management firstly, to evaluate the early development of the digestive tract to 28 days of age and secondly, to determine the growth performance of these chickens up to 20 weeks of age. One hundred and seventeen chicks, 13 chicks per age class (day 1, 4, 7, 10, 14, 17, 21, 24, 28) were randomly purchased from six rural villages in the Vhembe District, Venda, South Africa. The chickens were weighed and sacrificed for measurement of the different parts of its gastrointestinal tract. The liver and pancreas were also weighed. The relative weight of the storage organs and liver peaked at day 4 while that of the small intestine and duodenum peaked at day 10. The relative lengths of the small intestine and jejunum peaked at day 7, duodenum at day 10 and ileum at day 4. Four hundred and forty four (444) chicks from 13 households were recorded at two weekly intervals starting from day old until 20 weeks of age. The mean body weight obtained for males and females were 201.7 and 171.5 g at six weeks of age and 1048.1 and 658.6 g at 20 weeks of age, respectively. The indigenous chickens under village management were characterised by slow digestive tract development, poor growth performance and high mortalities. Further research needs to be conducted to determine the effect of early feed supplementation on the development of the digestive tract and the performance of indigenous chickens under village management.

Keywords: digestive organs, relative weight, relative length, growth performance, rural communities

1 Introduction

The gastrointestinal tract (GIT) of birds undergoes rapid development during the early post-hatch period, which plays a major role in inducing early growth (Lilja, 1983; Sell *et al.*, 1991). Post-hatch development studies have been conducted in broilers (Lija, 1983, Nitsan *et al.*, 1991a,b; Katanbaf *et al.*, 1998; Noy & Sklan, 1998; Ravindran *et al.*, 2006) and in Yangzhou goslings (Liu *et al.*, 2010) and reports indicated that the digestive organs increased more rapidly in weight relative to the whole body mass. The relative weights of these organs were maximal at 6–8 days of age in turkey poults (Sell *et al.*, 1991; Noy & Sklan, 1998) and at 6–10 days of age in broiler chicks (Katanbaf *et al.*, 1998). Kadhim *et al.* (2010) reported that the rate of organ growth relative to the increase of body weight in both Malaysian fowl and broilers fed commercial diets reached a maximum at 10 days post-hatch and after that declined sharply.

Access to nutrients initiates growth about 24 hours after ingestion of exogenous feed for the first time after hatch. Early access to feed resulted in a more rapid post-hatch development of the intestine (Sklan, 2001). Feeding behaviour, rather than differences in individual body weight, accounted for gross anatomical differences in the intestine (Yamauchi & Zhou, 1998). The relative weight of the duodenum, jejunum and pancreas but not ileum was found to be higher in light breeds than heavy breeds (Dror *et al.*, 1977). Breed effect on the development of the digestive tract post-

* Corresponding author – thomas.raphulu@gmail.com
Phone (cell): 0828518296; Phone (work): 0159627200;
Fax: 0159627239

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hatch, however, was not noticeable when chickens had full access to feed.

Indigenous chickens are the most common types of poultry raised in the rural communities of Vhembe District, South Africa. Young chicks scavenge with their mothers for food around the household during the day and are provided with shelter at night. Chicks relying on scavenging for their feed might have a low and unbalanced nutrient intake, which could impair growth and the development of the digestive tract. Post-hatch development of the digestive system and growth performance of local chickens under village management have never been documented. Availability of such information might form the basis for improving the productivity of Venda Indigenous Scavenging (VIS) chickens in the rural communities. The study was carried out, firstly, to evaluate changes in the development of the digestive tract up to 28 days of age and, secondly, to determine the growth performance of VIS chickens under village management up to 20 weeks of age.

2 Materials and methods

The study was conducted at 6 adjacent villages, Tshifudi, Tshidzini, Tshamutshedzi, Tshivhilwi, Tshitereke and Makhuvha. All villages are situated between latitude 22°48′ S to 22°53′ S and longitude 30°28′ E to 30°42′ E in the Thulamela Municipality, Vhembe District in the Limpopo Province of South Africa. Vhembe District is the most northern district of the Limpopo Province and shares borders with Botswana, Zimbabwe and Mozambique. The villages are in a summer rainfall area (October to April). The wettest months and the hottest season is between October and March, when the mean maximum temperatures range from 26.7 to 29.1 °C. The coldest season is between May and August, when the minimum temperatures range from 12 to 14 °C. Winter is usually cold but rarely reach freezing point. The main crops cultivated in the area are maize, groundnuts and vegetables e.g spinach, Chinese cabbage (locally known as *mutshaina*), tomato, and beetroot.

2.1 Digestive tract measurements

A hundred and seventeen (117) VIS chicks, 13 chicks per age class (day 1, 4, 7, 10, 14, 17, 21, 24, 28) were randomly purchased from rural villages and were sacrificed in the laboratory through neck cut. The weights of the chickens were recorded before slaughtering. Directly after killing, the abdominal cavity was opened and the digestive tract from the tongue to the cloaca of each bird was removed. The GIT was separated into crop, proventriculus, gizzard, small intestine and caeca. The small intestine was divided into three regions (duodenum, jejunum and ileum) following the demarcation described by Mitchell & Smith (1990). The different segments of the digestive tract were flushed out with water and the empty weights were recorded and length measured. The accessory organs, liver and pancreas, were also removed and weighed.

2.2 Growth performance

Thirteen households participated voluntarily in the study. These households kept chickens under the traditional village management system of allowing the birds to roam free during the day to scavenge for feed, while providing shelter during the night. Shortly after hatch, 444 chicks were tagged for identification. Individual chicken live weights were recorded at two weeks intervals starting from day-old until 20 weeks of age. Prior to data collection, farmers were requested to keep the chickens in the shelter until weighing was completed in the morning.

2.3 Statistics

Data for organ weights were calculated as total or absolute weights (g) and relative weight (g/100 g body weight), absolute (cm) and relative length (cm/100 g body weight) of the digestive tract and growth performance (g). Individual birds were considered as the experimental unit. All the data (growth performance, absolute and relative weights of digestive organs, absolute and relative length of digestive organs) was subjected to General Linear Models procedure of SAS, Version 9.3 (SAS, 2016). The following model was employed on organ weights data: $Y_i = \mu + A_i + E_i$, where Y_i is an observation for a given variable; μ is the general mean common to all observations; A_i is the effect due to ith age and E_i is the random error. On body weight and growth rate data of VIS chickens, the following model was employed : $Y_j = \mu + G_j + E_j$, was employed and a 5 % significant level was used, where Y_j is an observation for a given variable; μ is the general mean common to all observations; G_j is the effect due to jth gender of chickens and E_j is the random error. Differences among means were determined by the least significant difference (LSD) procedure of SAS (2016).

3 Results

As shown in Fig. 1, an increase in mass and length of the different parts of the GIT with age was observed ($P < 0.005$). The relative weights of the storage organs (crop, proventriculus and gizzard) and liver increased rapidly and peaked at day 4 where after it remained more or less constant.

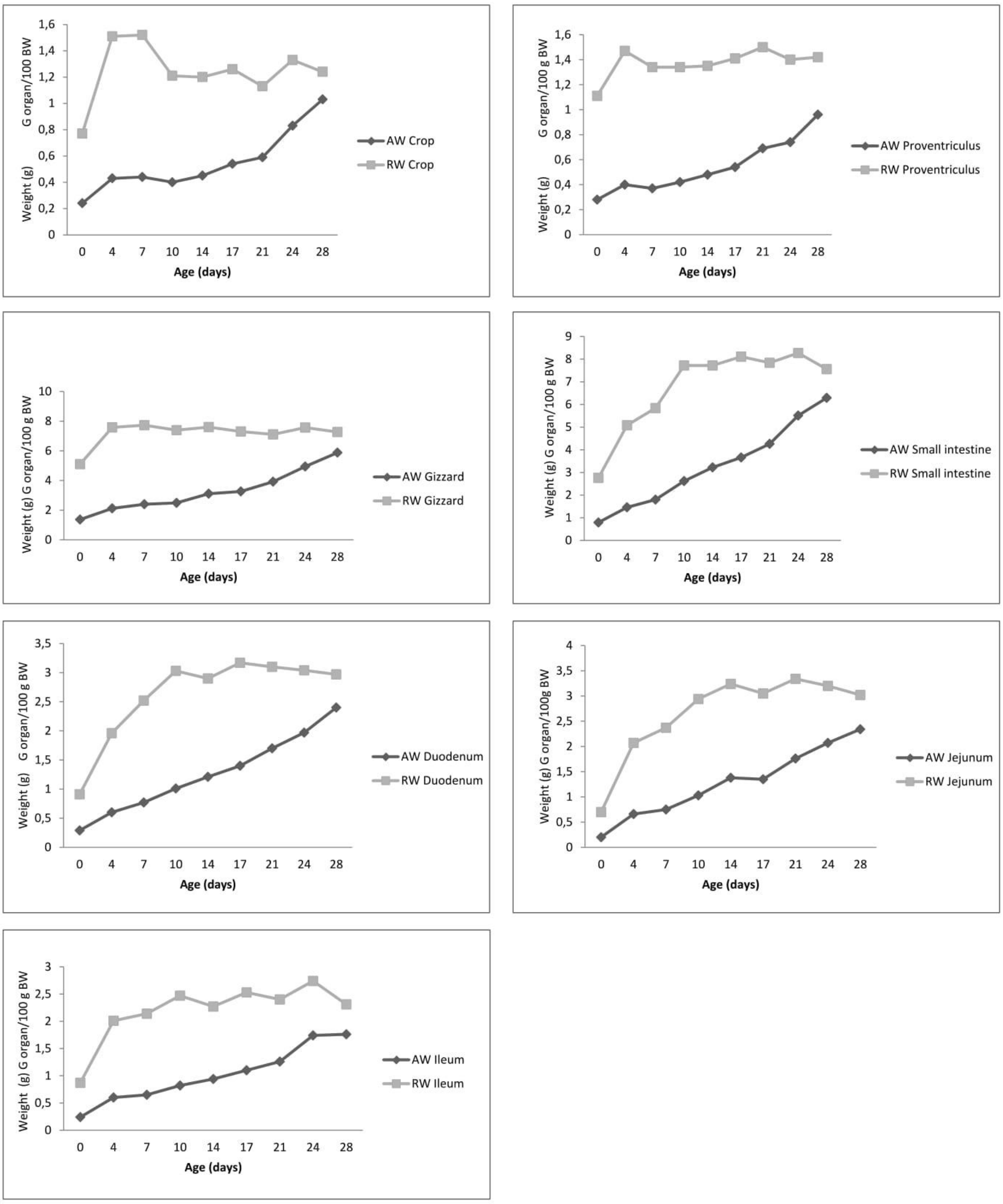

Fig. 1: *Changes in the weight of the gastro-intestinal tract segments of scavenging chicks during the first 28 days after hatch (AW – absolute weight, RW – relative weight).*

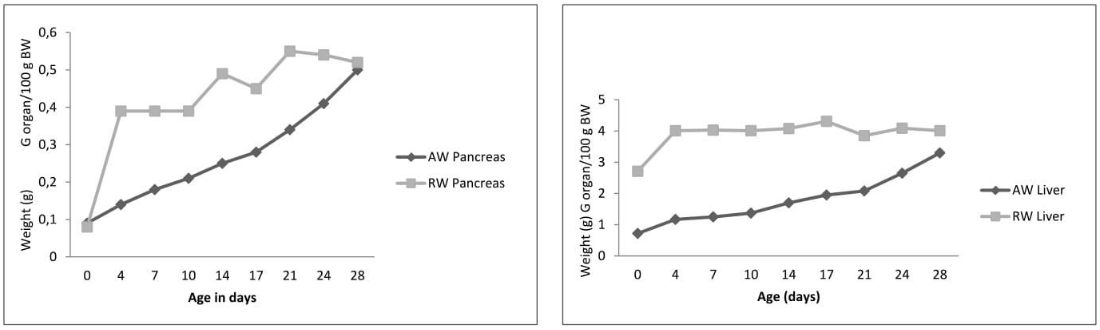

Fig. 2: *Changes in the weight of the pancreas and liver of scavenging chicks during the first 28 days after hatch (AW – absolute weight, RW – relative weight).*

