Nutritional quality of protein-rich feed resources for scavenging chickens

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By

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DECLARATION

I, **Cyprial Ndumiso Ncobela,** declare that;

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2. This dissertation has not been submitted for any degree or examination at any other university.

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ABSTRACT

For sustainable intensification of village chickens, it is imperative to explore the potential of non-conventional animal protein (NCAP) feed resources. The broad objective of the study was to assess the nutritional quality and potential of scavengeable feed resources for scavenging chickens. A survey was conducted in 239 resource-poor households of Msinga local municipality in uMzinyathi district, KwaZulu Natal, using pre-tested semi-structured questionnaire, to assess farmer perceptions on the use of NCAP source for scavenging chickens. Females were the prominent heads of households, followed by males, and then youths. Chicken feed shortages were among major challenges to chicken production. A logistic regression model showed that farmers who did not provide overnight housing to their chickens were likely to not provide any supplementary feeding. More than half of the farmers (56.6 %) were aware that NCAP sources have a huge potential to be used as protein supplements to enhance sustainable intensification of scavenging village chickens. Common animal protein sources were termites, earthwoms and locusts.

Before attempting to supplement chickens using NCAP sources, it is critical to firstly understand the nutritional quality and amino acid composition of diets that scavenging chickens consume. The second trial, therefore, used a total of 120 Ovambo chickens were used to detrmine the effect of season on nutritional quality and amino acid composition of feeds consumed by scavenging hens and cocks using their crop and gizzard contents. The chickens were randomly purchased during the rainy, post rainy, cool dry and hot dry seasons (15 hens and 15 cocks each season). Fresh crop and gizzard content weights were high ($P < 0.05$) during the cool dry season. The cereal grain weights were high ($P < 0.05$) during cool dry and hot dry seasons. The weights of animal protein sources were higher ($P < 0.05$) during the rainy and post rainy seasons. The levels of crude protein (CP), crude fibre, acid detergent fibre, neutral detergent fibre, nitrogen free extract and true metabolisable energy varied ($P < 0.05$) with season. There was a significant season and sex interaction on the levels of dry matter, body weight, CP and lysine content. Hens had a higher ($P < 0.05$) CP and lysine content during the rainy season than cocks. Histidine, serine, arginine, threonine, cysteine and lysine contents varied with seasons. It was conclude that nutritional quality and amino acid composition vary with season and sex of bird.

Keywords: Amino acid composition; Crop contents; Earthworms; Flock size; Non-conventional animal protein sources; Nutritional quality; Resource-poor farmers; Scavenging cocks; Scavenging hens; Termites; Season.

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DEDICATIONS

This dissertation was written to honour and express affection to……..

My mother, Fusi Elizabeth Ncobela;

My beloved son, Simukelo Hlelolwenkosi Ncobela;

Late father, Mahlasela Ncobela;

Late Brother, Khanyile Ncobela (who utimely demised while I was less than one year old)

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LIST OF ABBREVIATIONS

Abbreviation	Description	units
ADF	Acid detergent fibre	g/kg
AOAC	Association of Official Analytical Chemists	none
CF	Crude fibre	g/kg
CL	Cooking loss	g/ 100g
CP	Crude protein	g/kg
DM	Dry matter	g/kg
EE	Ether extracts	g/kg
LW	Live weight	g
ME	Metabolisable energy	MJ
NCAP	Non-conventional animal protein	none
NDF	Nutrient detergent fibre	g/kg
NFE	Nitrogen free extracts	g/kg
NRC	National Research Council	none
PDIFF	Probability of difference	none
SAS	Statistical Analysis System	none
SFR	Scavengeable feed resources	none
SS	Sewage sludge	none
TME	True metabolisable energy	MJ/kg
UKZN	University of KwaZulu-Natal	none
WHC	Water holding capacity	%

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CHAPTER ONE: General Introduction

1.1 Background

The majority of resource-constrained farmers in Southern Africa are largely food insecure (Tarwireyi and Fanadzo, 2013). This is because most rural households face acute protein shortages, resulting in malnutrition (Kingori *et al*., 2010). Village chickens have a potential to alleviate protein shortages in rural households because they are kept by almost every household (Mtileni *et al*., 2013). They provide the highly nutritious meat and eggs. Village chickens are also used for cultural and social activities in rural communities such as traditional ceremonies and welcoming of relatives (Muchadeyi *et al*., 2004; Mapiye *et al*., 2008). They also have few, if any, religious prohibitions in Southern Africa.

Village chickens are usually raised under the extensive system and, to a lesser extent, semi-intensive system with little or no investment in housing, feeding and health care (McAinsh *et al*., 2004). The system is low input-low output, where birds scavenge for feed from the surrounding environments and are supplemented with minimal amounts of grain and kitchen wastes. Consequently, the productivity levels are low (Mwalusanya *et al*., 2001; Kingori *et al*., 2003). Feed shortages are considered to be among the major constraints to chicken productivity (Guèye, 2009; Kingori *et al*., 2010). The bulk of the dietary supplements given to village chickens are rich in energy and have marginal levels of proteins (Goromela *et al*., 2006). Low protein content is, therefore, likely to be the limiting factor in village chicken production. The contribution of the scavengeable feed resources (SFR) to the diet of village chickens is largely unknown. The protein quality of the feeds that scavenging chickens consume need to be characterized. The use of crop and gizzard contents, although destructive, indicates the nutritional quality of the diets selected.

Conventional protein-rich feeds, such as soyabeans, are rarely used to feed village chickens because they are expensive (Minh, 2005; Khusro *et al*., 2012). In Southern Africa, the potential non-conventional animal protein (NCAP) sources that should be explored include earthworms, locusts, termites, maggots, caterpillars, cockroaches and snails. Depending on location and season, these NCAP sources form a huge component of the scavengeable feed resources. The NCAP sources contain up to 600 g/kg crude protein (Ravindran and Blair, 1993). Chickens fed on grasshoppers, for example, produced meat that had a preferred taste and higher market price than those fed on conventional protein source (Mapiye *et al*., 2008; Khusro *et al*., 2012). The utilisation of NCAP sources, therefore, has the potential to produce organic products that can fetch high prices on the market, thereby improving the economic well-being of resource-limited households.

1.2 Justification

For sustainable development of village chicken systems, the views of the resource-poor households who are the primary intended targets of the technologies to be developed should be considered. Traditional, cultural and social statuses of communities and households influence their acceptance of and adoption of technologies. Farmer perceptions on the contribution of the scavengeable resource base indicate their readiness to use NCAP sources in feeding village chickens. Selecting a suitable feed resource should be based, not only on their nutritional value, but also the circumstances of the views of the farmer. It is possible to have nutrient-rich NCAP sources but is acceptable to farmers to be fed to chickens.

Determining nutritional composition of scavenging chickens helps to develop appropriate feed supplementation strategies to improve productivity of scavenging chickens. There is a need to determine the available feed resource and nutrients obtained by the chickens. This would assist to quantify the amounts of supplementary feed needed to optimize village chicken productivity (Sonaiya, 2004). Understanding seasonal changes in quantity and quality of feed resources would establish periods of the year when nutritional supplementation could be needed to optimise chicken productivity. The nutritional quality of contents of the crop and gizzard is the best estimation of what feed resources are available to the chickens. Comparison between hens and cocks on feed consumption has not been done. The majority of the available reports focus on hens and growing chickens. It is, therefore, likely that these different sexes my exhibit different ability to hunt for feed resources to meet their needs for production. Understanding the interaction between sex of bird and season on nutritional quality is also of relevance to municipalities and the Department of Agriculture, for them to formulate strategies to fight poverty, food insecurity and create wealth among resource-poor households. The study also lays a foundation for poultry nutritionists to determine the estimations of nutrient requirements for scavenging hens and cocks.

1.3 Objectives

The broad objective of the study was to assess the potential of scavengeable feed resources for scavenging chickens. The specific objectives were to:

1. Assess farmer perceptions on the use of non-conventional protein sources for scavenging village chickens; and

2. Determine seasonal changes in nutritional quality and amino acid composition of hens and cocks

1.4 Hypotheses

The hypotheses tested were that:

1. The perceptions of farmers on feed resources for scavenging chickens vary with socio-economic status of the households; and

2. Hens and cocks have different nutritional quality and amino acid composition at different seasons.

1.5 References

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CHAPTER TWO: Literature review

Part of the review has been submitted as review paper to Animal Feed Science and Technology (Under review) see **Appendix 6.1**

2.1 Introduction

Scavenging chickens play an enormous role in rural livelihoods through egg and meat provision. Sonaiya (2007) defines scavenging village chickens as any genetic stock of improved or unimproved poultry raised extensively or semi-extensively in relatively small numbers. These chickens roam around to find feed from the surroundings. The overall diet and nutritional composition of scavenging chickens vary considerably. Since scavenging chickens provide protein-rich products, protein content of the diet becomes critical. This chapter reviews the challenges to village chicken production and factors affecting availability of feed resources for scavenging chickens. The common NCAP sources are also discussed.

2.2 Overview of chicken production in South Africa

The poultry industry in South Africa is mainly characterized by exotic and scavenging village chickens. Exotic chickens consist of broilers and layers for meat and eggs respectively. These chickens are reared under intensive systems in the commercial industries, urban and partly semi-urban areas (Olwande *et al*., 2010). In this system, there is a high input, production and risk (Bishop, 1995). Broilers and layers under intensive system are attributed with high capital investments, mechanization, specialization and improved stock (Mcainsh *et al*., 2004).

In spite of the increase in production of imported commercial birds, the productivity of scavenging village chickens found in communal production systems is low (Mack *et al*., 2005;

Mapiye *at al*., 2008; Guèye, 2009). These chickens contribute to a maximum of 90 % of the total poultry products in developing countries (Mack *et al*., 2005) and are commonly reared with little or no human interventions (Olwande *et al*., 2010). They are usually owned by women and children. The chickens supply high quality protein from meat and eggs and also provide income to poorly resourced smallholder households, particularly women (Guèye, 2009). Scavenging chickens are, however, faced with a lot of challenges that hinder them to reach optimal growth and egg production.

2.3 Challenges to scavenging chicken production

There are numerous challenges that limit the productivity of scavenging chickens. There is need for innovative and appropriate strategies to address these challenges. The major challenges are the high prevalence of diseases and parasites, poor housing, predation, poor market access and low availability of feed resources.

2.3.1 High prevalence of diseases

Disease outbreak is a main challenge that reduces number of birds and productivity (Dessie and Ogle, 2001; Permin and Pedersen, 2002). Newcastle disease, for example, has the ability to kill the entire flock (Naidoo, 2003; Alexander *et al*., 2004; Kumaresan *et al*., 2008). In a random survey of village chickens in rural poultry farms in Benin, 65 % were seropositive for the Newcastle disease virus (Chrysostome *et al*., 1995). Inadequate supply of required nutrients could reduce the immunity of the birds, making them weak and susceptible to disease infections (Permin and Pedersen, 2002).

2.3.2 Parasite infestation

Scavenging chickens are always in direct contact with parasite vectors, soil and faeces (Abdelqader *et al*., 2008) and have a high possibility of cross-infection with wild birds through contact (Mukaratirwa *et al*., 2001; Magwisha *et al*., 2002). The chickens often search for feed in shallow layers of the soil which is contaminated with living organisms that act as hosts for gastro-intestinal parasites (Hassouni and Belghyti, 2006). They also search in underground composts in the cattle kraals and river banks for nutrients. Scavenging in these localities predisposes birds to parasites.

Mwale and Masika (2009) reported that gastro-intestinal parasites are more dangerous than external parasites. Infestation of internal parasites causes anaemia and hinders productivity (Hassouni and Belghyti, 2006; Mwale and Masika, 2009) and may results in subclinical disease (Magwisha *et al*., 2002). They also lead to poor body weight gain and emaciation (Mungube *et al*., 2008). The most common gastro-intestinal parasites include helmithnths, coccidia and nematodes. Prevalence of helminths can be as high as 95 % (Phiri *et al*., 2007). Nnadi and George (2010) reported prevalences of 62, 36 and 2 % for lice, fleas and mites, respectively. Lice, fleas, avian fawl ticks and mites suck blood. They are a major challenge when reported in high frequencies (Mungube *et al*., 2008). In cases where housing hygiene is poor, the prevalence of ectoparasites could be high (Mungube *et al*., 2008).

2.3.3 Poor availability and quality of housing

Quality of housing reflects how a household values its chickens. Therefore, availability of housing differs from household to household. Mtileni *et al*. (2013) reported that 34 % of farmers did not provide housing. On the other hand, Badubi *et al*. (2006), in Botswana, observed that only 35 % s of the chicken farmers did provide housing. The structure of chicken houses is either grounded or raised (McAinsh *et al*., 2004). It is constructed with local available materials (Naidoo, 2003) to prevent predation, theft, extreme weather and provide shelter for egg-laying brooding hens (Petrus, 2011). These materials consists of wooden poles, branches or bricks, mesh wire, iron sheets, asbestos sheets and canvas roofing, perches (McAinsh *et al*., 2004). For brooding hens, material used comprises of cardboard boxes, buckets, drums and dry grass (Naidoo, 2003; McAinsh *et al*., 2004). Inadequate housing for brooding hens is likely to have hens laying eggs in the same locale, resulting in reduced egg hatchability.

When chickens are not housed at night, they could be severely vulnerable to nocturnal predators, theft, disease and parasites. In addition, feed supplementation practises could be a bias to birds that are not available at the time of feeding. When practicing supplementary feeding, housing could be vital by ensuring and simplifying supplementation for the entire flock before scavenging or during late hours of scavenging. Absence of housing also creates inconveniences when gathering birds for vaccination or any handling needs. Muchadeyi *et al*. (2004) reported that chicken house constructed from wooden poles was effective to reduce ectoparasites infestation.

2.3.4 Predation

Common predators are dogs, cats, mongooses, snakes, eagles, wild cats and hawks (Muchadeyi *et al*., 2004; Mapiye and Sibanda, 2005). Predation occurrence is largely seasonal, being dominant in rainy season and cool-dry seasons (Mapiye and Sibanda, 2005; Gondwe and Wollny, 2007). Predation is more common in chicks (Khalafalla *et al*., 2000; Olwande *et al*., 2010).

2.3.5 Poor marketing access

There is a lack of organized marketing channels in most developing countries for scavenging chicken production and products. Farmers directly sell live birds and eggs at the gate or local village markets to consumers and small retailers. The small retailers then convey birds to urban and semi-urban areas where they sell in large city centres (Das *et al*., 2008). Transaction costs are high and the farmers are, therefore, not willing to sell. The middleman benefits more than farmers in the marking channel (Mlozi *et al*., 2003). The markets of these local village markets are not reliable and erratic. Meseret *et al*. (2011) reported that price instability and seasonal demands are the major constraints in the marketing of eggs and live chickens. The price of the birds is also influenced by weight, feather colour, combo type and sex (Mekonnen, 2007).

2.3.6 Low availability and poor quality of feed resources

Scavenging village chickens roam around the surroundings to find feed that is available at that time. Common feeds available for chickens include cereal grains, sorghum, kitchen remnants, insects and worms, seeds, green forages, sand and grits (Goromela *et al*., 2006). In addition, these feed resources are inadequate in quantity and quality to meet bird's protein requirements for maintenance and production. The scavengeable feed resource (SFR) base is likely to be deficient in protein rather than energy because energy feed resources, such as green materials and household-based supplement such kitchen waste and maize, are almost ever-present around the homestead. Protein sources are scarce, seasonal and low in proportion, therefore, the optimal growth and production is compromised. Sonaiya *et al*. (2002) reported that, during early and late harvest, SFR had as low as 21 g/kg CP.

Under extensive production system, village chickens can obtain about 67 g/kg of CP (Kingori *et al*., 2003; Hanyani, 2012). This indicates that physical and nutritional composition of the diet of scavenging chickens is poor due to the low protein content. In addition, consumption of materials of no nutritional value such as feathers, hair, polyethylene plastics, pieces of glass, brick paper products, buttons also reduce the nutritive value of the diet. The SFR vary season, climate, insect cycle, type of bird and their nutrient requirement, location and land preparation, nature of location, households system, farming system, social habits and flock biomass (Minh, 2005). It is, therefore, crucial to understand these factors in some detail.

2.4 Availability and quality of feed resources for chickens

There is a need to determine and characterize factors affecting availability and quality of feed resources, as a first step in understanding the nutrient consumption for scavenging chickens.

2.4.1 Season

Cereal grains are abundant during the harvest time (Mwalusanya *et al*., 2002). Green materials and insects and worms are dominant in the rainy season (Mekonnen e*t al*., 2010). High amount of green materials consumed during non-harvesting season are a result of large consumption of emerging sprouts (Mwalusanya *et al*., 2002). Insects and worms are mostly found in moist environments and (Goromela *et al*., 2006).

There is a variation on the quality of feed resources with season. The CP content is high in the rainy season (Goromela *et al*., 2008; Mekonnen e*t al*., 2010). There is high DM and ME consumption in the harvesting season due to high energy-rich feedstuffs such as grains (Rashid *et al*., 2005). Calcium and phosphorus contents are usually higher in rainy season than during the dry season (Goromela *et al*., 2008), due to large consumption of green materials that contain have high calcium and phosphorous (Mekonnen e*t al*., 2010). Information regarding vitamins availability for birds is scant.