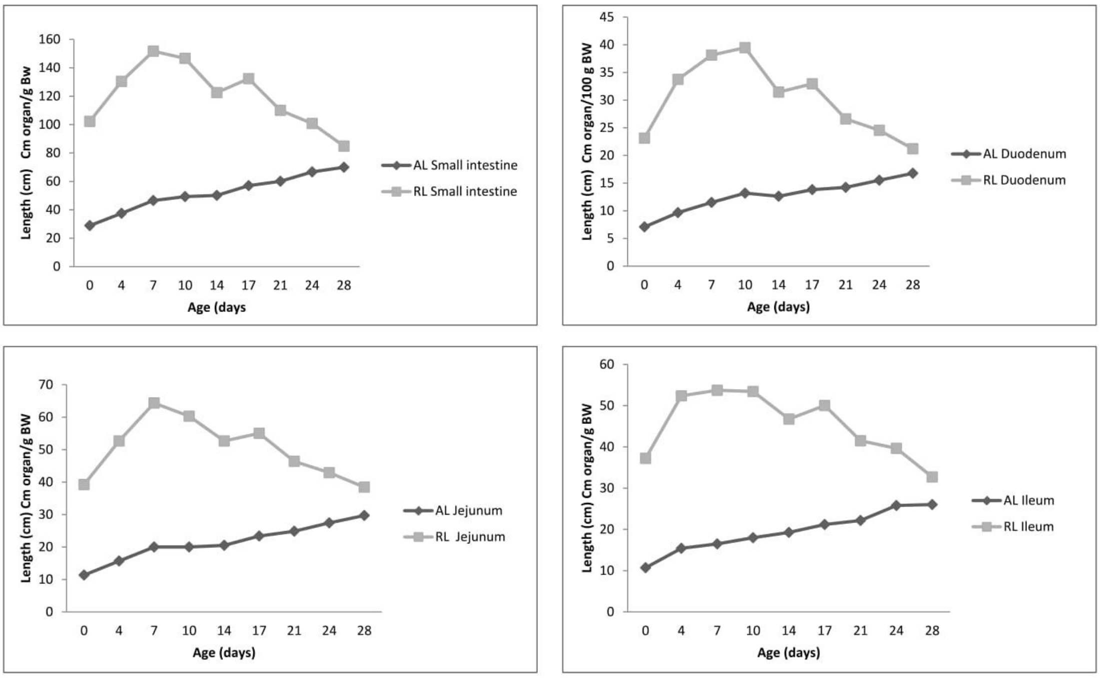

Fig. 3: *Changes in the length of small intestine segments of scavenging chicks during the first 28 days after hatch (AL – absolute length, RW – relative length).*

The relative weight of the small intestine and its separate components rapidly increased with age and peaked at about 10 days of age. The absolute mass of the small intestine increased by 127.8 % during the first 7 days. The relative weight of the pancreas increased rapidly up to day 4, and continued to increase at a slow rate up to about 21 days of age (Fig. 2). The relative length of the small intestine and jejunum peaked at day 7, duodenum at day 10 and ileum at day 4, where after it decreased (Fig. 3).

The mean body weight obtained for males and females were 201.7 and 171.5 g at six weeks of age and 1048.1 and 658.6 g at 20 weeks of age, respectively (Table 1). The cumulative mortality observed in chicks under the age of six weeks and 7–20 weeks was 57.4 and 26.3 %, respectively.

Table 1: *Performance of the VIS chickens under village management.*

Performance parameter	*Mean ± standard error*
Body weight at 6 weeks (g)	
Males	201.7 ± 5.80^{a}
Females	171.5 ± 6.74^{b}
Growth rate up to 6 weeks (g/day)	
Males	4.1 ± 0.36^{a}
Females	2.9 ± 0.42^{b}
Survival rate (%) up to six weeks	42.6
Body weight at 20 weeks (g)	
Males	1048.1 ± 28.09^{a}
Females	658.6 ± 22.94^{b}
Growth rate 7 to 20 weeks (g/day)	
Males	10.1 ± 0.51^{a}
Females	4.6 ± 0.50^{b}
Survival rate (%) 7 to 20 weeks	73.3

^{a,b} Means with different superscripts within a column and a factor differ significantly ($P < 0.05$).

4 Discussion

The development of the GIT during the post-hatch period played a major role in inducing early growth (Sell *et al.*, 1991). The digestive organs of the scavenging, indigenous chicks studied in this trial, followed a similar early growth pattern observed in other chickens (Dror *et al.*,1977; Lilja, 1983), turkeys (Sell *et al.*,1991) and ducks (King *et al.*, 2000). It has been suggested that the accelerated development of the digestive organs immediately after hatching is a prerequisite for sustained post-hatch growth in fast growing poultry (Katanbaf *et al.*, 1998).

According to Nitsan *et al.* (1991b), the pancreas of chickens first experiences a rapid growth phase from hatch to day 3 and then a slower growth phase from day 4–8. In this study, however, a rapid increase in the relative weight of the pancreas was noted until 4 days of age and a slower relative growth up to 21 days of age. The different segments of the small intestine developed at slightly different rates in relation to the increase in body weight. The observed results are in accordance with findings of Uni *et al.* (1999) who reported that the temporal increases in intestinal weight and length are not identical for different segments, with the duodenum developing at a faster rate than both the jejunum and ileum.

The absolute growth rate of the small intestine of the chicks in this study was much lower than reported by Noy *et al.* (2001), who found an increase in the mass of the small intestine by nearly 600 % within the first 7 days. Kadhim *et al.* (2010) found similar patterns of organ weights relative to body weights in both indigenous breeds (Malaysian local chickens) and broilers fed commercial diets, ruling out the possibility that genotype affects GIT development. The slower development of the small intestine in the current study could rather be attributed to the poor availability of quality feeds to the scavenging chickens in the rural communities. Growth is initiated about 24 hours after first ingestion of exogenous food and it is suggested that early access to nutrients results in the more rapid development of the intestine during the immediate post-hatch period (Sklan, 2001). The withholding of feed and water from birds resulted in reduced growth of all segments of the intestinal tract (Murakami *et al.*, 1992; Uni *et al.*, 1998). It is possible that the development of the digestive tract of the scavenging chickens in this study might have been impaired by a lack of feed and irregular access to water which inhibited the growth of the birds in general. It is known that little care is taken with regard to housing, feeding, breeding or parasite and disease control (Minga *et al.*, 1989). As a result, chicks might survive for a few days post-hatch mainly on nutrients supplied by the yolk. Sell *et al.* (1991) reported that nutrients from the yolk are depleted in broiler chicks and poults within 4–5 days. It has been reported that the yolk is used for maintenance, while exogenous energy is utilised for growth (Anthony *et al.*, 1989). The slower gut development and growth rate and high mortality of the chicks in this study could have been caused by a limited feed intake. There is no planned feeding for scavenging chickens in the rural areas. Chickens are left to scavenge around the homesteads during daytime feeding on household leftovers, waste products and environmental materials such as insects, worms, seeds and green forages (Goromela *et al.*, 2006; Raphulu *et al.*, 2015). Supplementation is rarely done since farmers assume that the chickens scavenging from the natural resource feed base get adequate nutrients to meet their maintenance, reproductive and productive needs (Nzioka *et al.*, 2017). The growth of an animal depends in part on its capacity to digest and assimilate ingested macromolecules (Liu *et al.*, 2010). Results from this study indicated that supplementary feed to chicks in the rural communities might be necessary during the first few weeks to promote the development of the GIT until chicks can scavenge successfully.

The peak of the relative length of the small intestine observed in this study was 2–3 days later than the 5–7 days post-hatch reported by Noy & Sklan (1998). However, our results are in accordance with that of Sell *et al.* (1991), that the process of rapid relative growth was maximal at 6–8 days in the poult and 6–10 days in the chick. Kadhim *et al.* (2010) found that the absolute length of the intestinal segments of the Malaysian local chicken fed a commercial diet were shorter by approximately one fold than those of broilers. Nir *et al.* (1993) suggested that the smaller breeds have relatively lighter and shorter intestines than broilers.

There is a lack of published data on the productivity of local chickens under village management under South African conditions. However, a few studies have been conducted in other parts of Africa. Under village management conditions in Tanzania, Lwelamira *et al.* (2008) reported mean body weights of 1135 and 1240 g for 20 weeks old female and male chickens, respectively. Mwalusanya *et al.* (2002) reported growth rates of chickens up to 10 weeks to be 5.4 and 4.6 g/day for males and females, respectively, whereas chickens aged 10–14 weeks old showed rates of 10.2 and 8.4 g/day for males and females. The obtained body weight gain of the chickens at eight weeks in this study were higher than those described by Mafeni (1995) for Cameroon, Omeje & Nwosu (1984) for Nigeria, and Tadelle & Ogle (2001) for Ethiopia, but less than those obtained by Lwelamira *et al.* (2008). Differences in growth performance of local chickens could be due to genetic differences between birds, climatic condition and local management that determine the availability of feeds between countries. Aini (1990) stated that the productivity of local birds is characteristically very low, but there is large variation in production performance between birds of different localities.

Mortality was high in chicks up to ten weeks of age (73.8 %). The observed results are comparable to the results of Minga *et al.* (1989) who reported 50 % mortality in scavenging chickens during rearing. Mwalusanya *et al.* (2002) reported a mortality of 40.3 % up to 10 weeks of age. Mortality is a serious problem in local chicken production and it needs intervention. It was noted from the famers that the causes of high mortality in local chickens under six weeks of age were lack of quality feeds, theft and predators (dogs and eagles). This was confirmed by Mwalusanya *et al.* (2002) who reported predation to be an important cause of loss in chicken flocks. Chicks can be protected from predators by providing shelters and supplementary feeds can be given to chicks under six weeks of age to improve survivability. It is believed that chicks older than six weeks might be able to escape attacks from the predators and also successfully search for food. The high costs involved in provision of housing and feeds to chicks might be challenging in the poverty restricted rural communities and it might be necessary but feasible to use locally produced feed resources and building materials.

5 Conclusion

The chickens under village management were characterised by slow digestive tract development, growth performance and high mortalities. Dietary supplementation strategies using locally produced feeds, brooding and provision of shelter to newly hatched chicks for the first six weeks might be important tools in improving chicken production in general, through reduced mortality at early age and improved growth rate. Further research needs to be conducted to determine the effect of early feed supplementation on the development of the digestive tract and the performance of chickens under village management.

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CHAPTER 5

Carcass composition of Venda indigenous scavenging chickens under village management

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Carcass composition of Venda indigenous scavenging chickens under village management

Thomas Raphulu [a,b,*], Christine Jansen van Rensburg [a],
Roelof Johannes Coertze [a]

[a] *Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria 0002, South Africa*
[b] *Department of Agriculture Limpopo, Mara Research Station, Makhado, 0920, South Africa*

Abstract

Four Venda indigenous scavenging (VIS) chickens (one young male and one young female of 10–16 weeks of age, a mature cockerel and a mature hen) were randomly purchased from each of six adjacent rural villages during three different seasons (autumn, winter and spring) to determine the meat yield and carcass chemical composition. A total of 72 chickens were slaughtered and feathers, head, neck, viscera, feet and lungs were removed. The live body weight, dressed carcass weight and also the mass of the breast without wings, thighs and drumsticks were recorded with bones and skin. The muscle tissues of the breast and both legs without tendons and fat were sampled for chemical analysis and were analysed for dry matter, ether extract, crude protein and ash. The carcass weight, dressing %, mass of the breast, mass of the thighs, mass of the drumsticks, breast yield, thighs yield and drumsticks yield of both grower and adult VIS chickens were not influenced by season. The crude protein of the grower chickens breast muscles and fat content of the adult chicken leg muscles differed with season. The meat from VIS chickens provided a constant nutrient (crude protein) supply throughout the year to the rural communities.