2.4.2 Type of bird

Mekonnen e*t al*. (2010) reported that insects and worms were more abundant in hens than the growers. The proportion of the grains in the crop contents of laying birds was lower than that of growing birds (Goromela *et al*., 2006). Laying hens tend to consume more feed materials that are rich in CP, calcium and phosphorous than growing birds, probably due to their high requirement for egg production (Rashid *et al*., 2005). When choice feeding is practised, laying birds are likely to prioritise picking up calcium and CP-rich feeds (Guranatne *et al*., 1993). Information on the feeding behaviour and nutritional composition of diets consumded by cocks is, to our knowledge, not available. This is depite the fact that cocks are the mostly slaughtered class of chickens in the households. It is, crucial that feeding behaviour and nutritional quality of cocks be determined. Their nutrient requirements are likely to differ to that of other classes of chickens.

2.4.3 Location and land preparation

Minh *et al*. (2006) reported that the proportions of insects, worms and grains were significantly higher for the lowland compared to the highland villages, while the proportion of green materials was higher in the highland than in the lowland village. The concentration of CF, ash, calcium, hosphorus and ME are also considerably lower for the lowland compared to the highland villages. Land preparation includes burning of crop residues, bushes and shrubs in the field (Goromela *et al*., 2007). It encourages the relocation of insects that were available for chickens. Cleaning the yard also has the potential to eradicate and deplete feed resources available for scavenging chickens.

2.4.3 Flock biomass and management

Flock biomass is defined as the number in the flock times the mean live weight (Goromela *et al*., 2006). The diet composition of bird varies with household size and village flock biomass (Dessie and Ogle, 2001). When there is high number of human dwellings in the village, land size available for chicken to scavenge from become small, resulting mixing the flocks between and among neighbours (Goromela *et al*., 2007). This induces competition among chickens in the village resulting in chicks and growers being victims (Roberts, 1991). Flock size, feed availability, population density, agricultural activities and predators also influence land availability and travelling distance to scavenge for feed (Awuni *et al*., 2009). Presence of other livestock has an impact on the chicken diet. Goromela *et al*. (2007) reported that kitchen remnants were also consumed by dogs, pigs and goats. Mwalusanya *et al*. (2002) also reported that pigs and chickens compete for kitchen left-overs.

2.5 Protein sources for scavenging chickens

Fishmeal, mash, soybean, sunflower, meat meal, bone meal and blood meal are the conventional protein supplements for chickens. The quality of these protein supplements vary with the source of protein and processing methods. The feed resources are expensive and therefore, unaffordable to resource-poor chickens farmers. The high prices for the conventional feedstuffs make it worthwhile for resource-limited farmers to consider using non-conventional animal protein (NCAP) sources.

There is a growing interest in optimizing the dietary protein concentration in scavenging chickens using locally available NCAP sources. Non-conventional animal protein sources are animal feed resources that are not traditionally used to formulate feed for chickens. These feed resources include earthworms, locusts, termites, maggots, caterpillars, cockroaches and snails.

2.5.1 Earthworms

Earthworms feed on a variety of organic wastes and have high propagative rates, easy to process and store. Thus, they also have a huge potential to be used as protein sources in chicken feeding (Ibáñez *et al.,* 1993). Earthworms are the ingredient constituent that makes up the diet for scavenging chickens. Therefore, they are a promising source of protein to chickens. They are abundant availability in rainy season and in swampy environments. In addition, they are easy to propagate and have high levels of protein that is rich in amino acids. The quality of earthworms varies with and within the species. *Eisenia fetida* were nutritional better than *Allolobophora caliginosa, Pheretima guillemi* (Zhenjun *et al*., 1997). Reinecke *et al*. (1991) reported that *Eisenia fetida, Eudrilus eugeniae* and *Perionyx excavates* contain 661, 584 and 616 g/kg of CP, respectively. Earthworm meal has equitable amino acids with notably high lysine content (Table 2.1). Calcium and phosphorus is, however, low due to lack of exoskeleton in earthworms (Ravindran and Blair, 1993). Ten percent earthworm meal showed higher (63 %) digestibility of CP and gave higher lactic acid bacteria counts (Loh *et al*., 2009). Protein from earthworms can be easily metabolized and utilized by animals (Zhenjun *et al*., 1997).

Earthworms also have 270 g/kg of crude fiber and high values of amino acid (Ibáñez *et al.*, 1993). Loh *et al*. (2009) reported that final body weight, growth rate and feed efficiency of broilers fed 15 % earthworm meal were better than the control group.

Table 2.1: Chemical and amino acid composition of potential non-conventional animal protein sources

Components	Earthworm meal	Maggot meal	Termite meal	Snail meal	Grasshopper meal	Silkworms pupae meal
Dry matter (g/kg)	906	964	964	-	-	949
Crude protein	546	375	463	600	654	503
Ether extract	73.4	192	301	60	83	164
Nitrogen free extract	-	196	90	-	-	103.4
Ash	212	231	36	100	351	120.3
Calcium	15.5	0.3	2.3	20	181	27.7
Phosphorus	27.5	0.5	3.8	10	9.9	10.5
Amino acids (g/kg)						
Aspartic acid	-	16.9	-	-	3.03	9.31
Glutamic acid	-	25.3	-	-	6.39	13.90
Serine	2.71	147	-	-	2.33	4.65
Histidine[#]	1.36	19	2.65	2.3	2.79	3.00
Glycine	3.12	0.35	-	6.2	3.42	4.10
Threonine[#]	2.72	2.83	3.73	4.6	2.15	2.81
Arginine[#]	3.27	1.74	3.63	8.0	3.42	4.50
Alanine	-	1.64	-		5.75	4.46
Tyrosine	1.73	0.95	-	3.9	2.96	3.41
Tryptophan[#]	-	0.58	0.78	1.4	-	-
Methionine[#]	1.01	1.66	2.08	1.7	1.70	3.02
Valine[#]	2.39	0.50	3.86	5.1	3.14	3.68
Phylalanine[#]	2.12	3.83	3.98	4.2	2.06	4.11
Isoleucine	2.40	0.63	2.32	4.2	2.61	3.32
Leucine[#]	3.94	2.11	3.26	7.5	4.96	7.25
Lysine[#]	4.26	1.66	6.97	7.2	3.79	5.02

Sources: Ravindran and Blair, 1993; Zhenjun *et al*., 1997; Ogunji *et al*., 2006; Wang *et al*., 2007; Sogbesan, and Ugwumba, 2008; Ijaiya and Eko, 2009; Okah and Onwujiariri, 2012; [#] essential amino acids for chickens

Prawns fed earthworm meal had a higher weight gain (0.3 ± 0.02), survival (90 %) and feed conversion ratio (0.9 ± 0.01) compared to silk worm pupae and soybean meal (Langer *et al*., 2011). Taboga (1980) reported no differences between feed supplemented with earthworms and commercial diet fed to chickens. Production of earthworms is behind the context of converting condemned, nutrient-rich organic waste into value added products for sustainable feeding for chickens and the use of agricultural land. For sustainable production of earthwoms for chickens, vermicomposting could be an appropriate way. Vermicomposting is decomposition of organic waste resource into odour-free humus like substances through the action of worms (Suthar, 2008).

Humus is used for crop production and then propagating earthworms can be used to feed chickens. Substrates used to produce earthworms are easily, freely and locally available. Earthworms can be produced using bovine slurry that is mixed with grass such as wheat straw (Ibáñez *et al*., 1993). Zhenjun *et al*. (1997) fed earthworms using animal manure and crop straws. Other possible methods of producing earthworms are through enclosing them into sewage fresh sludge. In three to four weeks, they will be proliferated and be ready to be harvested. Unutilized agricultural by products such as animal and poultry wastes and crop residues are the potential substrates to be used in vermicomposting. Potential crop residues are chopped maize, wheat, millets, sorghum stover. Household remnants such as kitchen waste, cardboards, papers are also promising organic waste to be used. Domínguez *et al*. (2000) reported that earthworms had higher reproductive rates in the paper and cardboard mixtures (Table 2.2). Earthworms raised in sewage sludge mixed with food waste obtained maximum weight and highest growth rate. The smallest size and the lowest growth rate were achieved in the combination of sewage sludge with sawdust.

Table 2.2: Growth and sexual development of *Eisenia andrei* in the different diet mixtures

Diet mixture	Maximum weight (mg) ± S.E[1]	Growth rate (mg/day) ± S.E	Mean maturation size (g) ± S.E	Time (days)	Cocoons per earthworm per week ± S. E
Sewage sludge (SS)	674 ± 11[a]	15.6 ± 0.42[a]	488 ± 07[a]	15	0.1 ± 0.01[a]
SS and paper	667 ± 03[a]	15.1 ± 0.56[ac]	494 ± 18[a]	15	2.8 ± 0.39[b]
SS and cardboard	656 ± 07[a]	16.1 ± 1.32[ad]	548 ± 15[b]	15	3.2 ± 0.30[b]
SS and grass clippings	672 ± 52[a]	14.5 ± 1.38[ac]	593 ± 60[b]	15	0.2 ± 0.04[c]
SS and pine needles	655 ± 22[a]	14.8 ± 0.41[ac]	515 ± 16[b]	15	0.7 ± 0.05[d]
SS and sawdust	572 ± 18[b]	11.0 ± 0.74[bc]	488 ± 14[a]	15	1.4 ± 0.10[e]
SS and food	755 ± 18[c]	18.6 ± 0.59[dc]	534 ± 08[b]	15	0.1 ± 0.02[a]

[1]Standard error, *Values in column with different superscripts differ* ($P < 0.05$)

Source: Domínguez *et al*. (2000).

Sonaiya (1995) reported that one kg of fresh earthworm biomass can provide at least 50 chickens with high proteins.

It is pertinent to utilize these omni-present organic products to sustain and retain soil integrity by converting the wastes into nutrient-rich organic fertilizer. Cattle dung is a good media of earthworm production (Goromela *et al*., 2007). To ease earthworm harvesting, worm bin contents need to be shifted to half side of the bin, then put the fresh organic waste into the other empty side. Earthworms will migrate to the fresh organic waste. Harvesting of earthworms can also be done by digging the lumps of earth and gently break them to release worms (Abowei and Ekubo, 2011). The method is, however, time consuming and energy demanding.

There is a need to develop convenience strategies of harvesting earthworms. The strategies should also be environmental safe and harmless to earthworms. Loh *et al*. (2009) reported that earthworms were dipped in the boiling water, oven dried for approximately 50^{o} C for 72 hours and then milled into powder form. On the other hand, Taboga (1980) reported that there were no signs of parasitic organism transmission that associated with feeding live worms with chicken droppings. Therefore, it is practical to feed scavenging chickens with live earthworm, as this would promote biological value of birds and enhance water intake. Earthworms often assimilate large amount of soil that contains high levels of toxic metals such as lead, cadmium, zinc and copper (Sharma *et al*., 2005). These metals can be harmful to animals when earthworms are fed to chickens without detoxifying and processed. In the earthworm food chain, these worms are likely to be a carrier of some parasitic nematodes of chickens (Zhenjun *et al*., 1997). Thus, they may be hazardous to birds. It is imperative to analyse the substrate of vermicomposting for contamination.

Harvesting of earthworms from the garden soil would hinder the break of plant-based organic matter and reduce soil microbial activity. There is no documented information on the storage of live earthworms or earthworm and the effect of processing on the shelf life of earthworm meal. Earthworms have been used largely for soil improvement by recycling waste materials into compost. The data on the use of earthworms to village and commercial chickens is little available. Much of the available information is focusing on fish industry. It is, however, practical for earthworms to support commercial production system when crop commercial farmers who produce compost for their vermiculture or vermicomposting liaise with commercial chicken producers.

2.5.2 Housefly maggots

Maggots are housefly larvae that are prepared to make maggot meal. They have a rapid reproductive rate, high feeding value and easy to process and stored for sustainable use. Maggots are available throughout the year (Moreki *et al*., 2012). This is likely due to presence of abundant waste like disposed kitchen waste, dead carcasses and unhygienic environments. Thus, maggots can be used as protein supplements for scavenging village chickens. Flies reproduce rapidly during the warm and rainy season and maggots are, therefore, available in large numbers.

As shown in Table 2.1, maggot meal has high values of chemical and amino acid composition. Dankwa *et al*. (2002) reported that village chickens supplemented with 30 to 50g of housefly maggots improved clutch size, number of eggs hatched, egg weight and chick weight (Table 2.3). Maggots have shown a great success to be utilized as protein source. Okah and Onwujiariri (2012) reported that the chickens fed the control diet gained lower weight than those fed the 20 and 30 % of maggot meal.

Table 2.3: Mean (± S.E) of various production parameters of scavenging village chickens in in response to maggot supplementation

Parameter	**Supplemented with maggots**	**Not supplemented (scavenging only)**
Age at first lay	173.5 ± 49.10	177.1 ± 71.81
Clutch size	11.5 ± 2.57^{a}	9.5 ± 1.14^{b}
Number of eggs hatched	9.8 ± 2.21^{a}	7.1 ± 0.70^{b}
Egg weight	43.5 ± 23.53^{a}	33.6 ± 2.73^{b}
Chick weight	34.2 ± 0.78^{a}	29.8 ± 1.89^{b}

Values in a row with different superscripts differ (P < 0.05)

Source: Dankwa *et al*. (2002)

The highest daily body weight gain was obtained to the birds fed 40 % maggot meal. Maggots can be rapidly propagated from waste materials by choosing suitable substrate, fly attractants and controlled environmental condition (Odesanya *et al*., 2011). A damp rotting organic waste, where maggots thrive, provides food and breeding site for the adults and nutrition for the growing larvae (Abowei and Ekubo, 2011). Maggots grow easily on poultry droppings or any organic waste in a short period of 2 to 3 days (Okah and Onwujiariri, 2012). A combination of fermented blood mixture, rumen contents and cattle dung can be used to produce maggot larvae (Smith, 1990). Maggots are beneficial by recycling poultry waste (Moreki *et al*., 2012). For example, Okah and Onwujiariri (2012) produced maggots through culturing houseflies in chicken excreta and larvae were ready to be harvested within 3 to 4 days. Since chickens are abundantly ever-present in communal production systems, construction of appropriate housing is needed to facilitate the collection of chicken droppings.

Abowei and Ekubo (2011) suggested that maggots can be harvested with a fine mesh sieve, washed to remove the substrate and allow them to dry. Washing of maggots is through adding water to a container with maggots full of debris, and then add water to submerge the debris which will allow maggots to floats (Akpodiete *et al*., 1998). Maggots can be sun or roast dried and milled using hammer mill. Village chickens like to feed on crawling housefly maggots (Ekoue and Hadzi, 2000), thereby, they can be fed on live unprocessed maggots (Dankwa *et al*., 2002). In addition, feeding live maggots to chickens is economically viable (Khusro *et al*., 2012). There is little or no information about the storage of maggots after harvesting. Consumer unacceptance of feed derived from maggots could limit their use. The unacceptability of maggots is based of cultural beliefs and negative perceptions about them. Religion could also limit the use of NCAP sources.

2.5.3 Termites

Termites, which are consumed by both humans and animals, are social insects that live in different colonies and have immense influence on the ecosystem. Unprocessed fresh termite contains about 700 g/kg CP and 18 MJ of energy (Men *et al*., 2005). Termite meal is also rich in essential amino acids (Table 2.1). Sogbesan and Ugwumba (2008) reported that the concentration of micro-minerals was low in termite and housefly larvae than fish meal.The possible solution to mineral shortages is to combine termites with other mineral-rich unconventional proteins supplements when feeding such as earthworms. These social insects can be categorized into specific physiological units with different colony members for growth, reproduction, defense, and maintenance (Tiroesele and Moreki, 2012). The colony members, which differ in appearance, require unique nutrients requirements for their respective functions and responsibilities. They are, therefore, have a different nutritional value when they are used as feed to chickens (Table 2.4).

These members of the colony include workers, soldiers and queens or reproductive termites. Termites are visible at the onset of rainy, post rainy season (Sogbesan, and Ugwumba, 2008; Tiroesele and Moreki, 2012). They, however, thrive well in dry conditions and mostly feed on dead plant materials such as wood, leaf litter and animal slurry (Okeno *et al*., 2012). Data on the effect of termites to poultry performance is limited. These chitin-containing insects reduce digestibility in rats, however, chitin existing in termites is likely to be digested by birds (Ravindran and Blair, 1993). The information on the digestibility of termites and their nutrients by birds need to be investigated.

Table 2.4: Nutritional composition of different colonies of termites

Nutrients (%)	Soldiers		Workers		Queen	
	1	2	1	2	1	2
Moisture	71.3 ± 0.30^{a}	69.1 ± 0.50^{b}	62.6 ± 0.44^{c}	60.2 ± 0.70^{d}	92.4 ± 0.40^{e}	90.1 ± 0.70^{e}
Ash	3.7 ± 0.30^{a}	4.5 ±0.30^{b}	3.4 ± 0.22^{c}	3.7 ±0.10^{d}	0.9 ±0.10^{e}	1.1 ± 0.10^{e}
Crude protein	54.7 ± 0.10^{a}	56.4 ± 0.44^{b}	25.4 ± 0.02^{c}	29.8 ± 0.25^{d}	31.9 ± 0.01^{e}	32.4 ± 0.02^{e}
Crude lipid	2.9 ± 0.40^{a}	2.5 ± 0.10^{b}	1.80 ± 0.20^{c}	2.4 ± 0.02^{c}	ND[1]	ND
Crude fibre	2.0 ± 0.20^{a}	34.8 ± 0.10^{b}	1.8 ± 1.00^{c}	1.6 ± 0.10^{d}	ND	ND
Carbohydrates	36.7 ± 0.20	34.8 ±0.10^{b}	67.1 ± 1.00^{c}	63.2 ± 0.06^{d}	ND	ND
Caloric value	391.7 ± 1.00^{a}	387.8 ± 1.00^{b}	390.9 ± 1.00^{c}	393.1 ± 1.00^{c}	ND	ND

[1]ND – Not determined; [abcde] Values with different superscripts along the row differ ($P < 0.001$).