Keywords: season, gender, meat yield, chemical composition

1 Introduction

Most poultry in Africa is kept under traditional production systems (Branckaert *et al.*, 2000) where chickens are allowed to roam free and scavenge for food around the household. Scavenging chickens are an efficient waste disposal system converting insects and leftover grains and human foods into valuable protein foods, such as eggs and meat (Minh, 2005). Production costs are generally low as no supplementary feeds and medication are used and the chickens are genetically adapted to harsh environments. Besides being a source of high quality food protein for rural communities (Qureshi, 1990; Wattanachant *et al.*, 2004), indigenous chickens are also kept for religious and cultural purposes (Swatson *et al.*, 2001). It is known that human diets in the rural communities are often deficient in protein, both qualitatively and quantitatively (FAO, 1997). Rural communities keeping scavenging chickens have more access to good quality protein through consumption of meat and eggs from their chickens which may improve their health status, alleviate malnutrition and also improve food security. Smith (1982) reported that poultry meat is low in fat and cholesterol which makes it a healthy food for children and aged adults. However, the meat yield and meat quality of indigenous chickens

* Corresponding author
Email: thomas.raphulu@gmail.com

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in South Africa is not yet fully explored. Van Marle-Köster & Webb (2000) reported 49.6 % crude protein and 28.8 % crude fat in the meat of Lebowa-Venda chickens reared intensively and concluded that carcasses of native chickens had higher crude protein and lower crude fat than broilers. The nutritional status of scavenging chickens under village management varies with season, climatic conditions and locality (Rashid *et al.*, 2004; Goromela *et al.*, 2008; Mekonnen *et al.*, 2010). Diet is one of the factors that determine the chemical composition of poultry meat, particularly fat. There are no reports available on the influence of season on the meat quality of the indigenous scavenging chicken in the Venda area (Limpopo province, South Africa). If the nutritional status of scavenging chickens varies between seasons, the meat quality may also fluctuate throughout the year. Knowledge on the meat quality of the Venda indigenous scavenging (VIS) chickens will assist in developing human nutritional supplementary interventions in the rural communities. The objectives of this study were to determine the meat yield and carcass chemical composition of the VIS chicken and also the influence of season on the meat yield and carcass composition.

2 Materials and methods

The research was approved by the Animal Use and Care Committee of the University of Pretoria (EC008-08). The local traditional leaders granted permission to conduct a study in the communities. The study was conducted at six adjacent rural villages, Tshifudi, Tshidzini, Tshamutshedzi, Tshivhilwi, Tshitereke and Makhuvha. All villages are situated between latitude S22°48' to S22°53' and longitude E30°28' to E30°42' in the Thulamela Municipality, Vhembe District in the Limpopo province of South Africa. Vhembe District is the most northern district of the Limpopo Province and it shares borders with Botswana, Zimbabwe and Mozambique. The villages are in a summer rainfall area, with the highest rainfall and temperatures normally recorded between October and March. The mean maximum temperatures during summer range from 26 to 29 °C, while the minimum temperatures range from 12 to 14 °C between May and August. Winter is usually cold but rarely reaches freezing point. Main crops cultivated in the area are maize, groundnuts and vegetables.

A total of four VIS chickens were randomly purchased from each of the six rural villages included in the study during three different seasons, i.e. autumn (April), winter (July) and spring (October). The four chickens comprised of a young male and a young female (10–16 weeks old), and a mature cock and a mature hen. Each village was regarded as a replicate and thus the study included six replicates for each age class (young and mature), gender (male and female) and season (autumn, winter, spring).

The chickens were killed, weighed and scalded in hot water for 2–3 minutes to facilitate easy plucking. The feathers, head, neck, viscera, feet and lungs were removed. The dressed carcass, breast, thighs and drumsticks were weighed with bones and skin. The wings were removed by a cut through the shoulder joint at the proximal end of humerus. The breast portion was obtained as described by Hudspeth *et al.* (1973). The thigh and drumstick portions were obtained by cutting through the joint between the femur and ilium bone of the pelvic girdle. The drumstick was separated from the thigh by a cut through the joint formed by the femur, fibula and tibia. The dressing percentage was calculated as weight of the carcass (without neck, head, feathers, feet and visceral organs) divided by live bodyweight multiplied by 100, while carcass traits were expressed as absolute mass (in grams) and as the percentages of the carcass weight.

The muscles of the breast and leg (drumsticks and thighs) were removed, freeze dried and grounded using a coffee blender. The muscle tissues of the breast and both legs without tendons and fat were sampled for chemical analysis. Dry matter, ether extract, crude protein and ash in muscles were measured according to the methods described by the AOAC (2000). Moisture content was determined by drying at least 2 g of meat to a constant weight at 105 °C overnight. Ash was determined at 600 °C. The data collected were statistically analysed using the GLM of SAS 9.2 (2010). The following model: $Y_{ijkl} = \mu + S_i + A_j + X_k + (SA)_{ij} + (SX)_{ik} + (AX)_{jk} + E_{ijkl}$, was employed where Y_{ijkl} is an observation for a given variable; μ is the general mean common to all observations; S_i is the effect due to i^{th} season; A_j is the effect due to the j^{th} age class of chicken; X_k is the effect due to the k^{th} effect of the gender of chickens; $(SA)_{ij}$ is the interaction effects between the i^{th} season and j^{th} age; $(SX)_{ik}$ is the effects between the j^{th} age and kth gender class; $(AX)_{jk}$ is the effects between the j^{th} age and k^{th} gender group and E_{ijkl} is the random error. A 5 % significant level was used.

3 Results

The slaughter weight, dressed carcass weight, dressing %, mass and yield of breast, thighs and drumsticks for grower and adult chickens were not influenced by season ($P \geq 0.05$) (Table 1). The slaughter weight of grower chickens showed a decreasing tendency with season with the highest obtained in autumn, while adult chickens showed increasing tendency with season, but it was insignificant ($P \geq 0.05$). The slaughter and carcass weight, dressing %, mass of breast, mass of thighs, mass of drumsticks, breast yield and thighs yield of the VIS chickens differed between age groups ($P < 0.05$). Differences exhibited in terms of the gender on carcass weight, mass of the breast and thigh and breast yield were statistically highly significant ($P < 0.05$).

Carcass chemical composition of the VIS chickens during different seasons (LS Means) is presented in Table 2. The dry matter and moisture content of both breast and leg muscle of both grower and adult, ash content of the grower breast muscle and leg muscle of the adult, crude protein content of the grower breast muscle and fat content of the adult muscle differed between seasons ($P < 0.05$), crude protein content of adult chickens for both breast and leg muscle were not influenced by season ($P \geq 0.05$), only fat content of the leg muscle differed with season ($P < 0.05$). The crude protein content of breast muscle of the grower chickens differed with season ($P < 0.05$).

The influence of age and gender on carcass yield and chemical composition of the VIS chickens is summarised in Table 3. Age had a significant effect on slaughter weight, carcass weight, dressing %, mass of the breast, thighs, drumsticks, drumstick yield, ash, fat and crude protein content of the leg muscle ($P < 0.05$). The leg muscle of the adult chickens had higher levels of fat and crude protein than in grower chickens. In the breast muscle no differences were observed in protein and fat content due to age effect ($P \geq 0.05$).

Table 1: *Meat yield of the Venda indigenous scavenging chickens during different seasons (LS Means)*

Parameters	*Age*	*Season*			*Mean*	*SEM*
		Autumn	*Winter*	*Spring*		
Slaughter weight (g)	Grower	582.58 ^{1a}	439.50 ^{1a}	419.75 ^{1a}	480.61	47.03
	Adult	1530.92 ^{1b}	1549.75 ^{1b}	1567.92 ^{1b}	1549.52	47.03
Carcass weight (g)	Grower	336.06 ^{1a}	264.17 ^{1a}	242.83 ^{1a}	281.02	40.02
	Adult	1001.11 ^{1b}	918.43 ^{1b}	1019.53 ^{1b}	979.69	40.02
Dressing %	Grower	56.46 ^{1a}	59.45 ^{1a}	57.26 ^{1a}	57.73	1.36
	Adult	64.84 ^{1b}	59.99 ^{1a}	64.41 ^{1b}	63.08	1.36
Mass of breast (g)	Grower	68.93 ^{1a}	52.92 ^{1a}	47.99 ^{1a}	56.61	9.41
	Adult	224.78 ^{1b}	206.35 ^{1b}	231.67 ^{1b}	220.94	9.41
Mass of thighs (g)	Grower	57.29 ^{1a}	44.55 ^{1a}	42.32 ^{1a}	48.05	6.82
	Adult	168.81 ^{1b}	181.16 ^{1b}	187.24 ^{1b}	179.07	6.82
Mass of drumsticks (g)	Grower	48.97 ^{1a}	51.70 ^{1a}	34.43 ^{1a}	45.03	6.98
	Adult	143.58 ^{1b}	158.02 ^{1b}	152.38 ^{1b}	151.33	6.98
Breast yield (%)	Grower	20.70 ^{1a}	19.80 ^{1a}	19.70 ^{1a}	20.07	0.42
	Adult	22.36 ^{1a}	22.65 ^{1b}	23.07 ^{1b}	22..69	0.42
Thighs yield (%)	Grower	16.67 ^{1a}	16.62 ^{1a}	17.45 ^{1a}	16.91	3.38
	Adult	16.77 ^{1b}	31.70 ^{1a}	18.17 ^{1a}	22.21	3.38
Drumsticks (%)	Grower	14.16 ^{1a}	19.77 ^{1a}	14.20 ^{1a}	16.04	3.23
	Adult	14.12 ^{1a}	27.60 ^{1a}	14.52 ^{1a}	18.75	3.23

^{1,2} Means sharing different superscripts within a row and a factor differ significantly ($p < 0.05$).
^{a,b} Means sharing different superscripts within a column and a factor differ significantly ($p < 0.05$).