Source: Ntukuyoh et al. (2012)

Farina *et al*. (1991) developed a simple technique of producing and propagating termites for chickens. The method involves fibrous material such as chopped stovers placed into moist clay pots or calabashes containing termites. The mouth of the clay pot is then placed over a hole in a termite colony. The clay pot is protected from desiccation by covering it with the jute sack. The heavy stone is placed over the clay pot to secure it and avoid any movements. After four weeks, the new colony of termites is expected to be ready to be harvested inside the clay pot for scavenging village chickens. Men *et al*. (2005) produced termites by filling cartons with bagasse or any other crop by products and wood. Termite nests were collected and put inside the boxes together with bagasse or wood. The cartons were sealed to keep environment inside the carton damp and dark with no rain and direct sunlight affecting it. After 3 to 4 weeks the termites were readily available for chickens. Termites are also gathered by introducing a palm leaf rib into the galleries of the nest; the soldiers biting it are then fished out (Paoletti *et al.*, 2003). Termites that nest above the ground can be opened using blade. Constructed packages made with leaves can be used to transport termites to household for cooking (Paoletti *et al*., 2000).

Termites are among the most threating pests in crop production and forestry. Harvesting them from their mounds, frame doors and other cellulosic materials will decrease their numbers and become less effective. Termites can be collected by shoving termiterium with the spade to discomfort them and they will erupt and come out. They can then be brushed into plastic container (Ntukuyoh *et al*., 2012). Termites can be fed to chickens as fresh without processing (Men *et al*., 2005). They can also be roasted to make termites meal (Ntukuyoh *et al*., 2012). Literature on storage of termites after harvesting for sustainable use is scant.

2.5.4 Snails

Snails live on land or in water and have a spiral protective shell. These slow-moving gastropod mollusks are good sources of protein for human consumption in Asia, Africa and Europe (Hardouin, 1997). They are also mostly used to feed fishes. Snails thrive in or nearby river lakes, ponds, swamps, irrigated fields, canals and waterlogged areas (June *et al*., 1991). Their high propagative capacity and rapid growth rate makes them to be a major threat to crop production, but more desirable as feed to chickens. They are the important pest particularly in transplanted and seedlings plants (June *et al*., 1991). Snails are the voracious feeders of variety of soft, fresh leaves and succulent plants. They are ample during rainy season after heavy rain where plants and leaves are abundant. Snail meal contains high CP and lipid content (Table 2.1). It is, however, deficient in methionine (Creswell and Kompiang, 1981). Snail meal improved broiler performance and investment returns (Table 2.5). Fingerlings fish fed 25 % garden snail meat meal had a highest relative growth rate of 151 %, feed conversion ratio of 1.2 % and 3.7 protein efficiency ratio, respectively (Sogbesan *et al*., 2006). Snails can either be cooked or uncooked. Cooking of snails for 15 minutes is used to remove toxic factors and facilitation the removal of shell (Ravindran and Blair 1993). Likewise, June *at el*. (1991) boiled snails for 5 minutes to kill and discard pathogenic organisms.

Snail shell can be used as calcium-rich ingredient in the diet of chickens. After the removal of shell, snails are called snail meat. The snail meat is sun dried and then grinded to be called snail meat meal. A kilogram of washed and unshelled snails produced 250 grams of fresh snail meat and 100g of dried meat (June *at el*., 1991). Live snails can be stored in water ponds and concrete tanks (Serra, 1997). Snail consumption is associated with *Pseudomonas*, *Aeromonas* and *Salmonella* infections (Hardouin, 1997).

Table 2.5: Final weight, feed intake, feed conversion efficiency and return on investment of broilers fed graded levels of snail meal

	Treatment (g/kg)			
Parameters	**40**	**80**	**120**	**Control**
Final weight (kg)	1.39^{b}	1.58^{a}	1.72^{a}	1.36^{b}
Feed intake (kg)	2.91	2.93	3.46	2.98
Feed conversion efficiency	2.17^{a}	1.91^{b}	2.05^{b}	2.29^{a}
Return on investment	21.11^{ab}	46.80^{a}	5.5^{ab}	14.28^{b}

Values in a row with different superscripts differ (P<0.01). Source: June *et al*., 1991

2.5.5 Grasshoppers (locusts)

Acridids represent sustainable feed resources in animal nutrition. Grasshopper (*Orthoptera: Acrididae*) meal contains about 76 % of CP but low in amino acid (Table 2.1). They have high calories (4.7-7 kcal/g), total fat (6-7.5 %), and carbohydrate (3.6 -7.5 %) and minerals contents (Anand *et al*., 2008). Shortage of amino acids and some minerals to grasshoppers suggest that feed derived from these sources should be supplemented with the limiting nutrients before supplementing (Khusro *et al*., 2012). Contrary, Wang *et al*. (2007) reported adequate amino acid profile with some of the amino acids higher than fishmeal. This discrepancy can be attributed by differ in species, processing and storage of grasshoppers. In Botswana, the grasshoppers are available during hot dry, rainy, post rainy season and are absent during cool dry season especially in June and July (Moreki *et al.*, 2012). Paoletti *et al*. (2000) observed that the Guajibo people from Amazonas and Venezuela rely mainly on grasshoppers during rainy season. In China, grasshoppers occur intensely during the period of June to December in semi-arid environments (Sun *et al*., 2013).

Broilers fed on desert locust meal (*Schistocerca gregaria)* improved average total feed intake from 4257.2 g per kg to 4658.3 g per kg. Feed conversion ratio of finisher chickens was improved from 2.4 from 0 % inclusion level to 2.3 from 1.7 % inclusion levels of desert locust meal with no physiological disorders (Adeyemo *et al*., 2008). Sun *et al*. (2012) reported that breast meat of chickens fed grasshoppers on the field pasture had less monounsaturated fatty acids than birds fed commercial diet under intensive system. Birds raised in pasture that is rich of grasshoppers also had a high fatty acid profile which is characterized by high levels (5.18 mg/g) of phospholipids.

Sun *et al*. (2013) reported that free-ranging broilers fed on pasture land with high grasshopper population had a breast meat with better physical and chemical and carcass characteristics (Tables 2.6 and 2.7).

Artificial propagation and production of locusts could be challenging due to their hard morphology and prolonged life cycle. They are, however, can be produced in mass when they are reared under control environment. The grasshopper mass production requires expensive infrastructure. Smallholders farmers are likely to not afford to facilities make a control environment, especially for mass production of grasshoppers. Government may need to intervene in building control environment houses for communal farmers. Grasshoppers are collected in several ways which include fire drive, mosquito nets and using hands (Paoletti *et al*., 2000a). Grasshoppers can be harvested from their habitats such croplands, grasslands, wetlands and paddocks (Khusro *et al*., 2012). Harvesting grasshoppers from these habitats could reduce the use of hazardous chemical to control pest. Ledger (1987) postulated that harvesting of brown locust *Locustana pardalina* for animal or human consumption reduces the use of insecticides. In doing so, transmission of pesticides to human food is reduced (Khusro *et al*., 2012). Processing of grasshoppers includes washing with tap and rinsing with distilled water to remove unhygienic materials and oven dried at 50^{o} C for 72 hours (Wang *et al*., 2007).

2.5.6 Silkworm pupae caterpillars

The eminent caterpillars in Southern Africa are Mopane caterpillar (Moreki *et al*., 2012). They are used for human consumption and are vended in townships, along the roads and households to households. Mopane caterpillars play an enormous role in alleviating poverty and positively enhancing rural economy.

Table 2.6: The physical and chemical characteristics of breast meat of broilers from the pasture with grasshoppers and control treatment

Physical and chemical characteristics	Grasshopper-rich pasture	Intensively-reared control system	SEM	[1]Significance
pH	5.8	6.0	0.05	*
Lightness	55.1	54.0	0.92	ns
Redness	4.1	2.1	1.16	**
Yellowness	15.6	15.2	0.06	ns
Shear force (kg/cm^2)	3.1	2.5	0.25	**
WHC (loss,% of total)	67.5	62.5	1.19	*
CL (g/100 g)	22.1	28.7	0.15	*
Moisture (g/100 g)	72.7	74.6	1.55	*
Protein (g/100 g)	24.6	22.4	0.56	**
Fat (g/100 g)	1.1	1.5	0.25	*
Ash (g/100 g)	1.4	1.5	0.05	ns

[1]Levels of significance are represented by *P<0.05 ** P<0.01, ***P<0.001, ^{ns} P > 0.05. Source: Sun *et al*. (2013) WHC = water hold capacity; CL = cooking loss

Table 2.7: Carcass characteristics of the broilers from the pasture and control treatment

Carcass characteristics	Grasshopper-rich pasture	Intensively-reared control system	SEM[1]	Significance
Live weight (g)	2213	2628	140.70	**
Dressing (g/100 g)[2]	64.1	62.5	0.79	*
Breasts (g)	287	313	10.99	**
Wings (g)	129.8	168.2	9.69	***
Thighs and drumsticks (g)	381	451	22.22	**
Abdominal fat (g/100 g)	2.3	3.9	0.69	**
Relative weight (g/100 g)[3]				
Breast	20.4	19.2	0.62	*
Wing	9.2	10.3	0.17	ns
Thigh and drumstick	27.1	27.6	0.02	ns
Muscle: bone				
Thigh	3.9	4.0	0.07	ns
Drumstick	7.4	7.0	0.17	ns

[1]SEM is standard error of means. [2]Ready-to-cook carcass/LW. [3]Relative to weight of carcass without head, neck and feet. [4]Levels of significance are represented by *P< 0.05, ** P <0.01, ***P <0.001, and [ns] P >0.05. Source: Sun *et al*., 2012

Silkworms (Lepidoptera: Bombycidae), which are used to produce silk protein fibre, are the common caterpillars that have a potential to be used for chicken feeding. Silkworm pupae, which are rich in protein, are available after the removal of silk cocoons through spinning or reeling as discarded waste in large quantities. In India, these protein-rich sources remnants are obtainable 4 times in a year with annual production of 51 tons (Khatun *et al*., 2005).

Silkworm pupae are among highly recognized NCAP source because of its high protein and crude fat content (Table 2.1). Silkworm pupae contain fibrous chitin which is hardy utilized by birds (Jintasataporn, 2012). Silkworm caterpillars are prominent during the onset of rainy season because they feed on the green fresh leaves of crops and trees (Ijaiya and Eko, 2009). Body weight gain of poultry chicks was high (26.7 g/day) in diet containing 50 % fishmeal and 50 % silkworm (Dutta *et al*., 2012). Layer chickens that received silkworm pupae had a low feed conversion ratio, high live weight gain and egg production percentages (Table 2.8). Ijaiya and Eko (2009) reported no significant difference on the average daily feed intake, average daily body weight gain, feed conversion ratio, protein efficiency ratio of broiler fed fish meal and silkworm meal. The results of the silkworm pupae on growth and production performance are positive, meaning that silkworm pupae have a potential to be used as protein source to chickens. In poultry commercial industry, the use of silkworm pupae would be beneficial by replacing the expensive traditional protein sources such as fish meal and soyabean. These worms can be processed by de-oiling to improve shelf life and feeding efficiency. After harvesting them from trees, they can be put in jute bags and dip in hot water for 3 minutes, and sun dry them for 3 to 5 days and mill them using locally available miller to make silkworm meal (Ijaiya and Eko, 2009).

Table 2.8: Growth and egg production performance of layer chickens fed on diets containing different levels of silkworm pupae

	Dietary level of silkworm pupae (g/kg)				
Variable	Control	60	80	Mean ± S.E	Significance
Body weight (g/ bird)	1406	1500	1450	1459 ± 23.04	**
Feed intake (g/bird/day)	78	68	72	73 ± 0.28	*
Feed conversion ratio	20.9	15.7	18.9	18 ± 0.14	*
Survivability (%)	86.7	86.7	93.3	86 ± 0.83	ns
Egg production (%)	79.3	81.5	79.3	80 ± 1.72	*
Feed efficiency (kg feed/kg egg mass)	2.3	2.1	2.2	2.2 ± 1.83	*

^{ns} $P > 0.05$; ** $P < 0.01$; * $P < 0.05$.

No abnormal hematological, clinical chemical and histopathological changes and clinical signs observed in rats when administered with silkworm pupae. Dutta *et al*. (2012) also reported that no toxicological effects were associated with feed silkworms to chickens. The information on the storage and shelf life of silkworm pupae need to be investigated. Jintasataporn (2012) postulated that famers can either produce high quality silk cocoon for silk thread in the reeling silk industry or produce low quality silk cocoon in the spinning silk industry. Safety evaluation of silkworm pupae done by Zhou and Han (2006) using mutagenicity test in rats revealed that silkworm pupae are free of toxic factors.

2.6. Ecological significance of using non-conventional anima protein sources

Ecology is the portion of the ecosystem that deals with the interrelationship of organisms to their natural surroundings. Non-conventional animal protein sources form an integral part of environmental biodiversity. They play a colossal role in natural and agricultural ecosystems. These protein sources are able to make use of unusable materials into food for plants and animals which benefits the ecosystem. With increasing in awareness of sustainable agricultural practices and environmental protection, it has become pertinent to understand the role of NCAP source to the ecosystem to reduce the use of agro chemicals that affect natural environment. These sources such as earthworms and maggots are able to recycle waste and, therefore, reduce organic pollution which fovour the process of ecosystem (Khusro *et al*., 2012). Snails, locusts and termites, on the other hand, are causing a major threat in agricultural ecosystem. Harvesting them in their natural habit will reduce the transfer of agro chemicals to human through food chain (Khusro *et al*., 2012). Feeding them to chicken is of interest to reduce the use of agro-chemicals that adversely affect the ecosystem.

Earthworms are the bio-indicators for the monitoring of state and changes of the ecosystem (Sharma *et al*., 2005). Earthworms have positive influence on the soil structure, decomposition of litter, mineralization and recycle of nutrients (Haimi and Huhta, 1990). They play a phenomenal role in the agro-ecosystem by increasing nitrogen availability by reducing microbial immobilization and enhancing mineralization (Blair *et al*., 1997). They are useful for improvement of soil aggregation, respiration, fertility, aeration and nutrition for plant growth (Sharma *et al*., 2005). When they are harvested from the soil for propagation to feed chickens, ecosystem could be imbalance.

Maggots are hatched eggs of flies that are efficient in decomposing detritus material. Maggots are detritivores, meaning they feed on detritus materials such as animal carcasses, leaf litter, faeces and kitchen remains. In that way, they reduce the organic pollution which benefits the ecosystem. Termites are predominantly soil animals that play major role in tropical terrestrial ecosystem using decomposition process. They decompose cellulose and lignin-rich materials. They also change soil properties through fixing gases such as carbon and nitrogen. Using isotope ratio, soil-feeding and wood-feeding termites were capable of fixing nitrogen derived from the atmosphere (Tayasu *et al*., 1997). Using a stable isotope technique, the organic carbon became enriched as it passes through the termite food chain (Boutton *et al*., 1983). The food chain of termites is diverse, some species of termites feed of woody materials while other species feed on herbaceous rotten plants and household waste. Termites as feed to chickens are important in sense of converting unusable fibrous materials into food for human consumption with benefits to the ecosystem (Okeno *et al*., 2012). They contribute to ecosystem by feeding on the dead rotten plants, woods and paper, leaf litter and animal slurry. Ravindran and Blair (1993) indicated that exploitation of snails for chicken feeding is important in the context of controlling pests. Using insects such as locusts and snails as feed to chickens would reduce to use of pesticides that are harmful to humans through food chain (Khusro *et al*., 2012). It would reduce contamination of water, air, soil and non-target flora and fauna.

2.7 Summary

Among challenges to chicken production, feed shortages and poor available nutrition pose a major threat to chicken productivity. Availability and quality of scavengeable feed resources are influence by various factors. Protein is the most limiting nutrient to scavenging chickens. Non-conventional protein sources can improve the productivity of chickens. The factors influencing feed availability and quality need to be characterized. Earthworms, insects and locusts have a huge potential to provide amino acids to chickens. There is need to determine the influence of seasons and class of bird on nutrient content. Amino acid profiles of the crop contents also need to be determined so as to better understand protein consumption by scavenging chickens. For sustainable intensification of village chickens, the views of the farmers need to be taken into consideration.

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CHAPTER THREE: Farmer perceptions on the use of non-conventional animal protein sources for scavenging chickens in semi-arid environments

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Abstract

For sustainable intensification of village production systems, it is important to understand views of farmers who keep the chickens on the utilization of available protein sources. The objective of the study was to assess farmer perceptions on the use of non-conventional animal protein (NCAP) sources for scavenging chickens. Resource-poor households of Msinga local municipality in uMzinyathi district, KwaZulu-Natal (n = 239) were interviewed using a semi-structured questionnaire. Logistic regression was used to analyse the data. Females were the prominent heads of households, followed by males, and then youths. Feed shortages were among the major challenges that limited chicken production. Provision of chicken housing and religion highly influenced (P<0.05) a household's likelihood of experiencing feed shortages. Farmers who did not provide overnight housing to their chickens were likely to not provide any supplementary feeding. Christian farmers were predisposed to chicken feed shortages compared to traditional-religious farmers. More than half of the farmers (56.6 %) were aware that NCAP sources have a huge potential to be used as protein sources for chickens. Farmers commonly used termites as a protein supplement. Other common NCAP sources were earthworms and locusts. The potential of using NCAP sources were high on farmers with large village chicken flocks and female-headed households.

Keywords: Scavenging chickens; Resource-poor farmers; Termites; Earthworms; Flock size

3.1 Introduction

Increasing productivity of village chickens has a huge potential to increase protein consumption among resource-poor households, particularly for children (Mwalusanya *et al*., 2001). Village chickens are usually raised with little or no investment in housing, feeding and health care (McAinsh *et al*., 2004). To increase meat and egg productivity, it is crucial to establish the scavenging behaviour of village chickens. Scavenging is an instinctive behaviour and skill that can be acquired from hens by their chicks. These skills are not well developed in most imported and synthetic chicken genotypes since they were selected under intensive indoor production systems. The scavengeable feed resource (SFR) is highly variable and mainly composed of snails, flying insects, worms in the soil, grass seeds, berries and foliage (Sonaiya, 2004). Quality and quantity of the SFR is inconsistent (Goromela *et al*., 2006) and depends on season, dominant crops grown, location and life cycle of insects, among other factors. Plants and grasses are the abundant feed resources that village chickens scavenge on. These green materials are rich in energy. Protein content of the SFR is, therefore, likely to be below the requirements of the chickens (Goromela *et al*., 2006). There is, therefore, a growing interest in developing methods on the propagation, harvesting, processing methods, storage and optimum inclusion levels of preferred non-conventional animal protein (NCAP) sources for scavenging chickens. Non-conventional animal protein sources include earthworms, locusts, termites, fly maggots, caterpillars, cockroaches and snails.

The increased interest in understanding the contribution of NCAP sources for village chickens is also motivated by the desire to produce organic chicken meat and eggs (Mtileni *et al*., 2013). These products can fetch premium prices and enhance household income and rural livelihoods. The supply of such products in the markets is, however, erratic, low and unreliable. The contribution of NCAP sources to the diets of scavenging chickens should, therefore, be estimated.

Before determining the nutritive value of these feed resources, it is essential to understand farmer perceptions on the potential of using NCAP sources so as to integrate their views in developing sustainable strategies to meet nutrient requirements for village chickens. The objective of the current study was, therefore to assess farmer perceptions on the use of NCAP sources for scavenging chickens. It was hypothesized that the perceptions of farmers on NCAP sources for scavenging chickens vary with socio-economic status of the households

3.2 Materials and Methods

3.2.1 Study site

The study was conducted in Msinga local municipality in UMzinyathi district, KwaZulu-Natal province, South Africa. Msinga local municipality is located at 28^{o}40'00"S and 30^{o}34′00"E with an average altitude of 672 m above sea level. It is semi-arid, hilly and rocky with annual average rainfall of 400 to 900 mm. Most residents in Msinga rely on subsistence production of crops and livestock for consumption and sale. Village chickens are among important livestock that are imperative to the livelihood of households. The municipality is characterized by irrigable land and irrigation infrastructure that is situated near the Tugela River where there is wide alluvial plain. Alongside the Tugela River, informal agricultural endeavours are practised in areas adjoining the irrigation scheme. Common agricultural produce from the irrigation scheme are tomatoes, butternuts, spinach, sweet potatoes, potatoes and onions. These products contribute considerably to the livelihoods and household economy. Agricultural activities in the rain-fed gardens include intercropping of maize and beans, cowpeas and pumpkin.

3.2.2 Sampling of households

Two villages were randomly selected from the municipality. Sampling of the households was based on chicken ownership and willingness to participate in the study. All farmers who owned chickens were randomly selected to participate in the study. Each farmer had an equal probability of being selected for the study. A pre-tested semi-structured questionnaire was administered to 239 households by eight trained enumerators. Enumerators were obtained from the local villages to ensure that farmers are comfortable to co-operate during the study.

3.2.3 Data collection

Discussions with key informants were held. The key informants were prominent livestock farmers in the municipality, officials from active non-governmental non-profit organisations, local traditional and political leadership, school headmasters and agricultural extension workers. A semi-structured questionnaire was also used to collect data. The questionnaire was granted ethical approval (HSS/0584/013M) by the University of KwaZulu-Natal. The questions were translated into the vernacular Zulu language to improve quality of data captured. The questionnaire captured data on household demographic and socio-economic status, uses and ownership patterns of chickens, challenges to chicken production, feeding practices and uses of NCAP sources. Data were also collected through direct observations of socio-economic status of farmers, housing structures and chicken genotypes used. Transect walks were also made in the communities to explore resource endowments in the area.

3.2.4 Statistical analyses

All the data were analyzed using SAS (2008). Household socio-economic status, uses of chickens, challenges to chicken production and the use of NCAP sources were analysed using PROC FREQ of SAS (2008). The PROC GLM procedure was used to analyse the effects of gender of head of the household on livestock herd size and chicken flock composition. Pair-wise comparisons of the least square means were performed using the probability differences (PDIFF) procedure. An ordinal logistic regression (PROC LOGISTIC) was used to predict the odds of a household to experience chicken feed shortages and farmer perceptions on the potential of using NCAP as a feed resource for chickens. The variables fitted in the logit model included age of the farmer, gender, marital status, religion, household size, production system, housing and flock size. The model used was:

$$\text{Ln}\,[P/1\text{-}P] = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \ldots\beta_tX_t + \varepsilon$$

Where: P is the probability of household experiencing chicken feed shortages;

$[P/1-P]$ is the odds of the household to experiencing chicken feed shortages;

β_0 is the intercept;

$\beta_1 \ldots \beta_t$ are the regression coefficients of predictors;

$X_1 \ldots X_t$ are the predictor variables;

ε is the random residual error

When computed for each predictor ($\beta_1 \ldots \beta_t$), the odds ratio for feed shortages was interpreted as the proportion of households that experienced chicken feed shortage versus those households that experienced no shortages. For farmer perception on the use of NCAP, odds ratio were interpreted as the probability of the farmer being aware of the potential of using NCAP as a feed resource versus those who were not aware of NCAP as potential feed resources.

3.3 Results

3.3.1 Household demographics and socio-economic status

The demographics and socio-economic status of farmers are given in Table 3.1. Adult males and females mostly relied on old age grants of South Africa rand of R14 400 per annum as their major

Table 3.1: Socio-economic status of heads of households of Msinga local municipality

Status	Adult females (n = 148)	Adult males (n = 50)	Youth (n = 41)
Farmers who were christians (%)	47.9	52.9	64.2
Farmers who were single (%)	73.1	40.0	65
Major source of income (%)			
Old age grant	41.9	47.0	0
Child support grant	35.8	19.6	50.8
Casual work	15.4	15.7	44.1
Formal work	6.9	17.7	5.1
Chicken raised under extensive system (%)	97.3	90.2	94.9
Household size (mean ± S.E)	6.1 ± 0.27^{b}	7.7 ± 0.46^{a}	6.0 ± 0.73^{b}

Values with different superscript along the rows differ (P<0.05) source of income. Child support grants of R 3 600 per annum and casual work were the main sources of income to youth. The common livestock species kept in Msinga local municipality are shown in Table 3.2. There was a large variation in flock size, with an average of 21.6 ± 12.82 ranging from 1 to 69 chickens per household. Surprisingly, chicks were fewer than hens. The cock: hen ratio was 1:3.5.

3.3.2 Chicken ownership patterns, gender participation and uses

Adult females (69.2 %) were dominant household members who owned chickens followed by males (24.5 %) and youth (6.3 %). The management of chickens was mainly performed by females (69.3 %), youth (21.4 %) and lastly males (9.3 %). Duties included feeding, housing, health management and sales. Chickens were largely used for meat, income and rituals in that order in female households (Table 3.3). Male-headed households mostly used chicken for meat, income and status. Youths used chickens mainly for meat, income and followed by manure.

3.3.3 Challenges to chicken production

Female-headed households were challenged by feed shortages, high disease prevalence and theft in that order (Table 3.4). The most prevalent diseases were reported as Newcastle disease, fowl pox, infectious bursal disease, ulcerative pododermatitis and diarrhoea. No definite diagnoses, were, however, conducted. High disease prevalence, predation and feed shortages were the major challenges faced by male-headed households. Farmers reported snakes, mongooses, dogs, hawks and wild cats as common predators. Youth-headed households were prone primarily to feed shortages, ecto-parasite infestation and predation in that order. Dominant ecto-parasites observed included scaly leg mites, chicken mites, Tampan fowl ticks and avian lice.

Table 3.2: Least square means (± s.e.) for livestock herd and chicken flock composition in Msinga local municipality

Livestock herd size	**Adult females (n= 148)**	**Adult males (n=50)**	**Youth (n=41)**
Scavenging chickens	22.8 ± 1.03^{a}	24.9 ± 1.75^{a}	14.5 ± 1.95^{b}
Cattle	2.6 ± 0.49^{b}	5.9 ± 0.84^{a}	3.5 ± 0.94^{ab}
Sheep	0.1 ± 0.21^{b}	2.0 ± 0.40^{a}	0.1 ± 0.45^{b}
Goats	10.3 ± 1.16^{b}	18.6 ± 2.00^{a}	7.4 ± 2.02^{b}
Ducks	0.1 ± 0.06^{b}	0.4 ± 0.10^{a}	0
Pigs	0.1 ± 0.06^{a}	0.2 ± 0.11^{a}	0.3 ± 0.12^{a}
Chicken flock composition			
Chicks	6.8 ± 0.68^{c}	10.0 ± 1.16^{a}	3.1 ± 1.29^{b}
Hens	12.0 ± 0.65^{a}	11.0 ± 1.12^{ab}	8.1 ± 1.24^{b}
Cocks	4.0 ± 0.22^{a}	3.9 ± 0.37^{a}	3.3 ± 0.41^{a}

^{abc} Values with different superscript along the row differ ($P<0.05$).

Table 3.3: The most important reasons (%) of uses of chickens in Msinga local municipality

Uses	Adult females (n = 148)	Adult males (n = 50)	Youth (n = 41)
Meat	71.6	70.6	61.0
Eggs	2.0	2.0	2.4
Income	15.5	9.8	20.1
Rituals	7.5	2.0	6.3
Manure	3.4	7.7	10.2
Status	0.0	7.9	0.0

Table 3.4: The most important challenges (%) to chicken production in Msinga local municipality

Challenges	Adult females (n = 148)	Adult males (n = 50)	Youth (n = 41)
High diseases prevalence	20.0	30.7	7.6
Ecto-parasite infestation	7.3	9.5	22.5
Intestinal parasites infestation	2.5	2.7	5.3
Theft	15.3	4.8	7.3
Predation	9.8	21.6	9.8
Poor market	0.8	7.8	3.3
Poor availability housing	8.8	5.8	2.0
Feed shortages	35.5	17.3	42.2

3.3.4 Low availability and poor quality of housing

The majority of the households (77.5 %) did not provide separate overnight housing for their chickens. Chickens that were not provided with housing mostly rested on tree branches. The housing materials commonly used were wood, mud and corrugated iron sheets, followed by combination of timber planks and nets and, to a lesser extent, bricks.

3.3.5 Predation

Snakes were the most important predator to growers and adults chickens followed by chicks and lastly eggs (Figure 3.1). Mongooses were also important to growers and adults chickens and lastly eggs. Dogs were a major problem to eggs and relatively less harmful to chicks and adult and growing chickens. Hawks were problematic to chicks, whilst growers and adult chickens and eggs were less affected. Wild cats were important predator to growers and adult chickens followed by chicks and to little extent, eggs.

3.3.6 Feeds and feeding practices

Thirty percent of the farmers practised supplementary feeding to their chickens. The predominant feeds used to supplement chickens were unground rotten maize, kitchen waste, bought-in feeds, sorghum and rice. Non-preferential feeding was mostly practiced (88.8 %)**.** Birds were commonly supplemented once a day (76.3 %) before they scavenge. At least 98.8 % of the chicken keepers provided water to their birds.

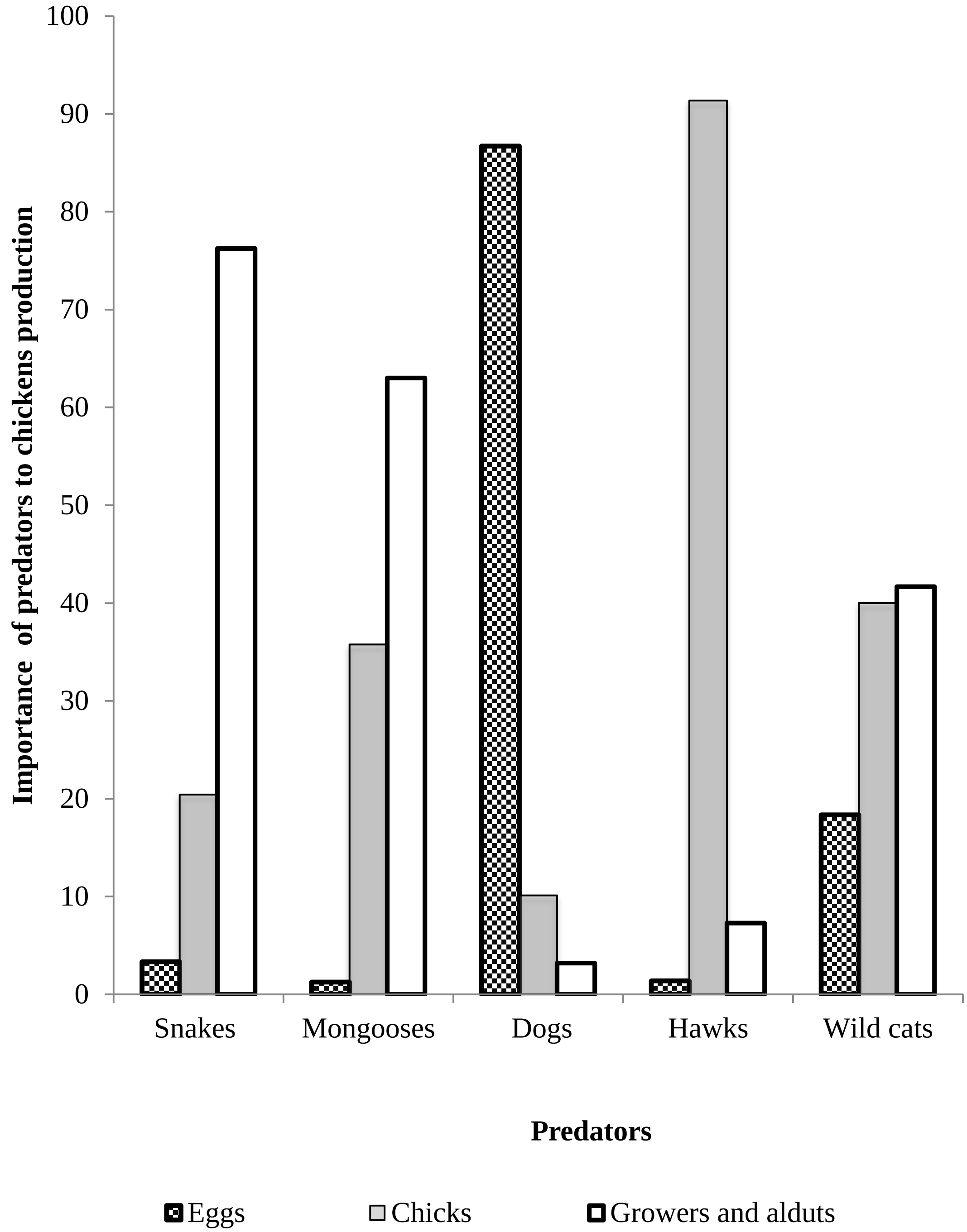

Figure 3.1: Percentage of the most important predators to chickens

3.4 Feed shortages

Chicken housing and household religion highly influenced (P <0.05) the household's likelihood to experience feed shortages (Table 3.5). Farmers with overnight housing for their chickens were less likely to experience feed shortages. Christian farmers were predisposed to chicken feed shortages compared to traditional-religious farmers.

3.5 Potential of using non-conventional animal protein sources to village chickens

Most farmers did not provide NCAP sources (94.6 %) to their chickens. However, more than half of the farmers (56.6 %) were aware that these NCAP sources have a potential of being used as chicken feed. One in four farmers (25.4 %) cited lack of knowledge on the methods of collection and bulking them to feed a large flock of chickens. Few farmers (5.4 %) supplemented chickens using termites. The members of the termite colony mostly used to feed chickens were soldiers and workers. These termites were predominantly found in tree stems, deteriorated wooden door frames and mounds. Farmers also trapped termites by opening a hole in the mound and incorporate clay pot with green materials then sealed with cover. Women were the main responsible household members to feed chickens with these animal protein sources.

The NCAP feedstuffs were relatively less available during the hot dry season, for example, 21.9 % of farmers reported that earthworms are more available during the hot dry season whilst 78.1 % observed less availability (Table 3.6). The NCAP sources were dominant in the rainy season. Earthworms, termites and locusts in that order were identified as NCAP sources with the highest potential for feeding village chickens. Farmers claimed that chickens preferred these NCAP sources because they are easy to obtain or hunt and are more available.

Table 3.5: Odds ratios for chicken feed shortages

Predictor	Odds ratio	Lower CI	Upper CI	Significance
Age (youth ≤35 versus adults >35 years)	2.4	0.62	4.78	ns
Gender (female versus male)	1.7	0.38	7.86	ns
Marital status (single versus married)	2.2	0.61	8.36	ns
Religion (tradition versus christian)	4.5	1.12	24.02	*
Household size (large >6 versus small ≤6 members)	1.4	0.36	5.39	ns
Production system (extensive versus semi-extensive)	3.9	0.58	26.14	ns
Chicken housing (no versus yes)	5.6	1.31	23.63	*
Chicken flock size (large >22 versus small ≤22)	1.6	0.42	6.30	ns

The higher the odds ratio the stronger the predictor of chicken feed shortages. CI: confidence interval. ^{ns} $P > 0.05$ * $P < 0.05$

Table 3.6: Seasonal availability (%) of non-conventional animal protein (NCAP) sources in the study area

Non-conventional animal protein sources	Hot dry	Rainy
Earthworms	21.9	99.6
Fly maggots	10.4	99.2
Termites	32.9	99.2
Locusts	18.3	96.7
Snails	3.3	98.8
Caterpillar	5.8	98.8
Cockroaches	21.3	95.8

Values indicate highest availability of NCAP, relative to low availability in the same season.