Table 2: *Carcass chemical composition of the Venda indigenous scavenging chickens during different seasons (LS Means)*

Parameters	*Age*	*Season*			*Mean*	*SEM*
		Autumn	*Winter*	*Spring*		
Breast muscle						
Dry matter (DM) (g/kg)	Grower	326.18^{1a}	262.91^{2a}	237.13^{3a}	275.41	6.48
	Adult	306.95^{1a}	273.20^{2a}	289.97^{2b}	290.04	6.48
Moisture (g/kg)	Grower	673.82^{1a}	737.09^{2a}	762.87^{3a}	724.59	6.48
	Adult	693.05^{1a}	726.80^{2a}	710.86^{1b}	709.96	6.48
Ash (g/kg DM)	Grower	38.03^{1a}	39.01^{1a}	42.20^{2a}	39.75	0.30
	Adult	40.21^{1b}	40.81^{1b}	40.67^{1b}	40.57	0.27
Fat (g/kg DM)	Grower	29.63^{1a}	31.22^{1a}	26.78^{1a}	29.21	2.21
	Adult	33.16^{1a}	23.95^{1a}	23.47^{1a}	26.86	2.03
Crude protein (g/kg DM)	Grower	881.95^{1a}	724.65^{2a}	878.13^{1a}	828.24	24.37
	Adult	892.93^{1a}	894.55^{1b}	889.82^{1a}	892.43	24.37
Leg muscle						
Dry matter (DM) (g/kg)	Grower	288.17^{1a}	265.95^{2a}	262.65^{2a}	270.12	3.06
	Adult	279.77^{1a}	263.38^{2a}	267.20^{2a}	272.26	3.06
Moisture (g/kg)	Grower	711.83^{1a}	734.05^{2a}	737.35^{2a}	727.74	3.06
	Adult	720.23^{1a}	736.62^{1a}	732.80^{2a}	729.88	3.06
Ash (g/kg DM)	Grower	37.99^{1a}	39.79^{1a}	38.94^{1a}	38.91	0.70
	Adult	39.85^{1a}	44.63^{2b}	39.99^{1a}	41.49	0.65
Fat (g/kg DM)	Grower	153.81^{1a}	165.41^{1a}	154.80^{1a}	158.01	7.49
	Adult	147.71^{1a}	106.31^{2b}	112.21^{1b}	122.08	7.25
Crude protein (g/kg DM)	Grower	754.95^{1a}	745.5^{1a}	788.78^{1a}	747.87	7.37
	Adult	775.71^{1a}	797.58^{1b}	743.13^{1b}	787.36	7.37

^{1,2,3} Means sharing different superscripts within a row and a factor differ significantly ($p < 0.05$).
^{a,b} Means sharing different superscripts within a column and a factor differ significantly ($p < 0.05$).

Male chickens weighed more than females ($P < 0.05$). Males showed higher yields of breast, drumsticks and thighs, whereas females had larger breast yield than males. The gender of the chickens did not influence the chemical composition of the breast and leg muscle ($P \geq 0.05$), but the fat and protein content of the leg muscles differed due to gender. Female chickens deposited more fat and less crude protein than male chickens. The slaughter weight, mass of the thighs, mass of the breast and drumstick yield were significantly higher ($P < 0.05$) for male chickens than female chickens in both the age groups.

4 Discussion

The obtained results do not show any significant variation in the meat yield (slaughter weight, carcass weight, dressing %, mass of breast, mass of thighs, mass of drumsticks, breast yield, thighs yield and drumstick yield) of the grower and adult VIS chickens between seasons. The highest slaughter and carcass weight for the grower and adult VIS were obtained in autumn and spring respectively, but this difference was not statistically significant. The obtained results are inconsistence with the findings by Goromela *et al.* (2007) who reported differences in slaughter and carcass weight due

Table 3: *The influence of age and gender on the carcass yield and carcass chemical composition of the Venda indigenous scavenging chickens*

Parameters	*Age*			*Gender*			*SEM*
	Grower	*Adult*	*P value*	*Female*	*Male*	*P value*	
Slaughter weight (g)	480.61[a]	1549.53[b]	0.0001	888.23[a]	1141.90[b]	0.0003	47.02
Carcass weight (g)	281.02[a]	979.69[b]	0.0001	550.69[a]	710.02[b]	0.0006	40.03
Dressing %	57.73[a]	63.09[b]	0.0074	60.47[a]	60.34[a]	0.9476	1.36
Mass of the breast (g)	56.62[a]	220.94[b]	0.0001	129.42[a]	148.13[a]	0.1652	6.98
Mass of the thighs (g)	48.05[a]	179.07[b]	0.0001	93.21[a]	133.90[b]	0.0001	6.82
Mass of the drumsticks (g)	45.03[a]	151.32[b]	0.0001	79.16[a]	117.21[b]	0.0003	9.41
Breast yield (%)	20.06[a]	22.69[b]	0.0001	22.41[a]	20.34[b]	0.0008	0.41
Drumsticks yield (%)	16.05[a]	18.74[a]	0.5577	15.62[a]	19.17[a]	0.5577	3.38
Thighs yield (%)	16.91[a]	22.22[a]	0.2713	16.74[a]	22.40[a]	0.2713	3.37
Chemical composition							
Breast muscles							
Dry matter (DM) (g/kg)	275.41[a]	290.04[a]	0.1156	281.07[a]	284.37[a]	0.7202	6.48
Moisture (g/kg)	724.59[a]	709.96[a]	0.1156	718.92[a]	715.63[a]	0.7202	6.48
Ash (g/kg DM)	39.75[a]	40.56[b]	0.0500	40.44[a]	39.87[a]	0.1650	0.28
Fat (g/kg DM)	29.21[a]	26.86[a]	0.4379	27.87[a]	28.20[a]	0.9144	2.13
Crude protein (g/kg DM)	828.24[a]	892.43[a]	0.0674	859.28[a]	861.39[a]	0.9513	24.36
Leg muscles							
Dry matter (DM) (g/kg)	272.26[a]	270.1[a]	0.6233	274.19[a]	268.18[b]	0.1709	3.39
Moisture (g/kg)	727.75[a]	729.88[a]	0.6233	725.81[a]	731.81[a]	0.1709	3.06
Ash (g/kg DM)	38.9[a]	41.49[b]	0.0076	39.53[a]	40.87[a]	0.1817	0.68
Fat (g/kg DM)	122.08[a]	158.01[b]	0.0001	154.94[a]	125.15[b]	0.0059	7.37
Crude protein (g/kg DM)	747.87[a]	787.36[b]	0.0004	754.06[a]	781.17[b]	0.0188	12.78

[a,b] Means with different superscripts within a row and a factor differ significantly ($P < 0.05$)

to season, with higher weights recorded during the dry season than the rainy season. The authors of this study attributed these differences to higher intakes of cereals and their by-products spilled on the ground during harvesting, threshing and winnowing activities in the dry season. It could be suggested that differences in nutritional status of the scavenging chickens with seasons as reported by Mekonnen *et al.* (2010); Goromela *et al.* (2008), and Rashid *et al.* (2004) did not influence meat yield of the VIS chickens in the present study.

The mean slaughter weight of 1549 g reported in the present study was higher than the 1238 and 1121 g reported by Goromela *et al.* (2008) and Tadelle (1996), respectively, for adult village chickens during the dry season. Goromela *et al.* (2007) attributed differences in slaughter weight to changes in seasonal conditions, farming activities, land size available for scavenging and village flock size. The overall mean of the carcass weight, dressing %, mass of the breast, mass of the thighs and mass of the drumsticks obtained for growers and adult VIS chickens were 281.02 g, 57.73 %, 56.61 g, 48.05 g, 45.03 g and 979.69 g, 63.08 % 220.94 g, 179.07 g, 151.33 g, respectively. The mean dressing percentage of 63.08 % of adult VIS reported in this study was in conformity with the reports by Goromela *et al.* (2008) (63–64 %), but higher than Pousga *et al.* (2005) reports (60.6 %) for scavenging pullets in Bukina-Faso and lower than reported by Tadelle (1996) (65.6 %) for scavenging chickens. Differences in dressing % could be due to heavier weights of the gastro intestinal tract (GIT) and its contents. Observed dressing % in the present study and from previous studies on scavenging chickens is much lower than dressing % reported for broilers. Poltowicz & Doktor (2011) reported an average dressing % of 68.47 and 69.04 for indoor and free-range broilers, respectively. According to Van Marle-Köster & Webb (2000) the lower dressing % found in native chickens is due to slower growth of the native chickens as compared to broilers.

The proportions of the major carcass portions (breast, drumsticks and thighs) as well as the chemical composition of the muscular tissue are regarded as vital parameters determining broiler meat quality (Holcman *et al.*, 2003). The overall mean of the breast yield, thighs yield and drumsticks yield of growers and adult VIS chickens were 20.07 %, 16.91 %, 16.04 % and 22.69 %, 22.21 % and 18.75 %, respectively. Literature on the major carcass portions of native chickens in rural communities in different seasons is very scarce. Bogosavljević-Bošković *et al.* (2010a) reported 31.69, 13.40 and 16.11 % of the breast, thigh and drumstick in free range broilers, respectively. Nikolova & Pavlovski (2009) observed 20.43, 9.73 and 10.63 % of the breast, thigh and drumstick portions in Cobb 500 broilers. The observed results of this study are in close agreement with Nikolova & Pavlovski (2009) in terms of the breast meat yield. However, the mean thigh and drumstick yield obtained in this study are much higher than found in previous studies (Van Marle-Köster & Webb, 2000; Nikolova & Pavlovski, 2009; Bogosavljević-Bošković *et al.*, 2010a). Castellini *et al.* (2002) found that percentages of breast and thigh meat increased when birds had outdoor access and kept at lower stocking density in free-range production systems. It could be suggested that the well-developed leg muscles in the VIS chickens could be due to their scavenging mode as they have to walk long distances to search for food.

The slaughter and carcass weight, dressing %, mass of breast, mass of thighs, mass of drumsticks, breast yield and thighs yield of the VIS chickens obtained in this study showed significant differences between age groups. Higher values were obtained in adult chickens than grower chickens. Similar findings were observed by Young *et al.* (2001).

Males showed higher carcass weight, mass of breast, drumstick and thigh and less breast yield than female chickens, which agrees with the results of Santos *et al.* (2004) and Rahayu *et al.* (2008). Shahin & Elazeem (2005) did not establish any influence of gender and genotype on the proportions of different carcass parts, when expressed as a percentage of carcass weight. Similar results were obtained in this study with the exception of breast yield. Female chickens showed larger breast yield than male chickens. This was confirmed by Young *et al.* (2001) and Rondelli *et al.* (2003) who reported that female carcass had significant bigger breasts and fillet yield and less thighs and drumstick yield compared to male carcass.

Nutritional status of scavenging chickens can vary with season, climatic conditions and locality (Goromela *et al.*, 2007, 2008; Mekonnen *et al.*, 2010). There are reports that diet is one of the factors that determine the chemical composition of poultry meat, particularly that of the fat and protein content (Leenstra, 1986; Liu *et al.*, 2006). Protein and fat of muscle tissue are important meat quality parameters and contribute substantially to the nutritional characteristics of meat. Rural communities consume meat from adult chickens; it can therefore be concluded that meat quality, particularly protein content of the VIS chickens in the rural communities is similar throughout the year and the differences in nutritional status of scavenging chickens reported in previous studies (Rashid *et al.*, 2004; Goromela *et al.*, 2008; Mekonnen *et al.*, 2010) do not have any effect on the meat quality of the VIS chickens. However nutritional status differences reported showed seasonal effect on the fat content of the leg muscle. The highest fat content of the leg muscle was obtained in autumn, which could be attributed to abundance availability of cereals and by products spilled during harvesting.

It was reported that raw chicken meat has a water content of 60.4 to 75.4 %, a protein content of 17.0 to 23.3 %, a fat content of 1.0 to 17.4 %, and an ash content of 0.7 to 3.6 % (Demby & Cunningham, 1980). Similar results were obtained in this study with the exception of protein content. Protein content observed in this study was higher than reported by other authors (Perreault & Leeson, 1992; Žlender *et al.*, 1995; Van Marle-Köster & Webb, 2000). The higher crude protein values in VIS chickens than in broilers was supported by Van Marle-Köster & Webb (2000); Wattanachant *et al.* (2002), and Meluzzi *et al.* (2009) who reported that the carcasses of indigenous chickens contain higher protein and less fat than that of broilers, emphasising the differences in chemical composition of poultry meat due to genotype. It seems as if meat from VIS chickens is superior to broiler meat as it contained high protein levels. It is likely that the higher carcass protein in the VIS chickens than in broilers and other intensively-kept native chickens could be due to tougher muscles as VIS were slaughtered at older age. Bogosavljević-Bošković *et al.* (2010b) observed protein content increase of breast, thigh and drumstick with age. The results indicate that the meat from the VIS chickens is of economic value to the rural communities and has potential of alleviating malnutrition, poverty and improved food security and health in general.