Farmers also reported that NCAP are common animal protein feedstuffs consumed by scavenging chickens. However, they are low in proportion especially during dry season. They were mostly found in river banks, crop fields, kraals, wetlands and in deteriorated materials. The odds ratio estimates of farmers being aware of NCAP as potential feed resources to chickens were high on chicken flock size, gender of head of the household and household size (Table 3.7). Farmers with large chicken flock sizes were likely to be aware of NCAP as potential feed to chickens.

3.6 Discussion

Females are liable for any homestead related activities (Halima *et al*., 2007; Tarwireyi and Fanadzo, 2013). Most females in rural areas are over-burdened with a wide range of activities, tasks and responsibilities, in agriculture, animal husbandry and in the household (Guèye, 2003). The finding that households major source of income was through receiving old age pension and government grant agrees with Nyoni and Masika (2012). Extensive production system is the common management of scavenging chickens in Africa (Halima *et al*., 2007; Mtileni *et al*., 2013; Muchadeyi *et al*., 2004). Village chickens have a potential to alleviate protein shortages in rural households because they are ubiquitous as they are kept by almost every household (Mtileni *et al*., 2013). The mean flock size of 21.6 was higher than 17 and 10.9 of reported earlier (Nyoni and Masika, 2012; Mtileni *et al*., 2013). Production practices, flora and fauna in the locality, disease outbreaks, predation and feed shortages were the major reasons for losses from flocks (Kuit *et al.*, 1986) could explain these flock size differences.

Table 3.7: Farmer perceptions on the potential of using NCAP sources as feed for scavenging chickens

Predictor	Odds ratio	Lower CI	Upper CI	Significance
Age (youth ≤35 versus adults >35 years)	0.6	0.30	1.36	ns
Gender (female versus male)	2.8	0.78	9.94	ns
Marital status (single versus married)	1.7	0.46	6.35	ns
Religion (tradition versus christian)	1.1	0.31	3.66	ns
Household size (large >6 versus small ≤6 members)	2.4	0.65	8.98	ns
Production system (extensive versus semi-extensive)	0.2	0.03	1.77	ns
Chicken housing (no versus yes)	1.2	0.25	5.46	ns
Chicken flock size (large >22 versus small ≤22)	4.5	1.06	20.43	*

The higher the odds ratio the stronger the probability of farmer being aware of the potential of using NCAP as feed resources. CI: confidence interval. ^{ns} P > 0.05, * P<0.05

The observed hen to cock ratio obtained is similar to observations by Yakubu (2010) in Nigeria. Cocks are usually slaughtered to keep reasonable ratios of cock to hen, meanwhile providing meat. There is, therefore, a need to determine how the nutritional composition and amino acid composition of cocks compare with other classes of chickens. High proportion of hens in flock indicates that they are reared to produce eggs and chicks. Low proportion of chicks in the flock is a result of high disease prevalence, feed shortages, predation which hampers the growth and production of chicks (Gondwe and Wollny, 2007). Chicks are the weaker group in flock, non-preferential feeding could, therefore, explain the low number of chicks in the flock (Dessie and Ogle, 2001).

The high ranking of chickens for human consumption agrees with Mwale and Masika (2009) who reported that the purpose of keeping chicken was mainly for meat in Centane district, Eastern Cape. Village chickens can be slaughtered easily and can be consumed in one meal without need for refrigeration. Msinga local municipality is one of the most undernourished rural areas of KwaZulu-Natal, which could explain why farmers consider using chicken for meat consumption rather than selling. The observation that the ownership and management of chickens were predominantly by females agrees with Halima *et al*. (2007). Village chicken production could be a sustainable resource for rural women empowerment. Higher proportion of adult males than youths in owning chickens agrees with Muchadeyi *et al*. (2004) who reported that men owned 36 % of the chickens and boys and girls owned 6 and 6 %, respectively.

The finding that households were largely challenged by diseases agrees with previous reports (Aboe *et al*., 2006; Okeno *et al*., 2012). Extension officers of the municipality highlighted that

Newcastle disease was the commonest disease that can kill the almost entire flock (Naidoo, 2003). Government extension officers, in conjunction with local non-government organizations and farmers, need to collaborate when attempting to purge prevalence of Newcastle disease. When the management or combating of Newcastle disease has been done, it would promote investment in chickens (Aboe *et al*., 2006). Chicken theft necessitates appropriate chicken housing with security features. Chicken feed shortages to rural households could be because harvested maize has many needs in the household. For example, females mostly threshed maize to make maize meal and porridge. Female, male and youth-headed households have different household resources and priorities, these differences are considered to affect the interest of household scale of operation, management strategies and knowledge of poultry (Aklilu *et al*., 2008).

The finding that most chickens were not provided with overnight housing suggests that farmers do not invest much into their chickens. The interviewed farmers and prominent livestock farmers in the municipality argued that providing overnight housing invites predators, such as snakes. Political leaders, school head masters and farmers also added a plausible explanation that females were responsible for chickens whilst chicken house construction is generally done by males which could also explain minority of households who provide overnight housing. The main reason for providing housing is to protect birds from predation and theft (Gondwe and Wollny, 2007). The major predators were snakes, mongooses, dogs, hawks and wild cats. Harmfulness of hawks to chicks indicates that chicks need to be restricted from scavenging by enclosing them to their house. Dogs prefer eggs more than chickens, probably because they are not fed on balanced diets. Active non-governmental non-profit organisations revealed that high incidence of snakes killing chickens are related with the current study area that is rocky and therefore, provides a good habitat for snakes which are often found underneath the rocks.

The materials used for houses and nests could increase infestation for external parasites such as fowl ticks, mites and fleas which spend most of their lives hiding in cracks and crevices in building (McAinsh *et al.*, 2004). Housing also delays birds to come out and keep them away from the fields during this time of the year (Muchadeyi *et al*., 2004). Farmers who provided housing at night resorted to cheap and locally available materials such as wood, mud and metal sheets, combination of plank timber and nets and using bricks, as also reported earlier (Mtileni *et al*., 2013). Farmers should be encouraged and trained to construct appropriate houses for chickens to reduce predation, parasites infestation and improve productivity.

One major constraint to the increase in chicken productivity is feed availability and quality. Unground rotten maize grain was the main supplementary feed given to chicken as also observed in other parts of South Africa (Naidoo, 2003; Mwale and Masika, 2009; Nyoni and Masika 2012). Maize is available in large quantities during harvesting and threshing periods (Mtileni *et al*., 2013). Although maize grain is rich in energy, aflotoxins and mycotoxins are usually a huge challenge. Supplementing with maize grain could only sort out energy requirements issues but not protein. Therefore, scavenging chickens have to use their ability to hunt for protein-rich feed resources, such as earthworms around the surroundings to meet protein needs. As a result, they are vulnerable to theft and predation. Furthermore, they interact with other neighbouring flock which makes them vulnerable to disease (Kitalyi, 1998). Water supply to birds is useful by reducing hunting responsibility for water in niches where they are susceptible to predation, theft and disease. Supplying of water to birds is likely to promote scavenging for feed resources, thus improve feed intake and growth.

African traditional religious farmers stored remainders of sorghum to feed chickens after making traditional beer for ritual ceremonies. This could explain why they had less likelihood of facing chicken feed shortages. Sorghum is, however, deficient in protein content. Negligible feeding input to chickens raised under extensive production system could be related to farmers not affording feed that is sold in the market. Youths largely relied on child support grants and casual occupations for income generation. Unstable occupation and meagre income could be the reason young farmers face feed shortages for chickens. Youths have limited access to resources such as credits, agricultural inputs, technologies (Kitalyi, 1998).

Unfamiliarity of farmers with the use of NCAP to chickens calls for training of farmers about importance of NCAP sources to chickens for sustainable feeding system and improvement of chicken productivity. Training should include possible propagating and harvesting techniques using locally available resources to produce these protein sources. Existence of termites during the dry season has been reported by farmers. Termites are known to thrive under dry conditions and recycle to contribute to ecosystem by feeding on dead plants such as wood, leaf litter and animal dung (Okeno *et al*., 2012). Feeding termites to chicken would be, therefore, a way of converting unusable materials to food for rural people.

Farmers indicated that NCAP sources are available even during the hot dry season could those who are residing in village situated near Tugela river where there is wide alluvial plain. Along the river, there are swampy areas where NCAP sources such earthwoms and flies mostly found. Seasonal availability of NCAP sources necessitates innovative methods that need to be implemented to produce these novel sources at all times to supply birds with protein sources throughout the year. Before, attempting to supplement birds with these protein sources, it is crucial to determine seasonal availability and nutritional quality of feed available for chickens. The method of producing these protein sources should be inexpensive and complement the living standards of smallholder farmers by using locally available materials. For example, possible methods of producing and harvesting earthworms are through enclosing them into fresh sludge. Cattle dung provides sources of NCAP sources such as earthworms and cut worms and is used as a media of production (Goromela *et al*., 2007). Combination of fermented blood mixture, rumen contents and cattle dung can be used to produce maggot larvae (Smith, 1990).

Earthworms, termites and locusts are potential protein sources to birds. They are a natural food source for poultry and are highly palatable to chickens. They are used for human consumption in other countries (Paoletti *et al*., 2000). Using them as feed to chickens can increase productivity of chickens while maintaining low input cost of production. These protein-rich feed resources have a beneficial effect when included into the poultry diet (Tiroesele and Moreki, 2012). Interviewed famers, prominent livestock owners and local traditional indicated that unlike fly maggots and snails, these protein sources are not disgusting, meaning that they could consume a chicken being supplemented with earthworms, termites, locusts. The farmers and key informants highlighted that they are prepared and willing to adopt technologies that can increase the availability and supply of earthworms, locusts and termites as feed for chickens. Earthworms are easy to produce, since some of the farmers are aware of the concept of vermicomposting which utilises crop residues, detritus material such as kitchen wastes. There is need to determine the digestibility, nitrogen retention, absorption and utilization of these protein sources in village chickens. Although locusts are commonly consumed by chickens, the farmers and active non-government non-profit organizations felt that propagation and production of locusts seems difficult. Consumer unacceptance of feed derived from maggots and snails could limit their use. The unacceptability of maggots and snails is based of cultural beliefs and negative perceptions about them.

Presence of NCAP sources has been reported in crop contents of birds (Goromela *et al*., 2007). There are variety of reservoirs of NCAP such as river banks, crop fields, cattle dung, and wetlands. Farmers with large chicken flock sizes are likely to have more attention on chicken husbandry, thereby aware of the potential of NCAP as potential protein feed source for chickens. Women involvement on chicken management and production explains why they are likely to understand the potential of NCAP as feed to chickens. Nutritional value of NCAP sources need to be determined. Nutritional quality of feeds that scavenging chickens consume is also a prerequisite in different locations, seasons, and farming systems. This will help to determine how much of NCAP sources need to supplemented.

3.7 Conclusions

Challenges to chicken production varied with gender of the head of household. Feed shortages were among the major challenges to chicken production. Chicken housing highly influenced the household's probability to experience feed shortages. Farmers who supplemented chickens with NCAP were few and were mostly women. Farmers were aware that these NCAP sources have a potential of being used as chicken feed. Odds ratio estimates showed that farmers with large chicken flock sizes were likely to be aware of NCAP as potential feed to chickens. Availability of these animal protein sources is seasonal. The NCAP sources were the main of proteins that chickens scavenge on.

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CHAPTER FOUR: Effect of season on nutritional quality and amino acid composition of feeds consumed by scavenging hens and cocks

Subimitted to Animal Science Journal

Abstract

The trial was conducted to determine the effect of season on nutritional quality and amino acid composition of feeds consumed by scavenging hens and cocks. A total of 120 Ovambo chickens collected from Gugwini village of uMzimkhulu municipality were used. The chickens were randomly purchased during the rainy, post rainy, cool dry and hot dry seasons (Fifteen hens and 15 cocks each season). Fresh crop and gizzard content weights were high ($P < 0.05$) during the cool dry season. Cereal grains, kitchen wastes, green materials, animal protein sources and inorganic materials were the main components of the crop and gizzard contents. The contents varied with season and sex of bird (P < 0.05). The cereal grain weights were high during cool dry and hot dry seasons. The weights of animal protein sources were higher ($P < 0.05$) during the rainy and post rainy seasons. The weights of animal protein sources were high ($P < 0.05$) in hens than cocks. The levels of crude protein (CP), crude fibre, acid detergent fibre, neutral detergent fibre, nitrogen free extract and true metabolisable energy varied ($P < 0.05$) with season. There was a significant season and sex interaction on the levels of dry matter, live weight, CP and lysine content. Hens had a higher ($P < 0.05$) CP and lysine content during the rainy season than cocks. Histidine, serine, arginine, threonine, cysteine and lysine contents varied with seasons ($P < 0.05$).

Keywords: Amino acids; cocks; crop contents; hens; scavenging chickens; season

4.1 Introduction

Scavenging chickens are unexploited rural resource available to almost every rural household in developing countries (Mwalusanya *et al*., 2001). They are the integral part of rural communities. They provide meat and eggs as sustenance to undernourished rural households (Mtileni *et al*., 2013). Nevertheless, challenges to chicken production have maintained meagre chicken productivity and low contribution to rural livelihoods in relation to their high numbers (Dessie, 2001). Major challenges to chicken productivity are inconsistent availability and quality of feed resources (Mwalusanya *et al*., 2002). The low feed supply and poor feed quality is likely to lead to low levels of productivity.

Scavenging chickens hunt for consumable feed materials in the surrounding environment. The materials consumed are influenced by farming activities, locality, land size, flock size, planting to harvesting time, lifecycle of insects and seasonal conditions. There is a need to identify and characterize these sources of variation, as the first step in designing supplementation strategies to optimize production.

In-depth research has been made on hens and growing chickens (Mwalusanya *et al*., 2002; Rashid *et al*., 2004; Mekonnen *et al*., 2010). Cocks are often overlooked yet they are the first option when slaughtering occurs to maintain reasonable cock to hen and avoid fighting among each other. They also provide more meat from their large frame size. Since nutrient demands for hens differ from that of cocks, it is likely that the nutritional and physical composition of feed resources they scavenge on differ. The objective of the study was, therefore, to assess the interaction of season and sex of bird on the physical and nutritional composition of the crop and gizzard contents of scavenging chickens. It was hypothesized that physical and nutritional composition of scavenging chickens varies with season and sex of bird.

4.2 Materials and Methods

4.2.1 Study site

The study was conducted in Gugwini village of uMzimkhulu local municipality. The village is located in the south west of uMzimkhulu municipality under in Ward 14 of Harry Gwala district, KwaZulu-Natal, South Africa. The village lies at 30°31′0″S and 29°55′0″E; receiving a mean annual rainfall that ranged from 800 to 1280 mm. The village experiences four distinct seasons .These are the rainy (November to January), post rainy (February to April), cool dry (May to July) and hot dry (August to October) seasons. In the cool dry season, the village experiences mean annual temperatures range from 16.9º to 18º C and occasional frost. The village has a low population density with scattered households and cropping being common in the rainy season.

The village vegetation cover is characterized as Southern KwaZulu-Natal moist grassland. Vegetation is dominated by the variety of grass species which include *Melinis repens, Cymbopogon excavatus* and *Paspalum dilatatum.* Poor management of the grassland in the study area has led to increases of grasses such as *Eragrostis curvula*, *E. plana, Sporobolus africanus* and *S. pyramidalis* (Mucina and Rutherford, 2011). The common herbaceous plants are *Amaranthus hybridus* and *Galinsoga parviflora*. The majority of the households have subsistence gardens. Crops grown in the household garden and community co-operation fields include maize, pumpkins, beans, taros, sweet potatoes and cabbages. Scavenging chickens are common in sustaining livelihoods in the village.

4.2.2 Household sampling for questionnaire and data collection

Eighty households were selected based on ownership of scavenging chicken and willingness to further participate on crop and gizzard experiment. All farmers were willing to participate in the study. The households were randomly selected. The structured questionnaire was randomly administered to households by four trained enumerators. The enumerators were obtained in the local village to make members of the community to be comfortable with responding to questions. The questionnaire captured household demography, socio-economic status and management of chickens. Transect walks were also made in the participating households to explore resource endowments, assessing socio-economic status and chicken breeds available.

4.2.3 Birds sampling and collection of crop and gizzard contents

A total of 120 Ovambo chickens were be used in the study. Thirty birds consist of 15 hens and 15 cocks were randomly purchased from households. The hens had to go through at least one cycle of laying period while cocks had to be at least one year old. The cock had to show signs of sexual maturity such as treading, crowing, pecking and chasing hens, copulating, mounting, tidbitting, waltzing and wing flipping. The sampling of the crop and gizzard contents in the households was conducted over two to three days in each season. The same selected households were used throughout the study. Birds were slaughtered in four different months to accommodate different seasons of the year. The collection of crop and gizzard contents was, therefore, conducted in November to January (rainy season), February to April (post rainy season), May to July (cool dry season), and August- October (hot dry season). Birds were collected directly from the households between 1700 and 1900 hours after spending the day scavenging. Live birds were weighed and slaughtered by the household member who generally slaughters chickens in the household. Most of the chickens were slaughtered by cutting and dislocating cervical region using a sharp knife and manually plucking feathers after few minutes of hot water dipping of the carcass. Each bird was eviscerated and the digestive tract opened.

The crop and gizzard of each bird were collected and inserted into polyethylene plastic samples and were enclosed to cooler box with ice. They were then transported to the University of KwaZulu-Natal (UKZN), Animal and Poultry Science Laboratory. It took about two hours to transport crop and gizzard from to UKZN. Afterwards, they were allowed to defrost. The crop and gizzard for each bird was dissected and the contents were sun-dried for four hours to avoid putrefaction. The feed resources found were identified and partitioned on as-is basis using visual observation. These feed resources categorized as grains, kitchen wastes, green forages, animal protein sources, inorganic sources and miscellaneous materials. Partitioning of the feed resources was physically done with the aid of forceps. Partitioned feed materials were weighed before they were mixed together for each bird. In the gizzard contents, only feed items that were visually identifiable were separated. The fine feed particles of gizzard contents were added to a mixture of diet per bird for chemical analyses. The diets of each bird were put into sample containers and stored at -20 ^{0}C in the fridge-freezer for nutritional analyses (Mwalusanya *et al*., 2002).

4.2.4 Chemical analyses of chicken crop and gizzard contents

All crop and gizzard contents samples were analysed in duplicate. The dry matter content (DM) was analysed in accordance to the standards of the Association of Official Analytical Chemists (AOAC) based on the official method 934.01 (AOAC, 1990). To determine DM, the crop and gizzard mixture per sample was heated in an oven at 100 ^{o}C for 16 hours. Samples were ground and milled to pass through a 1mm sieve. Ash content was determined by incinerating the sample at 550 ^{0}C for 16 hours (AOAC, 1990). Crude protein was determined using nitrogen to protein conversion factor of 6.25 to convert total nitrogen to CP. The N content of the DM was determined using the Duma Combustion in a Leco Truspec Nitrogen Analyser, St Joseph MI, USA, according to 900.03 of AOAC (1990). Ether extract (EE) was determined using Soxhlet apparatus according to method 920.39 of AOAC (1990). The crude fibre (CF) was determined according to ANKOM, AOCS Ba 6a-05. The neutral detergent fibre (NDF) was determined according to ANKOM Technology Method 7-07-06 and acid detergent fiber (ADF) was determined according to ATM 08-26-05 using ANKOM^{200} Fibre Analyser (Ankom, Macedon, NY, USA), according to Van Soest (1991). The CF content was determined according to ANKOM, AOCS Ba 6a-05. The NDF content was assayed using heat stable α-amylase (Sigma A3306; Sigma Chemical Co., St. Louis, MO, USA). Nitrogen free extract was calculated by using the equation: NFE (g/kg) =1000 – (CP g/kg + CF g/kg + EE g/kg + Ash g/kg) (NRC, 2001).

Calcium and phosphorus were determined by atomic absorption flame spectroscopy, method 6.5.1 (AOAC, 1990). The TME (MJ/kg) levels were determined by an indirect method using the following formula: True Metabolisable energy (TME) (MJ/kg dry matter) = (3951 + 54.4EE – 88.7CF – 40.8 Ash) x 0.004184 (Wiseman, 1987). Amino acids were determined using an iron-exchange column in a high performance liquid chromatographic system according to AOAC (1990).

4.2.5 Statistical analyses

All data were analysed using SAS (2008). Household demography and chicken management was analysed using PROC FREQ of SAS (2008). The association between sex of bird and season on the occurrence of animal protein sources was determined using the Chi-square test. The physical and nutritional composition of crop and gizzard contents data were analyzed using general linear models procedure of SAS (2008) based on the model:

$Y_{ijk} = \mu + S_i + B_j + (SxB)_{ij} + \varepsilon_{ijk}$, where,

Y_{ijk} is an observation for a physical and nutritional composition of the diet;

μ is the overall mean;

S_i is the effect of i^{th} season;

B_j is the effect of j^{th} sex of bird;

$(SxB)_{ij}$ the interaction of season and sex of bird;

e_{ijk} is the random error.

4.3 Results

4.3.1 Household demography and chicken management

Table 4.1 shows demographics of Gugwini village. The majority of the farmers were females. Farmers relied chiefly on child support and old-age grants from the government. Scavenging chickens were integral components of all the households.

Table 4.1: The demographical information of Gugwini village of uMzimkhulu local municipality

Variable	Percentage (n= 80)
Famers who were single	56.0
Farmers who were unemployed	64.7
Farmers who were traditional-religious	66.7
Major source of income	
Child support grant only	44.4
Old age grants	33.3
Formal work	22.3
Gender of head of the households	
Female	55.6
Male	44.4
Most important livestock	
Scavenging chickens	54.1
Cattle	36.6
Sheep	5.3
Goats	4.0

The majority (70 %) of the households did not provide appropriate overnight housing. The birds were found scavenging around 0600 hours. Around 1900 hours, they rested in tree branches and human dwellings. Of those households that provided overnight housing for their chickens, 60 % cleaned housing using sweeping brooms. None of the households cleaned the chicken houses with water and detoxifying chemicals to kill bacteria. Water provision was occasional. The common chicken breeds kept were Natal game, Ovambo, Naked Neck and Venda. All the farmers allowed hens to scavenge with their chicks. Virtually all (95 %) farmers reported that high disease prevalence and feed availability are the major challenges to village chickens production. Chickens were occasionally supplemented with maize grain (75 %) and to some extent, rice (46 %). Wild cats (80 %) and snakes (63 %) were reported as the important predators to chickens. Seventy two percent of the famers reported that hens were more vulnerable to predation than cocks. All farmers were aware that maize is the prominent feed resources found in the crop and gizzard contents. Scavenging of feed occurred throughout the year for all classes of chickens.

4.3.3 Birds and physical components of the crop and gizzard contents

The effects of season and sex of bird on the weight of the crop and gizzard contents and their physical components are depicted in Table 4.2. The body weight of the chickens differed ($P < 0.05$) with season and sex of bird. The interaction between season and sex of bird had a significant effect on the body weight of chickens. The body weight of the birds was highest ($P < 0.05$) during the cool dry and post rainy seasons. Cocks had a higher ($P < 0.05$) body weight than hens.

Table 4.2: Effects seasons and sex of bird on the physical properties of scavenging crop and gizzard contents

Components	Seasons (S)				Sex of birds (B)		*P*-value		
	Rainy	Post rainy	Cool dry	Hot dry	Hens	Cocks	S	B	S X B
Relative fresh crop and gizzard contents (g)	0.03 ± 0.002[b]	0.02 ± 0.002[c]	0.04 ± 0.002[a]	0.03 ± 0.002[b]	0.03 ± 0.001[a]	0.03 ± 0.002[a]	**	ns	ns
Physical component (g/kg)									
Cereal grains	29.0 ± 6.71[b]	26.8 ± 6.92[b]	52.1 ± 6.36[a]	49.8 ± 7.23[a]	36.6 ± 4.08[a]	42.3 ± 5.46[a]	*	ns	ns
Kitchen wastes	20.4 ± 5.82	17.4 ± 5.29	15.4 ± 7.26	4.2 ± 8.43	17.8 ± 3.71	10.9 ± 5.71	ns	ns	ns
Green materials	7.9 ± 0.75[a]	5.1 ± 0.80[b]	4.3 ± 1.12[b]	3.3 ± 1.08[b]	5.0 ± 0.60[a]	5.3 ± 0.73[a]	**	ns	**
Animal protein sources	1.5 ± 0.23[a]	1.0 ± 0.19[a]	0.4 ± 0.38[b]	0.4 ± 0.22[b]	1.1 ± 0.12[a]	0.6 ± 0.24[b]	**	*	ns
Organic sources	1.4 ± 0.22[a]	0.9 ± 0.19[ab]	0.5 ± 0.25[b]	00.4 ± 0.23[b]	0.9 ± 0.15[a]	0.7 ± 0.17[a]	**	ns	ns
Miscellaneous materials	1.2 ± 0.36	4.5 ± 3.10	3.4 ± 2.68	4.9 ± 2.02	4.4 ± 1.69	2.7 ± 1.95	ns	ns	ns

Values in the same row with different superscripts differ ($P < 0.05$)

*$P < 0.05$; **$P < 0.01$; [ns] $P > 0.05$

Cocks had a higher body weight than hens during the rainy season ($P < 0.05$) while during the post rainy season, the body weights of both sexes were similar ($P > 0.05$) (Figure 4.1). The relative fresh crop and gizzard contents varied considerably among seasons. The relative fresh crop and gizzard content weights were highest ($P < 0.05$) during the cool dry season. The weights of the cereal grains were the highest in the crop and gizzard contents ($P < 0.05$). The weights of the cereal grains in the crop and gizzard were highest during cool dry and hot dry seasons ($P < 0.05$). *Zea mays* was the main cereal grain found in the crops and gizzards during cool dry and hot dry seasons. *Oryza sativa* and samp were mostly observed during the rainy season.

The kitchen waste content in the crops and gizzards did not vary ($P > 0.05$) with either season or sex of bird. Common components of kitchen waste found in crops and gizzards were cooked mealie meal, potato peels, cooked vegetable trimmings and canned fish remnants. The fresh weight of green materials in crops and gizzards was highest ($P < 0.05$) during the rainy season. The prominent green materials observed in the crop and gizzard contents were *Melinis repines*, *Cymbopogon excavatus*, *Paspalum dilatatum*, *Amaranthus hybridus* and *Galinsoga parviflora*. The weight of animal protein sources in the crops and gizzards was highest ($P < 0.05$) during the rainy and post rainy season. The common animal material found in the crops and gizzards were Beetles (*Coleoptera*), locusts (*Acrididae*), caterpillars (*Larva)*, earthworms (*Eisenia fetida* and *Perionyx excavatus*), bugs (*Hemiptera*), ants (*Formicidae*). The weights of animal protein sources were higher in hens than cocks ($P < 0.05$).

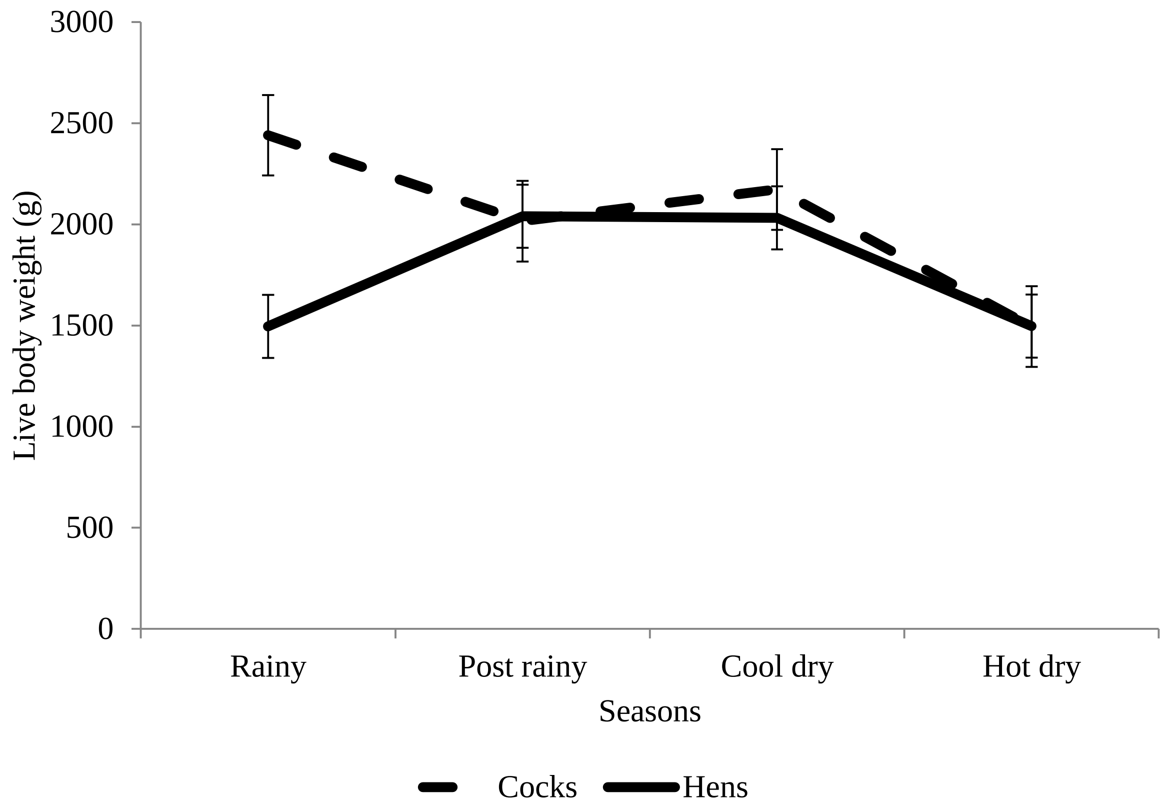

Figure 4.1: Changes in body weight of scavenging cocks and hens

There was high number of hens ($P < 0.05$) that had animal protein sources in the crop and gizzard contents that cocks (Table 4.3). Organic materials, which were predominantly soil, sand, stones, grits, chicken bones, egg shells occurred mostly ($P < 0.05$) during rainy and post rainy seasons.

4.5.5 Chemical and amino acid composition of crop and gizzard contents

The chemical composition of the crop and gizzard contents is given in Table 4.4. Hens and cocks had a similar DM content during rainy and cool dry season (Figure 4.2). The DM content was, however, marked higher in the hot dry season to cocks than hens. Crude protein and CF concentrations were higher ($P < 0.05$) in the rainy season. There was a significant interaction ($P < 0.05$) between season and sex of bird on level of CP content (Figure 4.3). Hens had a higher ($P < 0.05$) CP during the rainy season than cocks. The NDF and ADF were highest ($P < 0.05$) in the hot dry season than the other seasons. Ash, calcium and phosphorous were not affected ($P > 0.05$) by season and sex of bird. Nitrogen free extract and TME content were highest ($P < 0.05$) in the cool dry season. The relationship between TME and CP is depicted in figure 4.4. The CP content was highest during the rainy season and TME content was lowest ($P < 0.05$). Amino acid concentration varied with season ($P < 0.05$) (Table 4.5). The amino acids were significantly high during cool dry season. These amino acids were histidine, serine, arginine, threonine and cysteine. The concentration of lysine and cysteine in the crop and gizzard contents diet was generally low across seasons. The interaction between seasons and sex of bird had a significant effect on lysine concentration (Figure 4.5). The concentration of lysine in crop and gizzard contents of hens was highest during the rainy season while in cocks it was highest during cool dry season ($P < 0.05$).

Table 4.3: Percentage of cocks and hens which had animal protein sources in their crop and gizzard contents

Seasons	Cock	Hen	Chi-square test
Rainy	33.3	90.9	**
Post rainy	16.7	56.5	*
Cool dry	25.0	27.3	ns
Hot dry	80.0	41.2	ns

*$P < 0.05$; **$P < 0.01$; ^{ns} $P > 0.05$.