The leg muscle of the adult chickens had higher levels of fat and crude protein than in grower chickens. In the breast muscle no differences were observed in protein and fat content due to age effect ($P \geq 0.05$). The results conforms with the findings by Wattanachant & Wattanachant (2007) who reported that during growth of the indigenous chickens, moisture content in muscles decreased from 77.8 to 71 %, whereas protein and fat increased from 21.5 to 24 % and 1.35 to 3.90 %. There were no significant differences between the genders on the carcass chemical composition, except for the fat and protein content of the leg muscles. Females deposited more fats than males. The obtained results are in conformity with the findings of Grey *et al.* (1983) who found that gender effect at various ages was significant only for the thigh muscles which had the highest lipid concentration. According to Tůmová & Teimouri (2010) the differences could be attributed to metabolic differences, higher competitiveness among males, different fat accumulation capacity, different nutritional requirements and different hormonal effects in males. Fat plays an important role in the reproduction process, when birds mature the production of egg yolk is influenced by lipid metabolism Rahayu *et al.* (2008). Carcasses of male chickens had higher protein content than that of females. Similar findings were reported by De Marchi *et al.* (2005) and Bogosavljević-Bošković *et al.* (2010b).

It is known that leg muscles have higher fat content and lower protein content than breast muscles (Simeonovová, 1999). Similar observations were made in the present study. According to Díaz *et al.* (2010) the differences in breast and leg muscles could be attributed to the very structure of these organs, with breast muscles being mostly composed of white fibres, as opposed to drumsticks made up of muscles that contain red fibres having different metabolic functions. The observed results suggest that the breast muscle is the leanest meat in the chicken.

5 Conclusion

The slaughter weight, carcass weight, mass of the thigh, mass of the drumstick, breast yield of both grower and adult chickens were not influenced by season. Season had effect on the protein content of the grower chicken breast muscle and fat content of the adult chicken leg muscle. Gender of the VIS chickens influenced slaughter weight, carcass weight, mass of the thigh, mass of the drumstick, breast yield and carcass composition (fat and protein content of the leg muscle). The thigh and drumstick yield of VIS chickens were higher than previously found for broilers, but the meat of the VIS chickens contained less fat and more crude protein than the meat of broilers. The meat from VIS chickens provided a constant nutrient supply throughout the year to rural communities and suggests that the supplementation of protein to human diets in the rural communities might not be necessary if sufficient chicken meat is consumed. Keeping VIS chickens has a potential to solve the problem of malnutrition, improve food security and overall health status of the Venda rural communities.

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CHAPTER 6

Dietary protein and energy requirements of the Venda indigenous chickens

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Dietary protein and energy requirements of Venda village chickens

Thomas Raphulu [a,b,*], Christine Jansen van Rensburg [a]

[a] *Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria 0002, South Africa*
[b] *Limpopo Department of Agriculture and Rural Development, Mara Research Station, P/bag x 2467, Makhado, 0920, South Africa*

Abstract

The objective of this study was to determine the dietary protein and apparent metabolisable energy (AME) requirements of local chickens. Freshly laid eggs of scavenging chickens collected in rural villages were hatched and randomly distributed to 27 floor pens, 10 chicks per pen. Chicks were fed 9 experimental diets that were combinations of three CP levels (140, 170 and 190 g kg^{-1} DM) and three AME levels (11.0, 11.7 and 12 MJ kg^{-1}) during the starter phase (0–6 weeks) and combinations of three CP levels (120, 150 and 180 g kg^{-1} DM) and three ME levels (11.3, 12.0 and 12.4 MJ kg^{-1}) during the grower phase (7–17) weeks. Significant differences within means on CP × AME interaction effect were observed in all parameters measured, except feed intake during starter period and dressing percentage (%) and breast yield of 17 weeks old chickens. The results of the present study indicated that during the starter and grower phases, unsexed chickens would require dietary combinations of 170 g CP kg^{-1} and 11.0 AME MJ kg^{-1} and 150 g CP kg^{-1} and 12 AME MJ kg^{-1} in their diets to optimise weight gain and FCR, and 150 g CP kg^{-1} and 11.3 MJ kg^{-1} to optimise ash content of muscles, protein content of the breast and fat content of the leg muscle. Supplementation of 27 g CP kg^{-1} feed to grower scavenging chickens would be enough to improve chicken production in the rural villages.

Keywords: starter phase, grower phase, weight gain, feed conversion ratio

1 Introduction

Villages in the rural areas of the Vhembe District, Venda, South Africa, have relative high numbers of chickens which in most instances have to scavenge for feed. These chickens are mainly kept for religious and cultural reasons, income generation and a supply of high quality protein in the form of meat and eggs (Swatson *et al.*, 2001; Raphulu *et al.*, 2015a). The typical chicken population found in these areas are characterised by slow growth rate and late maturity, low egg production and small egg size (Melesse, 2000). Low husbandry input levels cause numerous nutritional and parasitic problems in these chickens. In a stress-free environment, given adequate access to essential nutrients, growth rate will increase until a genetically determined upper limit is reached (Campbell & Taverner, 1988). A few studies have been conducted to determine the nutrient requirements of indigenous chickens in Africa. Mbajiorgu (2010) reported that a diet containing a crude protein content level of 178 g kg^{-1} DM and energy level of 14 MJ ME kg^{-1} DM allowed for optimal utilisation of absorbed protein and energy for growth of Venda chickens between one and six weeks old. Alabi *et al.* (2013) fed Venda Indigenous chickens diets that were isonitrogenous with different energy levels and concluded that dietary energy levels of 12.42 and 12.66 MJ ME kg^{-1} DM, in a diet of 180 g CP kg^{-1} DM, supported optimum growth rates at starter (1–7 weeks) and grower phases (8–13 weeks) of Venda chickens, respectively. The dietary protein requirement of indigenous chickens in Kenya were found to be between 130 g kg^{-1} (Chemjor, 1998) and 160 g kg^{-1} (Kingori *et al.*, 2003) during 14–21 weeks of age and on average 170 g kg^{-1} during a 19 weeks growing period (Ndegwa *et al.*, 2001).

The improvement of chicken production in the rural areas of Venda can increase the availability of quality protein

* Corresponding author – thomas.raphulu@gmail.com
Phone (cell): 0828518296; Phone (work): 0159627200;
Fax: 0159627239

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in the form of meat and eggs to the communities, which will result in alleviation of malnutrition, increased household income and job creation. Because of the limited information on the nutrient requirements of the chickens in Venda, it is difficult to come up with nutrient supplementation strategies to assist the rural communities. The objective of this study was to determine the genetic growth potential of these chickens (eggs collected from the rural villages) under good environmental conditions and management, and to determine the nutrient requirements in terms of dietary protein and metabolisable energy to optimise its growth performance.

2 Materials and methods

The experiment was conducted at the University of Pretoria, Gauteng Province; South Africa (coordinates 25°15′28.9″ E, 25°45′03.6″ S). All procedures were approved by the University of Pretoria, Animal Use and Care Committee (EC008-08). Thousand freshly laid eggs of scavenging chickens collected in 6 rural villages of Venda in the Vhembe District, South Africa, were hatched at the University of Pretoria Experimental farm. Two hundred and seventy (270) chicks were randomly distributed to 27 floor pens, 10 chicks per pen. Chicks were fed 9 experimental diets that were combinations of three CP (140, 170, 190 and 120, 150 and 180 g kg^{-1}) and three AME (11.0, 11.7, 12.0 and 11.3, 12.0 and 12.4 MJ kg^{-1}) levels during the starter (0–6 weeks) and grower (7–17 weeks) phases, respectively (Tables 1 and 2).

Chickens were raised in an environmentally controlled house and temperature maintained at 30 to 33 °C and 23 to 25 °C during the starter and grower phase, respectively. Lighting was provided continuously. The chicks were vaccinated against Newcastle virus disease and infectious bronchitis. Feed and water were available ad libitum throughout the experiment. Feed intake, weight gain, and feed conversion ratio (FCR) were measured per pen weekly. Weight gain was calculated as the difference between the final and initial chicken body weight during each of the weighing periods. Feed conversion ratio was calculated by dividing feed intake by weight gain. Mortality was recorded as it occurred. At the end of the experiment, eight 17-week old chickens per treatment (4 males and 4 females) were randomly selected following a 12-hour fast and killed by bleeding from a neck cut. The chickens were scalded in water for 2–3 minutes to ease plucking. Head, neck, feet and the visceral organs were removed. The hot carcass was weighed

Table 1: *Composition of the experimental starter diets.*

Dietary CP/ME †	190/11	190/11.7	190/12.4	170/11	170/11.7	170/112.4	140/11.7	140/11.7	140/12.4
Ingredient (g kg^{-1} DM)									
White maize	605.4	677.6	612.3	626.6	702.8	694.9	658.3	734.6	808.4
Soya oilcake meal	226.8	281.3	98.9	158.8	180.5	119.9	56.9	78.6	120.3
Bran	76.8	0	0	119.7	21.4	0	184	85.7	0
Sunflower oilcake meal	50	0	0	50	50	0	50	50	20
Fullfat soya	0	0	247.5	0	0	140	0	0	0
Limestone	16.9	16.8	17.1	17.2	17.0	17.1	17.5	17.4	17.3
Monocalcium phosphate	10.3	11.2	11.3	10.7	11.5	12	11.2	12.1	13
Salt	3.9	4.0	4.0	3.9	4.0	4.0	3.9	3.9	4.0
Premix ‡	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Lysine	2.9	2.1	1.8	4.7	4.4	3.6	7.5	7.2	6.6
Methionine	1.7	1.8	1.9	2.0	2.0	2.1	2.5	2.4	2.4
Threonine	2.1	2.1	2.0	3.0	2.9	2.7	4.4	4.2	4.0
Tryptophan	0.11	0.13	0.24	0.39	0.4	0.5	0.8	0.8	0.8
Calculated analysis (g kg^{-1})									
Calcium	10	10	10	10	10	10	10	10	10
Phosphorus	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5

† CP/ME, crude protein (g kg^{-1} DM) / metabolisable energy (MJ kg^{-1} DM)
‡ Composition of the broiler starter premix. Each 2.5 kg contained vitamin A , 13,000,000 IU, vitamin D_3, 3,500,000 IU, B_1 (Thiamine) 2000 mg, vitamin B_2 (Riboflavin) 6000 mg, vitamin B_6 (Pyrodoxine) 6000 mg, folic acid 1500 mg, vitamin B_{12} (Cobalamine) 20 mg, E 40,000 mg, betaine 500,000 mg, niacin 60,000 mg, pantothenic acid 15000 mg, Vitamin K_3 stab 4000 mg, biotin 150 mg, cobalt 500 mg, iodine 3000 mg, selenium 300 mg, manganese 70,000 mg, copper 20,000 mg, zinc 70,000 mg, iron 50,000 mg, antioxidant 200,000 mg.

Table 2: *Composition of the experimental grower diets.*

Dietary CP/ME †	180/11.3	180/12	180/12.4	150/11.3	150/12	150/12.4	120/11.3	120/12	120/12.4
Ingredient (g kg^{-1} DM)									
White maize	648.5	691.8	654.9	680.2	756.5	778.9	711.8	788.3	831.8
Soya oilcake meal	201.8	215.3	111.2	99.8	121.5	142.7	46.9	19.6	32.0
Fullfat soya	0	50.3	191.2	0	0	30.0	0	0	0
Bran	57.2	0	0	121.4	23.2	0	187	87.4	31.3
Sunflower oilcake meal	50	0	0	50	50	0	0	50	50
Limestone	17.0	17.0	17.1	17.4	17.2	17.2	17.8	17.6	17.5
Monocalcium phosphate	10.8	11.6	11.7	11.4	12.3	12.7	12.0	12.9	13.4
Lysine	3.7	2.9	2.7	6.5	6.2	5.5	9.3	9.0	8.8
Methionine	1.9	2.0	2.0	2.3	2.2	2.3	2.7	2.7	2.6
Threonine	2.5	2.3	2.4	3.9	3.7	3.5	5.2	5	4.9
Tryptophan	0.3	0.3	0.4	0.7	0.7	0.7	1.1	1.1	1.1
Salt (fine)	3.9	4.0	4.0	3.9	4.0	4.0	3.9	4.0	4.0
Premix ‡	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Calculated analysis (g kg^{-1})									
Calcium	10	10	10	10	10	10	10	10	10
Phosphorus	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5

† CP/ME, crude protein (g kg^{-1} DM) / metabolisable energy (MJ kg^{-1} DM)
‡ Composition of the broiler grower premix. Composition of each 2.5 kg contained vitamin A , 11,500,000 IU, vitamin D_3, 3,500,000 IU, vitamin E 40,000 mg, vitamin K_3, 35,000 mg, vitamin B_1, 2000 mg, vitamin B_2 and B_6, 55000 mg, vitamin B_{12}, 20 mg, niacin, 55,000 mg, calpan, 13,500 mg, folic acid 1250 mg, bictin, 100 mg, selenium, 300 mg, manganese, 700,000 mg, iron, 450,000 mg, iodine 3000 mg, zinc, 65,000 mg, copper, 20,000 mg, cobalt, 500 mg, phyzyme XP 10,000 TPT, 100,000 mg, choline, 400,000 mg, antioxidant, 200,000 mg and rovabio excel AP, 60,0000.

and dressing percentage calculated as weight of carcass divided by live body weight multiplied by 100. Carcass cuts (breast, thigh, drumstick and fat) were also weighed and expressed as proportions of the carcass weight. Dry matter, ether extract, crude protein and ash were evaluated in the breast and leg (thighs and drumstick) muscles according to the recommendation of AOAC Official Methods of Analysis (2000). Data collected were subjected to analysis of variance for a 3 × 3 factorial in a completely randomised design, using the General Linear Model procedure of SAS, version 9.3 (SAS Institute, 2016). Differences among means were determined by LSD‘s option of SAS.

3 Results

3.1 Performance

The influence of dietary protein and metabolisable energy on growth performance of the chickens is shown in Tables 3 and 4. During the starter period (0–6 weeks), average body weight at the start of the experiment was 28.67 g. There was no effect of CP and AME or their interaction on feed consumption ($p > 0.05$). Dietary CP, AME and CP × AME interaction had significant effect ($p < 0.05$) on weight gain and FCR of chickens during the starter phase. Weight gain and FCR improved with increasing levels of dietary protein ($p < 0.05$). Crude protein above 140 g kg^{-1} feed at all dietary AME levels resulted in improved weight gain and FCR in the chickens. Chickens that received CP of 170 and 190 g kg^{-1} at all AME levels had similar weight gain and FCR. However, at CP level of 170 g kg^{-1} weight gain and FCR numerically, but not significantly, decreased with an increase in dietary AME, with 11.0 MJ kg^{-1} maximising weight gain and FCR. The dietary combination of CP 170 g kg^{-1} × AME 11 MJ kg^{-1} yielded best weight gain and FCR.

During the grower period (7–17 weeks) there was no significant CP × AME effect ($p \geq 0.05$) observed on any of the traits measured, although significant differences within means were observed. Feeding above 120 g CP kg^{-1} at all AME levels improved weight gain and FCR. There were no significant differences observed between chickens that received CP of 150 and 180 g kg^{-1} at all dietary AME levels on weight gain and FCR. The lightest and heaviest chickens were observed on dietary combinations of 120 g CP kg^{-1} × 12.4 MJ AME kg^{-1} and 150 g CP kg^{-1} × 12.0 MJ AME kg^{-1}, respectively. The feed intake decreased with increasing dietary AME levels ($p < 0.05$). The dietary combination of 150 g CP kg^{-1} feed × 12.0 MJME kg^{-1} feed maximised weight gain and FCR.

Table 3: *The influence of dietary protein and metabolisable energy levels on growth performance of Venda chickens (0 to 6 weeks old).*

Parameter	*Feed intake* (g/bird/day)	*Weight gain* (g/bird)	*FCR* (g/g)
Protein (g kg^{-1} DM)			
140	27.11	258.49^{b}	4.44^{a}
170	28.00	342.38^{a}	3.48^{b}
190	26.32	372.47^{a}	3.00^{c}
SEM†	1.05	7.46	0.13
AME (MJ kg^{-1} DM)			
11.0	27.95	328.49^{a}	3.67^{ab}
11.7	26.92	347.53^{a}	3.32^{b}
12.4	26.56	297.32^{b}	3.92^{a}
SEM†	1.05	7.46	0.13
CP × AME			
140 × 11.0	29.07	261.50^{de}	4.67^{a}
140 × 11.7	26.99	292.64^{cd}	3.86^{abc}
140 × 12.4	25.28	221.34^{e}	4.79^{a}
170 × 11	27.56	371.80^{a}	3.12^{bc}
170 × 11.7	26.56	357.40^{ab}	3.14^{bc}
170 × 12.4	29.86	297.94^{ab}	4.20^{ab}
190 × 11	27.20	352.16^{abc}	3.25^{bc}
190 × 11.7	27.21	392.56^{a}	2.97^{c}
190 × 12.4	24.55	372.70^{a}	2.77^{c}
SEM†	1.81	12.92	0.22
P values			
CP	0.5410	< 0.0001	< 0.0001
AME	0.6338	0.0006	0.0218
CP × AME	0.3855	0.0194	0.0111

[a,b,c,d,e] Means with different superscript within a column and a factor differ significantly ($p < 0.05$)
† Standard error of the mean; AME: apparent metabolisable energy; CP: crude protein

Table 4: *The influence of dietary protein and metabolisable energy levels on growth performance of Venda chickens (7–17 weeks old).*

Parameter	*Feed intake* (g/bird/day)	*Weight gain* (g/bird)	*FCR* (g/g)
Protein (g kg^{-1} DM)			
120	71.73	976.99^{b}	5.76^{a}
150	70.00	1262.53^{a}	4.34^{b}
180	67.32	1256.33^{a}	4.19^{b}
SEM†	2.08	38.68	0.09
AME (MJ kg^{-1} DM)			
11.3	72.59^{a}	1138.03	4.98^{a}
12.0	71.87^{a}	1219.91	4.79^{ab}
12.4	64.61^{b}	1137.91	4.50^{b}
SEM†	2.08	36.68	0.09
CP × AME			
120 × 11.3	75.47^{b}	1009.96^{bc}	5.77^{ab}
120 × 12.0	77.41^{a}	1010.85^{bc}	6.16^{a}
120 × 12.4	62.33^{c}	910.16^{c}	5.40^{b}
150 × 11.3	71.43^{abc}	1197.31^{ab}	4.64^{c}
150 × 12.0	73.93^{ab}	1392.28^{a}	4.24^{cde}
150 × 12.4	64.65^{bc}	1198.00^{ab}	4.16^{cde}
180 × 11.3	70.87^{abc}	1206.83^{ab}	4.52^{cd}
180 × 12.0	64.26^{bc}	1256.61^{a}	3.98^{e}
180 × 12.4	66.85^{abc}	1305.57^{a}	4.05^{de}
SEM†	3.60	66.99	0.16
P values			
CP	0.3408	< 0.0001	< 0.0001
AME	0.0257	0.2506	0.0149
CP × AME	0.2023	0.3062	0.0593

[a,b,c,d,e] Means with different superscript within a column and a factor differ significantly ($p < 0.05$)
† Standard error of the mean; AME: apparent metabolisable energy; CP: crude protein

3.2 *Carcass parameters*

There was no effect of CP and ME or their interaction on dressing per cent and breast relative weight (RW) ($p > 0.05$), except thigh RW that decreased with increasing levels of dietary ME ($p < 0.05$) (Table 5). Dietary AME of 11.3 MJ kg^{-1} showed higher thigh RW and lower fat RW. The differences within means on CP × AME interaction effect were observed on thigh, drumstick and fat relative weights, but there was no convincing trend.

3.3 *Carcass chemical content*

The influence of dietary protein and metabolisable energy levels on the carcass chemical content of the 17-week-old Venda chickens is shown in Table 6. There was CP × AME interaction effect on dry matter of the breast and leg muscles, ash and protein of the leg muscle ($p < 0.05$). The highest ash content of the leg muscle was recorded on dietary combination of 180 g CP kg^{-1} × 12.0 MJ AME kg^{-1}. Means of CP × AME interaction on ash, fat and protein of the breast muscle and fat of the leg muscle differed significantly, but there was no convincing trend. The protein and ash content of the breast muscle improved with increasing levels of dietary CP ($p < 0.05$). The fat content of the leg muscle decreased with increasing levels of dietary CP ($p < 0.05$). The breast muscle showed more protein content and less fat than leg muscle at all CP and ME levels.

Table 5: *The effect of dietary crude protein and metabolisable energy levels on some carcass parameters (%) of 17 weeks old Venda chickens.*

Parameter	*Dressing*	*Breast RW*	*Thigh RW*	*Drumstick RW*	*Fat RW*
Protein ($g\,kg^{-1}$ DM)					
120	69.05	24.01	16.93^{a}	14.75	4.40
150	70.10	23.47	17.08^{ab}	14.7	3.18
180	69.04	23.92	17.45^{a}	14.29	3.64
SEM †	0.53	0.50	0.21	0.25	0.57
AME ($MJ\,kg^{-1}$ DM)					
11.3	68.89	23.65	17.65^{a}	14.82	2.98^{a}
12.0	70.21	23.83	17.30^{a}	14.29	4.47^{b}
12.4	69.59	23.90	16.63^{b}	14.64	3.48^{ab}
SEM †	0.53	0.50	0.21	0.25	0.58
CP × AME					
120 × 11.3	68.73	23.95	17.16^{ab}	14.77^{a}	3.23^{a}
120 × 12.0	69.87	24.50	16.94^{ab}	14.53^{a}	5.81^{b}
120 × 12.4	68.54	23.57	16.69^{ab}	14.95^{a}	4.13^{ab}
150 × 11.3	69.31	23.72	17.98^{a}	14.92^{a}	2.18^{a}
150 × 12.0	70.70	22.48	17.32^{ab}	15.12^{a}	5.16^{b}
150 × 12.4	70.28	24.21	15.95^{b}	14.20^{ab}	2.20^{a}
180 × 11.3	68.62	23.33	17.84^{a}	14.78^{a}	3.49^{ab}
180 × 12.0	70.06	24.52	17.63^{ab}	13.25^{b}	3.33^{ab}
180 × 12.4	69.95	23.94	17.26^{ab}	14.78^{a}	4.09^{ab}
SEM †	0.91	0.86	0.36	0.43	0.98
P values					
CP	0.3767	0.7102	0.0805	0.3024	0.2773
AME	0.2165	0.9408	0.0036	0.3293	0.0977
CP × AME	0.9306	0.4769	0.2055	0.0747	0.3375

^{a,b} Means with different superscript within a column and a factor differ significantly ($p < 0.05$)
† Standard error of the mean; AME: apparent metabolisable energy; CP: crude protein