Table 4.4: Effect of season and sex of bird on the nutritional quality in the diet of scavenging chickens

Chemical components (g /kg)	Season (S)				Sex of bird (B)		*P*-value		
	Rainy	Post rainy	Cool dry	Hot dry	Hens	Cocks	S	B	S X B
Ether extract	18.9 ± 3.12	18.6 ± 3.12	25.6 ± 3.20	18.2 ± 3.79	19.0 ± 1.85	21.6 ± 2.76	ns	ns	ns
Crude fibre	207.0 ± 11.57^{a}	169.9 ± 10.97^{b}	141.2 ± 13.88^{b}	120.6 ± 13.18^{b}	151.1 ± 7.45^{a}	168.3 ± 9.98^{a}	**	ns	ns
NDF	854.2 ± 36.73^{b}	971.7 ± 34.11^{a}	836.9 ± 47.72^{b}	1049.5 ± 41.58^{a}	934.9 ± 23.53^{a}	921.3 ± 32.80^{a}	**	ns	ns
ADF	717.7 ± 40.99^{b}	866.8 ± 37.97^{a}	715.1 ± 53.12^{b}	949.5 ± 46.28^{a}	831.1 ± 26.19^{a}	793.2 ± 36.52^{a}	**	ns	ns
Ash	461.7 ± 53.85	387.4 ± 50.01	299.4 ± 69.95	513.9 ± 60.96	440.6 ± 23.53	390.6 ± 48.09	ns	ns	ns
NFE	267.8 ± 40.71^{b}	296.1 ± 40.71^{b}	471.7 ± 41.66^{a}	244.4 ± 49.47^{b}	339.9 ± 24.12^{a}	300.2 ±36.00^{a}	**	ns	ns
TME (MJ/kg)	3.1 ± 0.71^{b}	4.0 ± 0.71^{b}	7.9 ± 0.73^{a}	3.5 ± 0.86^{b}	4.9 ± 0.42^{a}	4.3 ± 0.63^{a}	**	ns	ns
Calcium (mg/kg)	108.6 ± 29.81	30.5 ± 27.41	64.1 ± 43.71	65.9 ± 34.39	83.1 ± 19.83	54.9 ± 28.82	ns	ns	ns
Phosphorous (mg/kg)	23.5 ± 2.77	22.8 ± 2.83	23.7 ± 4.05	20.7 ± 3.18	23.3 ± 2.67	22.0 ± 1.84	ns	ns	ns

Values in the same row with different superscripts differ (P < 0.05)

*$P < 0.05$; **$P < 0.01$; ^{ns} $P > 0.05$. NDF= Neutral detergent fibre, ADF= Acid detergent fibre, NFE= Nitrogen free extract, TME=, True metabosable energy

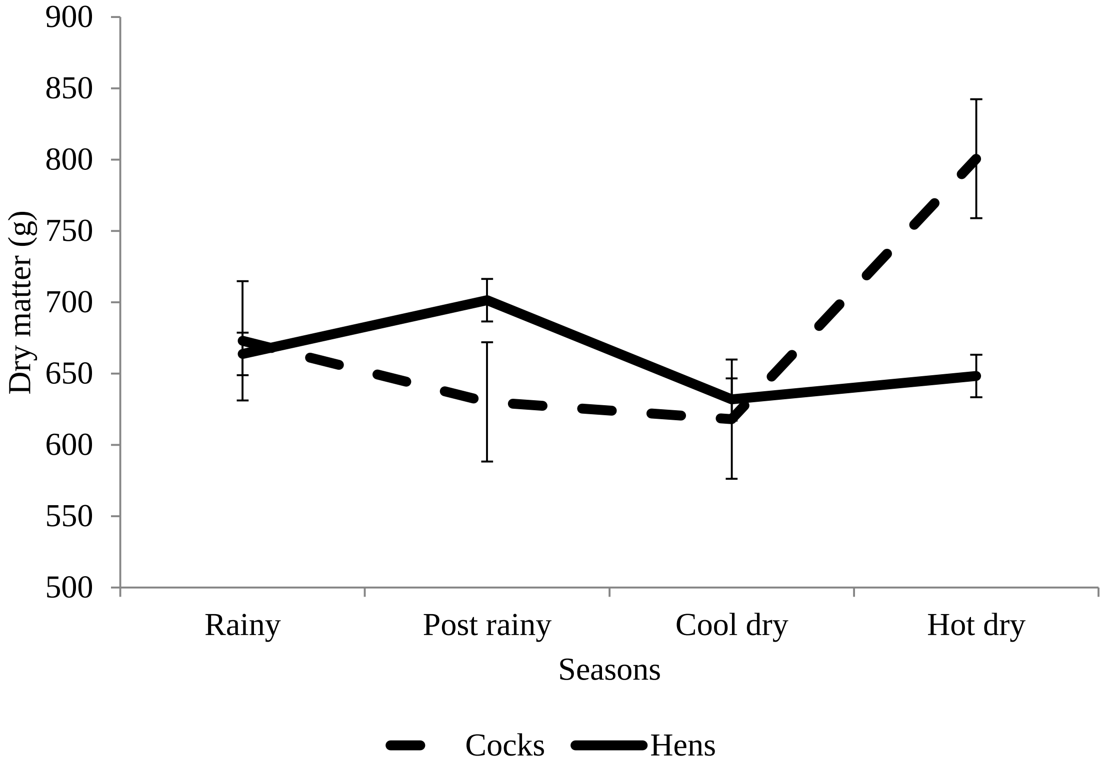

Figure 4.2: Changes in dry matter content of crop and gizzard contents of scavenging cocks and hens across seasons

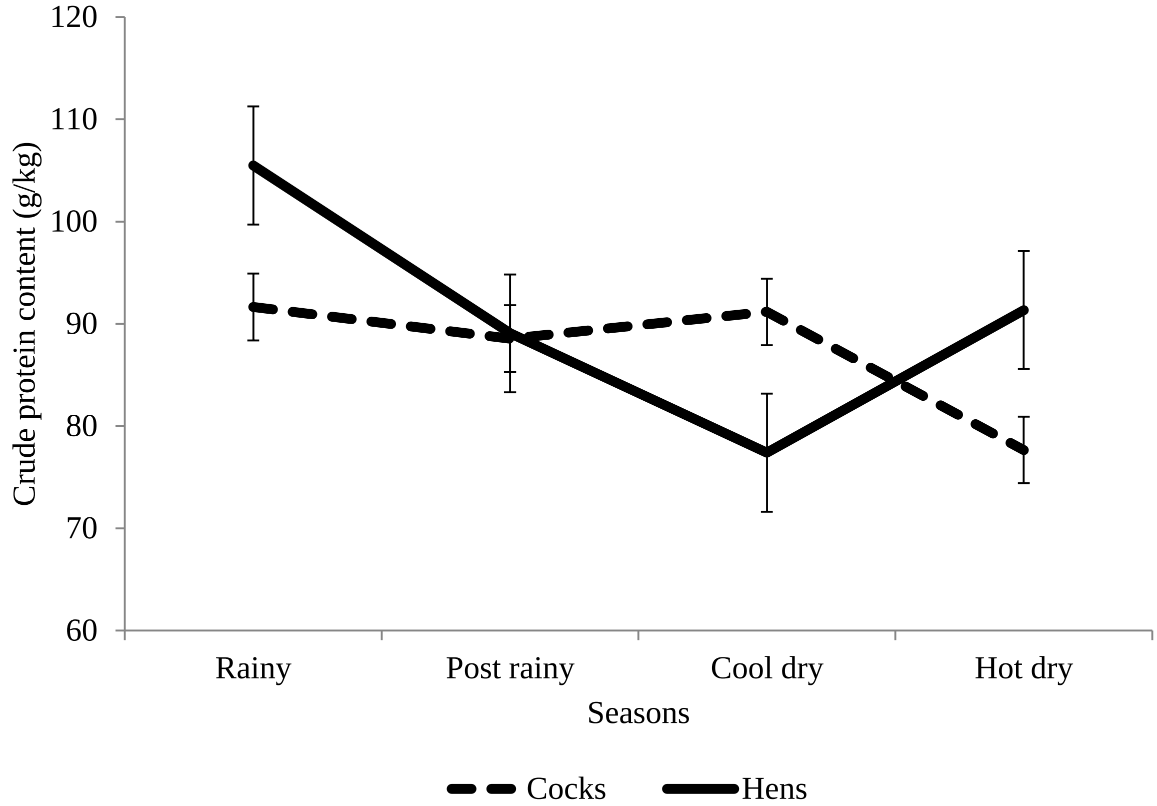

Figure 4.3: Changes in crude protein content of crop and gizzard contents of scavenging cocks and hens across seasons

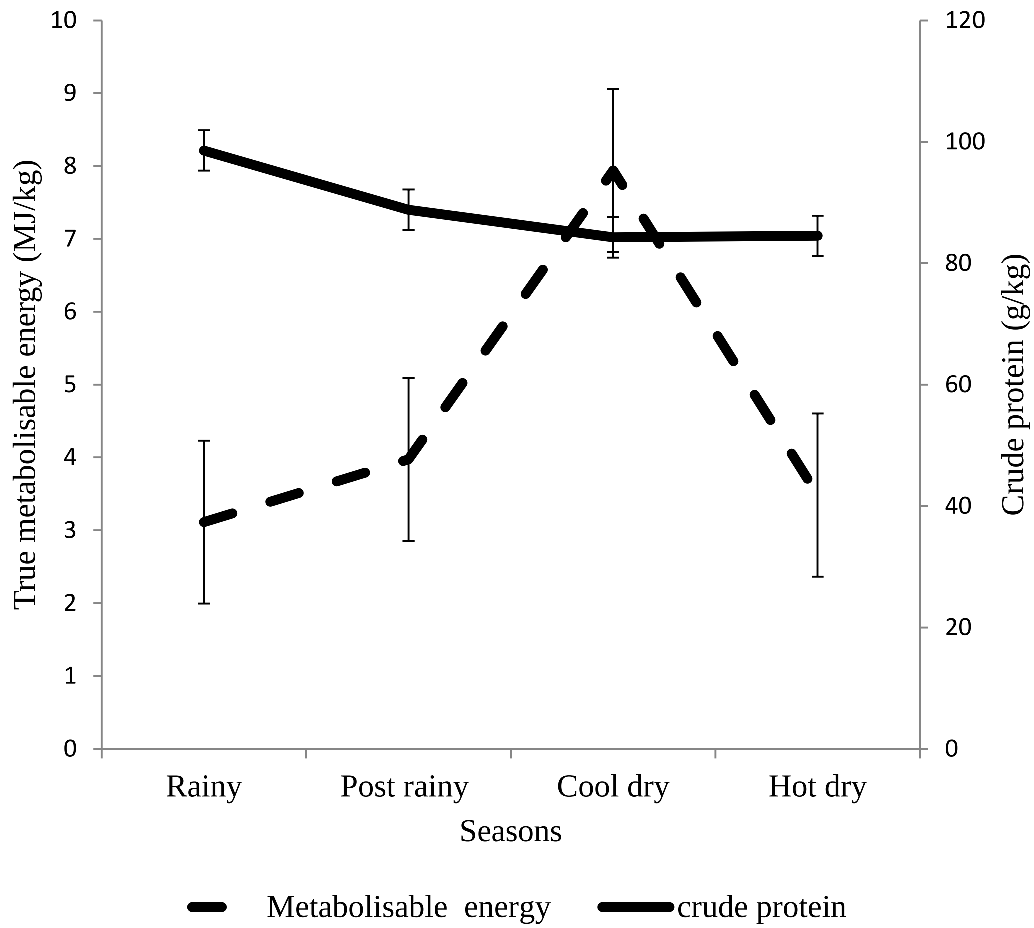

Figure 4.4: Seasonal changes in true metabolisable energy and crude protein in the crop and gizzard contents

Table 4.5: Effect of season and sex of bird on the amino acid components in the diet of scavenging chickens

Amino acids components (g /kg)	Season (S)				Sex of bird (B)		*P*-value		
	Rainy	Post rainy	Cool dry	Hot dry	Hens	Cocks	S	B	S X B
Histidine[#]	1.8 ± 0.03[b]	1.8 ± 0.03[b]	3.0 ± 0.03[a]	1.6 ± 0.03[b]	2.1 ± 0.02[a]	1.9 ± 0.02[a]	*	ns	ns
Serine	3.5 ± 0.03[ab]	2.9 ± 0.03[b]	3.9 ± 0.03[a]	1.2 ± 0.03[c]	2.9 ± 0.02[a]	2.9 ± 0.02[a]	**	ns	ns
Arginine[#]	3.6 ± 0.04[ab]	2.8 ± 0.04[b]	4.3 ± 0.04[a]	1.3 ± 0.04[c]	3.2 ± 0.03[a]	2.8 ± 0.03[a]	**	ns	ns
Glycine	4.9 ± 0.05	4.4 ± 0.05	5.5 ± 0.05	3.9 ± 0.05	5.0 ± 0.04	4.3 ± 0.04	ns	ns	ns
Aspartate	5.0 ± 0.07	4.5 ± 0.07	4.5 ± 0.07	2.9 ± 0.05	4.1 ± 0.05	4.0 ± 0.05	ns	ns	ns
Glutamine	11.3 ± 0.18	9.9 ± 0.18	11.4 ± 0.18	8.7 ± 0.18	10.5 ± 0.13	10.9 ± 0.13	ns	ns	ns
Threonine[#]	2.8 ± 0.03[a]	2.3 ± 0.03[a]	3.0 ± 0.03[a]	1.3 ± 0.03[b]	2.4 ± 0.02[a]	2.3 ± 0.02[a]	*	ns	ns
Alanine	4.9 ± 0.06	4.2 ± 0.06	5.1 ± 0.06	3.8 ± 0.06	4.6 ± 0.04	4.4 ± 0.02	ns	ns	ns
Proline	6.0 ± 0.06	5.6 ± 0.06	7.5 ± 0.06	5.5 ± 0.06	6.4 ± 0.04	6.0 ± 0.04	ns	ns	ns
Cysteine[#]	1.0 ± 0.02[a]	1.0 ± 0.02[a]	1.0 ± 0.02[a]	0.2 ± 0.02[b]	0.6 ± 0.02[a]	1.0 ± 0.02[b]	*	*	ns
Tyrosine	3.9 ± 0.04	3.9 ± 0.04	4.9 ± 0.04	3.5 ± 0.04	4.4 ± 0.03	0.38 ± 0.03	ns	ns	ns
Methionine	1.6 ± 0.02	1.5 ± 0.02	1.8 ± 0.02	1.1 ± 0.02	1.5 ± 0.01	1.4 ± 0.01	ns	ns	ns
Valine[#]	4.3 ± 0.04	2.8 ± 0.04	4.8 ± 0.04	3.4 ± 0.04	4.3 ± 0.03	3.7 ± 0.03	ns	ns	ns
Isoleucine[#]	3.0 ± 0.03	2.6 ± 0.03	3.0 ± 0.03	2.2 ± 0.03	2.8 ± 0.02	2.6 ± 0.02	ns	ns	ns
Leucine	8.1 ± 0.10	7.4 ± 0.10	9.3 ± 0.10	7.0 ± 0.10	7.8 ± 0.07	8.1 ± 0.07	ns	ns	ns
Phenylalanine	4.6 ± 0.06	4.5 ± 0.06	5.9 ± 0.06	4.3 ± 0.06	5.2 ± 0.04	4.6 ± 0.04	ns	ns	ns

Values in the same row with different superscripts differ (P < 0.05)

*P< 0.05; ***P* <0.01; [ns] *P* > 0.05. [#] Essential amino acids for chickens

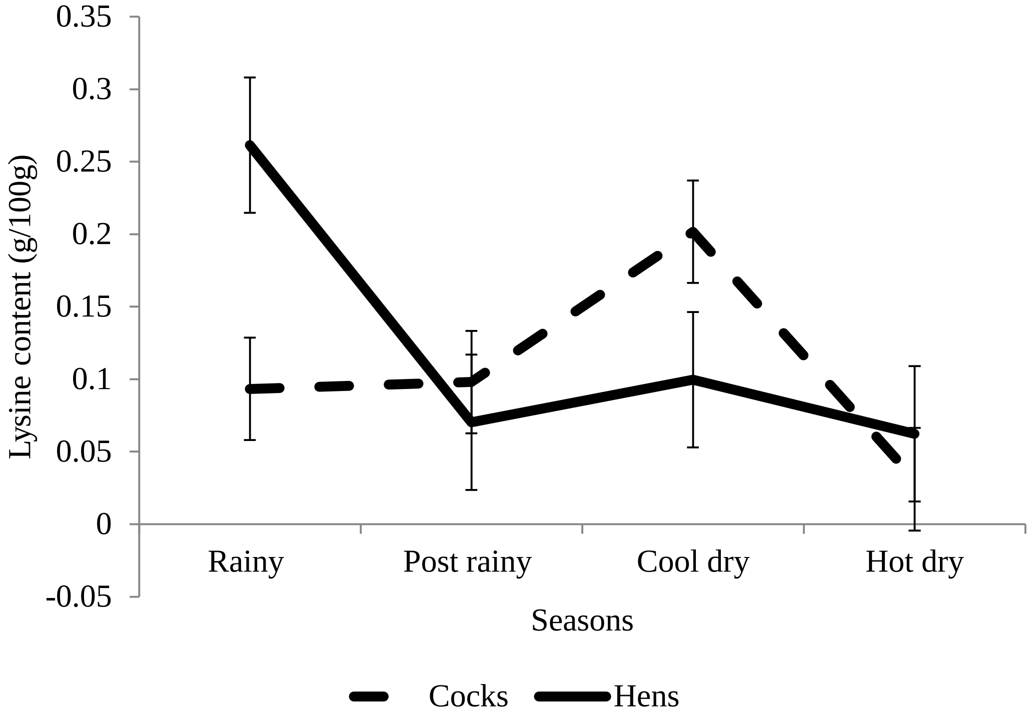

Figure 4.5: Changes in lysine content of crop and gizzard contents of scavenging cocks and hens across seasons

4.4 Discussion

High number of female-headed households available indicates that females are liable for any homestead related activities. Women play a major poultry management, in both female and male-headed households (Mekonnen *et al*., 2010). Scavenging chickens dominates other livestock in rural settings because they are kept in a low-input production system (Mwalusanya *et al*., 2001). Keeping chickens in human dwellings might limit the numbers and predispose them to disease (Sonaiya, 1990). Unavailability of housing to chickens indicates that farmers consider village chickens to be adapted to their local conditions such that they need no improvements in management.

The occasional supplementation reported in the current study complement with earlier findings (Mwalusanya *et al*., 2002; Mekonnen *et al*., 2010). Indiscriminative feeding favours stronger group of birds such cocks and hens to consume more share of supplemented feed. This results into weaker group such as chicks and growers to struggle to scavenge supplemented feed (Dessie and Ogle, 2001). As a result, they are likely to be nutritionally impaired. The occasional supplementation reported in the current study complement with earlier findings (Mwalusanya *et al*., 2002; Mekonnen *et al*., 2010). Indiscriminative feeding favours stronger group of birds such cocks and hens to consume more share of supplemented feed. This results into weaker group such as chicks and growers to struggle to scavenge supplemented feed (Dessie and Ogle, 2001). As a result, they are likely to be nutritionally impaired.

The physical and nutritional content of scavengeable feed resource is often done through identification of feed resources found in the crop of scavenging chickens. Chickens have the crop and the gizzard as a major stomach compartments that are responsible to store food. Feed emptying rate is quick in the crop than gizzard organ where the rate of accumulation is higher than the rate of emptying (Vergara *et al*., 1989). Crop gets completely filled in about four hours of scavenging and some of the feed resources can bypass the crop (Feltwell and Fox 1978; Minh *et al*., 2006). The gizzard is, therefore, the main retention organ for solid and tiny feed components in the diet where the feed is mixed and ground. The gizzard contents can, therefore, give more useful information about the physical and nutritional value of the diet.