4 Discussion

There was a highly significant interaction of dietary CP and AME on weight gain and FCR of six weeks old local chickens. Significant interaction between dietary CP and AME showed the importance of balanced protein to energy ratio to achieve optimum performance (Wang & Liu, 2002). Makinde & Egbekun (2016) reported a CP × AME interaction with high protein and energy levels resulting in higher body weight. In the present study, starter ration containing a CP content of $140\,g\,kg^{-1}$ at different AME levels yielded the lowest weight gain as compared to 170 or $190\,g\,kg^{-1}$ at all AME levels. The results suggest that Venda village chickens would require a dietary combination of $170\,g\,CP\,kg^{-1}$ and $11.0\,MJ\,kg^{-1}$ in the starter diet to maximise weight gain and FCR. These results imply that excess CP ($190\,g\,CP\,g\,kg^{-1}$ feed) has no advantage in village chickens of 0–6 weeks old. The results are in agreement with the findings of Nguyen & Bunchasak (2005) who observed that $170–180\,g\,CP\,kg^{-1}$ gave optimal results in Betong chickens of similar age. Previous studies however, reported higher optimal AME values than the present findings. Nakkazi *et al.* (2015) reported diet containing $180\,g\,CP\,kg^{-1}$ and $11.7\,MJ\,ME\,kg^{-1}$ were sufficient for rearing local chickens during the early growth phase (0–6 weeks), whereas Payne (1990) and Nguyen & Bunchasak (2005) recommended diets containing 11.46 and $12.56\,MJ\,ME\,kg^{-1}$ respectively. Mbajiorgu (2010) observed that slightly higher dietary CP level of $178\,g\,kg^{-1}$ DM and higher energy level of $14\,MJ\,kg^{-1}$ DM allowed for optimal nutrient utilisation for growth in Venda chickens between one and six weeks of age. Alabi *et al.* (2013) found that $12.42\,MJ\,ME\,kg^{-1}$ DM

Table 6: *The influence of dietary protein and metabolisable energy levels on the carcass chemical content of the 17 weeks old Venda chickens.*

Parameter	*Breast muscle*				*Leg muscle*			
	Dry matter	*Ash*	*Fat*	*Protein*	*Dry matter*	*Ash*	*Fat*	*Protein*
Protein (g kg^{-1} DM)								
120	270.29^{a}	45.27^{b}	37.81	892.44^{b}	253.47^{a}	39.86^{b}	141.61^{a}	813.85
150	270.75^{a}	52.31^{a}	35.67	907.03^{a}	246.56^{b}	40.89^{b}	121.65^{b}	824.60
180	265.33^{b}	52.91^{a}	44.67	901.84^{a}	240.20^{b}	42.22^{a}	117.31^{b}	824.72
SEM	1.34	1.34	2.97	3.85	2.46	0.62	5.32	5.43
AME (MJ kg^{-1} DM)								
11.3	267.60	52.90^{a}	38.35^{a}	902.55^{a}	243.98	40.96^{ab}	132.75	816.26
12.0	269.75	50.80^{a}	48.04^{b}	891.33^{b}	249.23	41.76^{a}	128.52	819.28
12.4	269.02	46.80^{b}	31.75^{a}	907.43^{a}	247.03	40.24^{b}	119.30	827.65
SEM	1.39	1.37	2.75	3.62	2.44	0.45	5.29	5.22
CP × AME								
120 × 11.3	270.89^{abc}	46.43^{e}	34.50^{bc}	894.32^{abc}	243.83^{bc}	40.76^{b}	139.64^{b}	824.55^{ab}
120 × 12.0	273.74^{ab}	44.57^{e}	48.82^{ab}	882.87^{c}	263.70^{a}	39.20^{b}	142.06^{a}	813.41^{ab}
120 × 12.4	266.28^{bcd}	44.79^{e}	30.09^{c}	900.00^{abc}	252.89^{ab}	39.60^{b}	143.14^{a}	803.60^{b}
150 × 11.3	264.14^{cd}	58.83^{a}	38.77^{bc}	904.00^{abc}	246.71^{bc}	41.43^{b}	135.32^{c}	805.73^{b}
150 × 12.0	274.18^{a}	52.52^{abcd}	39.46^{bc}	902.39^{abc}	242.98^{bc}	40.37^{b}	118.20^{abc}	826.86^{ab}
150 × 12.4	273.36^{abc}	45.58^{de}	28.76^{c}	914.71^{a}	250.01^{bc}	40.87^{b}	111.44^{bc}	841.12^{a}
180 × 11.3	267.77^{abcd}	53.42^{abc}	41.78^{abc}	909.33^{ab}	241.39^{c}	40.70^{b}	123.31^{abc}	818.37^{ab}
180 × 12.0	260.80^{d}	55.29^{ab}	55.83^{a}	888.73^{bc}	241.00^{c}	45.71^{a}	125.30^{abc}	817.56^{ab}
180 × 12.4	267.41^{abcd}	50.03^{bcde}	36.40^{bc}	907.47^{ab}	238.21^{c}	40.23^{b}	103.32^{c}	838.24^{a}
SEM	2.41	2.36	4.76	6.22	4.22	0.78	9.15	9.04
P values								
CP	0.0098	0.0002	0.0901	0.0309	0.0015	0.0034	0.0044	0.2751
ME	0.5224	0.0074	0.0011	0.0141	0.3254	0.2349	0.1967	0.3110
CP × AME	0.0009	0.0845	0.6745	0.7680	0.0470	0.0109	0.4449	0.0446

^{a,b,c,d,e} Means with different superscript within a column and a factor differ significantly ($p < 0.05$)
AME: apparent metabolisable energy; CP: crude protein

and 12.66 MJ ME kg^{-1} DM at 180 g CP kg^{-1} DM supported optimum growth rate and FCR, respectively, in Venda chickens. In the present study, chickens obtained a FCR of 3.2, which was slightly better than the FCR value of 3.5 noticed by Alabi *et al.* (2013). Differences in responses to dietary CP and AME interactions by local chickens might be attributed to different dietary protein and energy levels in the diet used during experimentation and also breed differences.

Feed intake of the local chickens during both the starter and grower phases was not influenced by the dietary CP level, agreeing with findings of Nguyen & Bunchasak (2005) who also reported no differences in feed intake of Betongs chickens with varying CP levels. Similarly, Ndegwa *et al.* (2001) reported that indigenous growing chickens fed diets containing 170–230 g CP kg^{-1} had similar feed intake. On the contrary, Melesse *et al.* (2013) observed an increase in the level of feed consumption of Koekoek chickens with increasing levels of protein supplementation. The effect of dietary protein on feed intake in poultry species is inconsistent due to genotype, age, body weight, stage of maturity and sex of the bird.

The decrease of feed intake with increasing dietary AME levels may suggest that the birds regulated their intake according to dietary energy. Several authors have shown that chickens eat to satisfy their energy requirements (Scott *et al.*, 1982; Leeson *et al.*, 1996; Velkamp *et al.*, 2005; Nahashon *et al.*, 2006). Onwudike (1983) and Nawaz *et al.* (2006) also found that feed consumption in broilers was lower with higher energy diets. These observations seem to be applicable to the grower phase of the local chickens aged 7–17 weeks in the present study, as chicks aged less than six weeks old failed to adjust their feed intake to match AME in the diet. It can be suggested that the adjustment of feed intake according to dietary ME may be related to age and energy needs for maintenance, growth and production of birds.

In the grower phase, there was no significant interaction of dietary CP and AME levels on weight gain and FCR, but significant differences within means were observed. Weight gain improvement with increasing levels of dietary CP is in agreement with findings of several researchers that increased dietary protein content resulting in improved growth performance (Jackson *et al.*, 1982; Nguyen & Bunchasak, 2005). There were no significant differences observed between chickens that received CP levels of 150 and 180 g kg^{-1} at all dietary AME levels on weight gain and FCR. However, at 150 g CP kg^{-1} feed weight gain decreased with increasing dietary AME levels, with 12 MJ ME kg^{-1} supporting optimum weight gain and FCR. Optimal use of protein is imperative for any feeding system because protein supplements are usually more expensive than energy feeds and wasteful usage increases the cost of production besides leading to environmental degradation (Church & Kellens, 2002). Bikker *et al.* (1994) reported that feeding above the protein requirements did not result in an increase in protein deposition, but nitrogen excretion through the urine increased. Feeding beyond 150 g CP kg^{-1} feed DM, irrespective of AME levels, yielded no improvement in weight gain and FCR, suggesting 150 g CP kg^{-1} feed DM as a threshold level for optimum production of Venda chickens. It can be concluded that the dietary combination of 150 g CP kg^{-1} × 12.0 MJ ME kg^{-1} maximised weight gain and FCR during the grower phase of the local chickens used in the present study. Nguyen *et al.* (2010) reported no significant interaction effect between protein and energy on any performance parameters measured during the growing phase of Betong chickens and subsequently recommended 190 g CP kg^{-1} and 12.56 MJ AME kg^{-1}, which are higher than the present study findings. Makinde & Egbekun (2016) observed no CP × AME interaction on feed intake and weight gain for 6–12 weeks old Fulani ecotype chickens, but recommended 200 g CP kg^{-1} and 12.56 MJ ME kg^{-1}. The recommended AME in the grower phase is in accordance with those recommended by NRC (1994) (12.14 MJ kg^{-1}) and Tadelle & Ogle (2000) (11.99 MJ kg^{-1}). Variations in age, genotype of the chickens and the environment may explain observed differences in nutritional requirements between studies.

A study on the assessment of the nutrient adequacy from the crop contents of free-ranging indigenous chickens in the rural villages of the Vhembe District, South Africa observed CP content of 123 g kg^{-1} and 118 g kg^{-1} for growers and adults, respectively (Raphulu *et al.*, 2015b). According to NRC (1994), the recommended levels of CP in diets for growing chickens (not broilers) range from 150 g CP kg^{-1} DM to 200 g CP kg^{-1} DM and for mature chickens from 100 g CP kg^{-1} DM to 160 g CP kg^{-1} DM. It appears therefore as if the birds raised under village condition did not receive adequate levels of dietary protein to support efficient production. Protein deficit of 27 g kg^{-1} for growers between feed resource base for scavenging chickens in the rural villages and the required nutrients observed in the present study has to be compensated with supplemental feed. No information is available on the performance of adult indigenous chickens fed different protein and energy levels raised in closed confinement.

The improvement of FCR with increasing levels of energy is in close agreement with results of Nawaz *et al.* (2006) and Holsheimer & Veerkamp (1992). The obtained mean FCR during the grower phase in the present study was slightly better than that reported by Kingori *et al.* (2003) and Chemjor (1998), who found FCR values of 5.8 and 5.2, respectively, for indigenous chickens of 14–21 weeks old.

The shares of major basic carcass parts (breast, drumsticks and thighs) and the presence of certain tissues in them, as well as the chemical composition of the muscular tissue, are regarded as vital parameters determining broiler meat quality (Holcman *et al.*, 2003). Carcass relative weights of the local birds were not affected by dietary protein or AME levels, with the exception of thigh yield that decreased with increasing levels of dietary AME. The results of the present study confirm other reports where dietary protein did not affect carcass yields (Nguyen & Bunchasak, 2005; Iheukwumere *et al.*, 2007; Melesse *et al.*, 2013). Makinde & Egbekum (2016) observed no significant effect of dietary ME on carcass yield in Fulani Ecotype chickens. The observed decrease of thigh RW with increase in dietary AME is similar to the results of Nguyen *et al.* (2010) where high energy levels decreased wing and leg relative weights. Feeding above 120 g CP kg^{-1} DM improved ash content, protein content of the breast and decreased fat content of the muscle and these parameters were not affected by dietary AME levels. Furlan *et al.* (2004) also reported that carcass protein was affected by the level of protein in the diet. The increase in dietary protein improves carcass protein by reducing lipid deposition and increasing protein content (Gous *et al.*, 1990). An increase in protein intake induces a decrease in the protein to energy ratio that causes a reduction in energy intake relative to the protein intake, resulting in decreasing body fat percentage (Ghahri *et al.*, 2010). Feeding 150 or 180 g CP kg^{-1} feed DM at any AME level yielded similar values. Results in the present study imply that dietary combination of 150 g CP kg^{-1} feed DM and 11.3 MJ ME kg^{-1} feed DM may optimise carcass chemical composition of 17 weeks old chickens, since there was no dietary AME effect observed. The fat content of the leg muscle was influenced by the changes in dietary protein. Higher protein diets induce higher meat protein content, while reducing the fat content of muscles (Si *et al.*, 2001; Bogosav-Boskovic *et al.*, 2010). The influence of dietary protein on the carcass chemical content seems to be dependent on the specific portion. In the present study, the breast muscle showed higher protein and less fat content when compared to leg muscle at all CP and AME levels. Ferket & Sell (1990) reported that breast meat contains more protein than leg meat. Diaz *et al.* (2010) related the differences in CP effect on the very structure of these portions, with breast being mostly composed of white fibres, as opposed to drumstick made up of muscles that contain more red fibres, which differ in metabolic function.

5 Conclusions

During 0–6 and 7–17 weeks, unsexed local Venda chickens would require dietary combinations of 170 g CP kg^{-1} feed DM and 11.0 MJ ME kg^{-1} feed DM and 150 g CP kg^{-1} feed DM and 12 MJ ME kg^{-1} feed DM, respectively, in their diets to optimise body weight gain. Neither dietary CP and AME nor their interactions influenced carcass relative weights, except for thigh yield that decreased with increasing AME levels. The dietary combination of 150 g CP kg^{-1} feed and 11.3 MJ ME kg^{-1} feed optimised ash content of muscles, protein content of the breast and fat content of the leg muscle of the 17 weeks old local chickens. It can be recommended that supplementation of 27 g CP kg^{-1} feed to grower scavenging chickens, would be enough to improve chicken production in the rural villages. Locally available feed resources high in protein like groundnuts, beans, meat and bone scraps, and insects should be used as supplement to compensate the nutrient intake deficit of scavenging chickens and also to reduce input costs.

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CHAPTER 7

General Conclusion, Critical Review and Recommendations

The rural communities keep indigenous chickens for supply of income and high quality food protein in the form of meat and eggs and finally for religious and cultural considerations. The access to quality protein by the rural communities may alleviates the problem of malnutrition. Whereas, sales of indigenous chickens has a potential of reducing poverty and employment creation. In order to sustain reliable supply of protein and job opportunities, productivity of indigenous chickens in the rural communities need to be improved. There is a need to identify improvement strategies in the rural communities without changing the low input production system. The present study was carried out to generate information on the nutritional status of the feed consumed by scavenging chickens in different seasons, changes in the development of digestive tract and growth performance , meat yield and carcass composition of the FRIS chickens and finally nutrient requirements.

Nutrient adequacy from the crop contents of free ranging indigenous chickens in the rural villages of the Venda region was assessed. The FRIS chickens consumed grains, household (HH) waste of plant origin, HH waste of animal origin, seeds, plant materials and worms and insects, grit and undistinguishable materials. The availability of grains, household (HH) waste of plant origin and HH waste of animal origin of the crop contents varied with season, with the more grains and HH waste of animal origin obtained in autumn and winter, respectively. Variability in the components of the dry crop contents due to season did not have any impact on the nutrient composition (crude protein and AME) of the crop content.

Crop contents of chickens reflect not only the availability of nutrients in the environment, but also the selective feeding habits of birds, which are related to their nutritional requirements. However, crop nutrient contents at any time do not indicate total daily feed intake or utilization of nutrients. Therefore, any recommendation based on crop content of nutrients should take into consideration that crop content is only a guideline, because there are many other important factors such as scavenging area, foraging habit and density of the chickens. The FRIS chickens in the Vhembe District had access to diet that were high in energy (12.34 MJ ME\kg to 12.91 MJ ME\kg), low in protein (113-130 g\kg DM), high in NFE (590-649 g\kg DM), and low in CF (<40 g\kg DM). Free-ranging chickens probably consumed insufficient quantities of protein, Ca and P to support efficient production. Supplementation of high quality protein, Ca and P to free ranging chickens would be beneficial to free ranging indigenous chickens, but for practical and economic reasons it might be more difficult to achieve under these subsistence husbandry conditions.

The concentration of Al, Cu, Fe, Mn, Zn and Co in the crop contents were above the requirements of poultry, though below the MTL of the element, except for very high Fe and Al concentrations. It is suggested that most of these elements were obtained through ingesting soil and dust, and consequently would probably have a relatively low bioavailability in the bird, including Al, which is considered non-toxic. However, the high Fe concentrations might have also originated from cast iron pots used for cooking food in the region, and Fe from these pots could have accumulated in the feed consumed by the birds. There seems to be no need for the supplementation of trace minerals in the diets of the birds in the region, though further studies might be necessary to establish the bioavailability of the elements in the feed consumed by the birds.

Identifying deficiencies in the diets of free ranging chickens in rural communities is valuable in planning strategy to overcome nutritional problems. A deficit between SFRB and the required nutrients has to be compensated with supplemental feed. In a study to determine CP and AME requirements of the indigenous chickens under controlled environment, diets containing 170 g/kg CP x 11.0 ME MJ/kg and 150g/kg CP x 12 ME MJ supported optimal feed intake, growth rate, feed conversion ratios and carcass yields during starter (0-6 weeks) and grower phase (7-17), respectively. The FRIS grower chickens had access to diets with protein content of 123 g\kg DM in the rural communities. The protein deficit of 27 g/kg for growers between feed resource (123 g\kg DM) base for scavenging chickens in the rural villages and the protein requirements under controlled environment (150 g/kg) has to be compensated with supplemental feed. It can be suggested that 27 g/kg DM of protein from locally available feeds would be enough to supplement FRIS grower chickens in the rural communities. It should be noted that rural communities could not afford expensive feeds, the use of locally available feed resources high in protein like soybean, groundnut, meat and bone scraps, and insects should be used as supplement to compensate the nutrient intake deficit of scavenging chickens. The rural communities should be encouraged to increase production of soybean and groundnut as protein supplements.

The adult free ranging scavenging chickens had access to diets with CP content (118 g/kg DM) from the components of the crop content. Supplementation of protein to adult FRIS chickens for maintenance might not be necessary as protein requirements could be met through SFRB. No information is available on the performance of adult indigenous chickens fed different protein and energy levels in closed confinement. However it can be recommended that supplementation with ≤ 27 g/kg DM of crude protein to mature FRIS chickens in the rural communities could bring changes in growth rate, carcass yields and also egg production

A study was conducted in the rural communities to determine the development of the digestive tract and growth performance of the FRIS chickens under village management. The storage organs of the FRIS chickens peaked at day 4 while small intestine and its segments peaked at day 7-14. The segments of the digestive tract of the free ranging chickens under village management were characterized by slow growth. Lack of feeds supply to young chicks impaired the development of the digestive tract and limited growth in general. The highest mortality (57.41%) was obtained in chickens younger than six weeks of age. Lack of feeds and predators were indicated by farmers as responsible factors for high mortalities. The provision of housing and feeds containing dietary combination of 170 g/kg CP x 11.0 ME MJ/kg to young chicks younger than six weeks could help in improving FRIS chicken production. Chicks older than six weeks might be able to escape attacks from the predators and successfully search for food.

Male and female free ranging chicken up to six weeks old weighed 189 and 147g, with growth rate of 4.10 and 3.10g\day, respectively. While a 20 weeks old free ranging chickens male and female chickens weighed 1097 and 676g with a growth rate of 9.96 and 4.13g\day, respectively. Chickens under controlled environment and fed (170 g/kg CP x 11.0 ME MJ/kg) had a weight gain of 400 g at 6 weeks and while 7-17 weeks old (fed 150 g/kg CP x 12 ME MJ) showed weight gain of 1332 g. The huge difference in weight gain between the FRIS chickens in the rural communities and well fed indigenous chickens under controlled environment would be due to nutritional deficiency. The gap in nutritional status could be bridged through nutrients supplementation and in turn the growth performance of the FRIS chickens could be improved. Adequate feed supplementation is necessary for improved productivity in the FRIS chickens in the rural communities. A well balanced supplementary feed to the FRIS chickens in the rural communities would help in improving productivity of chickens, which in turn could create jobs, alleviate poverty and malnutrition.

The FRIS chickens were slaughtered to determine the meat yield and carcass chemical composition of the VIS chicken and also the influence of season on the meat yield and carcass composition. The slaughter weight, carcass weight, mass of the thigh, mass of the drumstick, breast yield of both grower and adult chickens were not influenced by season. Season had effect on the protein content of the grower chicken breast muscle and fat content of the adult chicken leg muscle. Gender of the VIS chickens influenced slaughter weight, carcass weight, mass of the thigh, mass of the drumstick, breast yield and carcass composition (fat and protein content of the leg muscle). The thigh and drumstick yield of VIS chickens were higher than previously found for broilers, but the meat of the VIS chickens contained less and cruder protein than the meat of broilers. The meat from VIS chickens provided a constant nutrient supply throughout the year to rural communities and could suggests that the supplementation of protein to human diets in the rural communities might not be necessary if sufficient chicken meat is available. Keeping VIS chickens has a potential to solve the problem of malnutrition, improve food security and overall health status of the Venda rural communities.

Recommendations

Based on the above conclusion, the following recommendations are forwarded:

- Provision of shelter to newly hatched chicks for the first six weeks might be important tool in improving FRIS chickens production, and protection from predators should be provided. The housed chicks should be fed dietary combination of 170 g/kg CP x 11.0 ME MJ/kg formulated using locally available feed resources.

- The FRIS grower chickens would require a supplementation diet with 27 g/kg DM protein to optimize growth rate and carcass yields and should be given late afternoon.
- Supplementation of protein to adult FRIS chickens for maintenance might not be necessary as protein requirements could be met through SFRB. In order to improve growth, carcass yields and also egg production to adult chickens diet containing ≤27 g/kg CP might be enough as supplement.
- The FRIS chickens had access to diet with high energy, energy supplementation is not be necessary.
- Supplementation of Ca and P seems to be necessary to improve the nutritional status of scavenging chickens
- There is no need for the supplementation of trace minerals in the diets of the FRIS chickens
- For intensive production system, indigenous chickens would require a dietary combination of CP 170g/kg DM x ME 11.0 MJ/kg and CP 150 g/kg DM x ME 12.0 MJ/kg during starter (0-6 weeks) and grower phase (7-17 weeks), respectively, to optimize growth and carcass yields.
- Locally available feeds resources that are high in protein like bean, groundnut, meat and bone scraps and insects should be used as supplement to compensate the nutrient intake deficit of scavenging chickens and also to reduce input costs. Communities should increase the production of beans and groundnut on their fields.
- Excess kitchen waste and cattle dung should be stored as compost for the production of worms for feeding chickens as a source of proteins.
- Calcium should be supplemented to FRIS through addition of wood ash to their diets, wood ash could be mixed with kitchen waste.
- The FRIS chicken meat provided constant nutrient supply of throughout the year to rural communities, supplementation of protein to rural communities might not be necessary if sufficient chicken meat is available.
- The meat of FRIS chickens contain less fat and more proteins than broilers, but the rural communities prefer broiler meat than FRIS chicken meat. The FRIS chickens farming and meat consumption awareness should be encouraged to the rural community, especially to the youth

- Rural communities should be encouraged to have planted pastures in their yards for more locusts production to be scavenged by chickens.
- There is a strong need for disease control to reduce chicken mortality.
- Training of farmers and extension officers focusing on nutrition and feeding and disease control could help to improve productivity of FRIS chickens.

Further research

Further research that needs to be conducted:

- To determine effect of early feed supplementation on the development of the digestive tract and the performance of FRIS chickens under village management.
- The potential of locally available feed ingredients in formulating cheap supplements for scavenging chickens.
- To establish the bioavailability of the elements in the feed consumed by the FRIS