Seasonal and sex of bird variations on body weight were expected. The daily energy intake is likely to vary with the individual bird and with season, depending on the availability of energy-rich feed resources. High body weight of cocks than hens agrees with Maphosa *et al*. (2004) and can be attributed to hormonal differences between the two sexes. High body weight of chickens during cool dry season could be because of abundance of cereal grains such as *Zea mays* during this season. Cereal grains are a source of dietary energy and high dietary energy results in high body weight (Proudfoot and Hulan, 1987). High crop and gizzard contents during cool dry season could be ascribed with abundance availability of cereals grains (Goromela *et al*., 2008).

The cool dry season is the time of the year when harvesting of cereal grains often occurs (Dessie and Ogle, 2000). The abundance of cereal grain in the crop and gizzards is, therefore, expected to be high since it corresponds with harvesting time. High amount of kitchen waste during rainy season could be due to frequent and bulk cooking for visiting relatives and families since it is the time of family get-together. In the rainy season, most households partition food grocery stock affairs and, as a consequence, the food and subsequently kitchen waste becomes ample. High occurrence of green materials during the rainy season could related with abundance of emerging green sprout shoots that are palatable to the birds (Dessie and Ogle, 2000; Mwalusanya *et al*., 2002).

The finding that crop and gizzard contents had high amount of animal protein sources during rainy season could be attributed to the abundance of these materials during the rainy season (Momoh *et al*., 2010). The difference in the amount of animal protein sources between hens and cocks is difficult to explain. It could, however, be related with selective feeding behaviour which depends upon the nutritional requirements. Hens and cocks have different requirements (Nonis and Gous, 2008) and, thus, select different feed resources during scavenging to meet their requirements. Surprisingly, the cocks and the hes scavenge together. High weights of mineral materials in the crop and gizzard contents during the rainy season is related with abundance of feed resources such as termites and earthworms that are fouled with sand, soils and grits after rainfall (Dahouda *et al*., 2008).

The observed high CP content during the rainy season compared to other seasons could be related with abundant swarm of insects and amply availability of worms and young plants found in the rainy season. This could also be the reason why lysine content was high to hens during rainy season. High CP and lysine content to hens during the rainy season could be associated with selective feeding behaviour. Hens have better ability to for protein-rich resources (Mekonnen *et al*., 2010) probably to meet nutrient for egg production. High CP and lysine content found in the crop and gizzard contents of scavenging cocks compared to hens during cool dry season could associated with fact that cocks are strongest group in the scavenging chicken flock therefore they have power to overcome other groups and consume these barely available protein-rich sources.

High DM content found in crop and gizzard contents during hot dry season could be due to availability of cereal grains from harvesting. In a similar study, Mekonnen *et al*. (2010) reported that DM was high during the harvesting season. The CF content values found in this study are higher than those reported in previous studies (Mekonnen *et al*., 2010; Pousga *et al*., 2005). In commercial layers, the recommended CF for ration is 50 g/kg percent (Feltwell and Fox, 1978). Excessive CF is likely to be poorly digested by mono-gastric endogenous enzymes (Mekonnen *et al*., 2010). High CF and NFE content of gizzard and crop contents of chickens during rainy season could be due to occurrence of green materials such as herbs and legumes that are rich in fibre content. The consumption of undesirable materials such as feathers and pieces of boxes may also contribute to high levels of ADF, ADF and CF contents. High indigestible fibre results in poor availability nutrients (Soniya *et al*., 1999).

The TME content was high during cool dry season. The observed TME values were, however, lower than those reported by Pousga *et al.* (2005) and Goromela *et al*. (2008) who reported values of 11.6 MJ/kg and 12.2 MJ/kg, respectively. The differing results in the TME values could be because of differences in available feed resources between the study areas. High energy content in the cool dry season compare to other season could because of the increased availability of cereal grains which had just been harvested and were given to the birds in larger amounts than during the other seasons of the year (Dessie and Ogle, 2000).

Low amino acid levels could as a result of scantiness of animal protein sources in scavenging terrain. High concentration of amino acids during cool dry season is probable from the cereal grains (*Zea mays*) that were abundant in this season. Protein from maize is, however, deficient in the essential amino acids such as lysine (Minh, 2005). This could be the reason why lysine levels were low during the cool dry season. Lysine, whose levels were low across seasons, is the first-limiting amino acid in the diet of chickens (Nonis and Gous, 2008). There is, therefore, need to embark on using locally available lysine-rich feed resources such as earthworms. Earthworms have high levels of protein and amino acids with notably high lysine content (Zhenjun *et al*., 1997).

4.5 Conclusions

The nutritional quality and amino acid composition varied with season, sex of bird. Cereal grains were abundant during the cool dry season. The weights of animal protein and organic sources were notably high during rainy season. The animal protein sources were occurred to hens than cocks during the rainy season. Hens had a higher CP during the rainy season than cocks. The CF and NFE contents were high during rainy season than other season. The NDF and ADF were highest in the hot dry season. Apart from lysine, the amino acids were significantly high during cool dry season. Lysine concentration was high during the rainy season.

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CHAPTER 5: General discussions, Conclusions and Recommendations

5.1 General discussion

Chickens are mainly used for meat since it can be slaughtered easily and can be eaten as a once-off meal. Chicken production is hampered with various challenges which include poor feed availability and quality. These birds scavenge for green materials, animal protein materials, stones and grits. They are supplemented with energy-rich feed resources such as maize, sorghum and rice. To improve the household nutrition through chicken sales and consumption, there is a need for resource-limited farmers to first improve the nutritional status of their chickens. Scavenging chickens do not get adequate feed resources such as proteinous feedstuffs to support optimum growth, egg production and reproduction.

A structured questionnaire was administered to assess farmer perceptions on the use of NCAP source for scavenging chicken (Chapter 3). The study revealed that feed shortages were the major constraint to chicken production. Cocks were the main class of chickens that were slaughtered, largely because of their large frame sizes, control inbreeding and reduce fighting of cocks. Farmers who did not provide overnight houses also did not provide supplementary feeds for chickens. These findings indicate that farmers consider village chickens to be adapted to their local conditions such that they need no improvements in management. The use of sorghum as an alternative energy sources for chickens seem to viable approach to African traditional farmers to circumvent energy shortages for chickens. Protein-rich feed resources were viewed as very scarce and limiting to chickens for them to meet their protein requirements. There is, therefore, a need to explore the utilization of renewable NCAP sources as protein supplements. Earthworms and termites were the preferred NCAP sources. Farmers reported that these sources are more available during the rainy season. The farmers, however, lacked knowledge on how to propagate them so as to make them available in bulk for chicken feeding throughout the year.

In Chapter 4, the objective was to determine the interaction between sex of the bird and season on the nutritional quality of scavenging chickens using crop and gizzard contents. The results showed that nutritional status of scavenging chickens is poor and varied with season and sex of bird. Cereals grains, animal protein sources and green materials were the major feed materials in the crop. Fibre levels were high. Excessive indigestible fibre sources in the diet of scavenging chicken could impair the utilization of nutrients available for birds. Birds also consumed resources that do not add any nutritional value such as hair, plastic bags, boxes and glasses. The nutrient content of the crop suggest that the requirements for scavenging, walking, reproduction, maintenance, growth and fighting with prey and overcome it, are not likely to be met. The low levels CP particularly during cool dry season could be due absence of animal protein sources, such as insects and worms. Hens are dual purpose birds since are used for meat and eggs. They, therefore, have better ability to scavenge for protein-rich reed resources than cocks. As a result, they have higher CP content than cocks. Low levels and seasonal variation of amino acid composition could due to scantiness of protein-rich feed resources under scavenging conditions. Lysine is the essential amino acid and first limiting nutrient in the diet of chickens. It is, therefore, crucial to supplement with lysine-rich feed resources to satisfy amino acids needed by birds for optimum productivity.

5.2 Conclusions

Feed shortages were among the major challenges to chicken production. Chicken housing highly influenced the household's probability to experience feed shortages. Farmers with large flock sizes were more willing to consider using NCAP sources to meet nutrient requirements for their chickens. The nutritional quality of scavenging chickens was low with low quantities of animal protein sources and green materials. The diet had high contents of CF, NDF and ADF and low concentrations of TME, CP, minerals and amino acids. Hens had a high CP and lysine contents during the rainy season than cocks. Hens consumed more of animal protein sources during the rainy season than cocks.

5.3 Recommendations and further research

Scavenging chickens cannot find all nutrients they need under scavenging terrain at all year around. Moreover, the nutritional quality of scavenging village chickens is low. There as a need for efficient nutrient supplementation strategies to improve village chicken productivity. These supplementary strategies include the use of inorganic, sustainable and reliable feed resources to produce organic meat and eggs at optimal levels. It also is essential to identify, quantify and analyse the specific feed resources that chickens graze on, as a way to further understanding quality and quantity of feed items scavenged by scavenging.

Training of farmers about importance of NCAP sources to chickens for sustainable feeding systems and improvement of chicken productivity needs to be emphasized. Training should include possible propagating, harvesting techniques and processing using locally available resources. Training and capacity building raises awareness to farmers about importance NCAP sources should focus on farmers who are keeping chickens. Women and children should be targeted. There is, therefore, a need to conduct a collaborative and co-operative research projects involving government, non-government organizations, academics, farmers and other stakeholders on sustainable intensification of village chicken production. The information should also be written and addressed in vernacular language for farmers to understand. It can also be dissipated using local newspapers, radio stations and a magazine. For sustainable production of NCAP source, storage facilities are required. These facilities should locally available such cemented tanks, buckets and cemented holes.

Aspects that need further research include:

1. The effect of growth stages of maturity of NCAP sources on their nutritional profile and performance of scavenging chickens.
2. The effect of substrate source on the nutritional profile of NCAP sources.
3. Conducting trials on digestibility, nitrogen retention, absorption and utilization of NCAP sources in village chickens.
4. Assessing vitamin contents of the feed materials that scavenging chickens consume.
5. How do NCAP sources such as termites and earthworms digest fibrous materials?
6. Effect of processing procedures on the quality of NCAP sources.
7. On farm trials on the effect of NCAP sources on the performance and productivity of scavenging chickens.
8. Effect of different classes of chickens on the crop and gizzard contents of scavenging chickens.

Appendix 1: Questionnaire on the use of non-conventional protein sources in indigenous chickens

Community Name/ *igama lendawo*:	
District Name/ *igama lomaspala omkhulu*	
Do you have indigenous chickens in this household? (use code)/ *ingabe zikhona izinkukhu zesintu lapha ekhaya?* code: 1- yes/*yebo* 2- no/*cha*	
Time interview starts (HH:MM)/*isikhathi sokuqala imibuzo*	

SECTION A: Demographic and socio-economic status of the household/ *isimo sasekhaya kanye nomnotho*

1. Name of the head/ *igama lo mnini muzi*			
2. Age/ *iminyaka*		3. Gender/ *ubulili* codes:1-male/ *owesilisa* 2-female/ *owesifazane*	
4. Relationship/ *ubudlealwano* codes: 1-head/*inhloko* 2-spouse/*umama* 3-child/ *ingane*		5. Ethnic group/*ubudabu*	
6. Marital status/ *isimo sokushada* codes: 1-single/*akashadile* 2-married/*ushadile* 3-divorced/*uhlukanisile* 5-widowed/*ufelwe* 6-cohabiting/ *ukuhlalisana* 7-other/*okunye* (specify/ *cacisa*)		7. Primary occupation/ *ukuziphilisa* codes: 1-Farming/*ukulima* 2-Livestock rearing/*imfuyo* 3-Unemployed/*akasebenzi* 4-Pensioner/*impesheni* 5-Casual work/*amatoho* 6-Self-employed/*ukuzisebenza* 7-Formal work/*uyasebenza* 8-Student/*umfundi* 9- None/*lutho*	
8. Secondary occupation/ *enye indlela yokuziphilisa* codes: 1-Farming/*ukulima* 2-Livestock rearing/*imfuyo* 3-Unemployed/*akasebenzi* 4-Pensioner/*impesheni* 5-Casual work/*amatoho* 6-Self-employed/*ukuzisebenza* 7-Formal work/*uyasebenza* 8-Student/*umfundi* 9-None/*lutho*		9. Number of years residing in this area/*mingaki mimnyaka nihlala kule ndawo*	
10. Religion/*inkolo* codes: 1- Christian/*umkhrestu* 2- tradition-based/*amasiko* 3- other/*okunye* (specify/*cacisa*)		11. Number of adults in the households/ *Bangaki abadala abahlala lapha ekhaya? (>13years)*	
12. Number of children in the household up to 13 years of age/*bangaki amantwana anahlala lapha ekhaya? (<13years)*		13. The major source of income this household/*iyiphi indlela enithola ngayo imali?* codes: 1- formal work/*ukusebenza* 2- casual work/*amatoho* 3-hawking/*ukudayisa* 4- old-age grant/*impesheni yobudala* 5- child support/*isondlo sabantwana* 6- other/*okunye* (specify/*cacisa*)	

14. How much do you spent on food per month? / *Yimalini eniyisebenzisa ukuthenga ukudla njalo ngenyanga?*
    1) R0-R500 2) R501-R1000 3) R1001-R1500 4) R1501-R2000 5) R2001-R2500 6)>R250

Codes: 1= rarely (once or twice in the past four weeks), 2= sometimes (three to ten times in the past four weeks) 3= often (more than ten times in the past four weeks).

15. Ownership and benefits of different types of livestock/*ubunikazi kanye nokuhlomula ngemfuyo*

Other livestock type	Number of animals/ *zingaki*	How long have you been farming?/sekuyisikhathi esingakanani ufuyile (Code: 1= < 5 years, 2= 5-10 years, 3=10-20 years, 4=20-50 years)	Owner of the animals/*umnikazi* Code: 1.Father/ubaba 2. Mother/*umama* 3. Children/ *ingane* 4. Other/*omunye*(cacisa)	Responsible member in the household/ *wubani oyinakekelayo* Code: 1. Father/ *ubaba* 2.mother/ *umama* 3. Children./ *ingane* 4.Other/ *omunye*	Reason for rearing animals/*isizathu sokufuya* Codes 1.consumption/*ukudla* 2. Selling/ *ukudayisa* 3.Prestige/ *isithunzi* 4.Leisure/ *ukwenza nje* 5. Rituals/*imicimbi* 6. Manure/*umquba*	Which livestock that contribute significantly into livelihood of the household Tick (√) as many as you can./ *yingabe iyiphi imfuyo elekelela kakhulu esimeni sekhaya. Maka ngobuningi bazo*	Rank the importance of livestock/ *hlela ezintathu ngokubaluleka kwazo* 1 =most/ *kakhulu* 2= moderate/ *ngokusendimeni* 3=least/*kancane*
Broiler /*lamthuthu*							
Cattle/*izinkomo*							
Sheep/*iziklabhu*							
Goats/*izimbuzi*							
Ducks/*amaklewu*							
Pigs/*izingulube*							

16. What type(s) of chickens do you have? /*Yiziphi izinhlobo zezinkukhu ezikhona?*

Types of chickens/ *Izinhlobo zezinkukhu*	Flock size /*yinani le zinkukhu*				Hen: cock Ratio
	Cocks/amaqhude	Hens/*izikhukhukazi*	Chicks/*amachwane*	Total/*konke*	
Normal village chickens/*zesintu ezijwayelekile*					
Naked-neck/*ezichutheke intamo*					
Frizzle/*ezimvukumvuku*					
Exotic layers/*ezamaqanda*					
Exotic broilers/*olamthuthu*					
Other/*okunye* (specify/*cacisa*)					

17. What are the reasons of rearing indigenous chickens in this household? / *yiziphi izizathu zokufuya izinkukhu zesintu lapha ekhaya?*

Reasons/*izizathu*	Tick as many as possible/*maka ngobuningi bazo*	Rank the most 3 reason/*hlela zibe ntathu izizathu ngokubaluleka kwazo* 1= most/*kakhulu*, 2=moderate/*ngokusendimeni*, 3= least/*kancane*
Meat/*inyama*		
Eggs/*amaqanda*		
Income/*imali*		

Leisure/*ukwenzela nje*		
Rituals/*imicimbi*		
Manure/*umquba*		
Prestige/*isithunzi*		
Other/*okunye(cacisa)*		

18. Evaluating the importance of chickens/*ukukalwa kokubaluleka kwezinkukhu zesiNtu*

	Number of Chickens/ *Zingaki izinkukhu*	How long have you been farming chickens?/ *sekuyisikhathi esingakanani ufuye izinkukhu* (Code: 1= < 5 years, 2= 5-10 years, 3=10-20 years, 4=20-50 years)	Owner of the chickens/*umnikazi wezinkukhu* Code: 1.Father/*ubaba* 2.Mother/*umama* 3.Children/*izingane* 4. Other/ *omunye* (specify/*cacisa*)	Chicken responsible member in the household/ *ubani onakekela izinkukhu* Code: 1.mother/ *umama* 2.father/ *ubaba* 3.Children/ *izingane* 4.Other/*omunye (cacisa)*	Number of indigenous chickense bought since December 2012/ *Zingaki izinkukhu zesinti ozithengile kusuka ngo Dec 2012*	Total cost of purchasing indigenous chickens since December 2012/*wumalini esenithenge ngayo izinkukhu zesizulu kusuka ngo Dec 2012*	Number of indigenous chickens sold since December 2012/ *zingaki isinkukhu zesiZulu ezidayisiwe kusuka ngo Dec 2012*	Total number of indigenous chickens slaughtered since December 2012/ *zingaki Isinkukhu zesizulu ezihlatshiwe kusuka ngo Dec 2012*	Flock composition for adults chickens/Inani lezinkukhu ezifuyiwe ngobulili bazo	
									M	**F**

19. How can you describe you involvement in animal rearing? *Kungabe uzibandakanye kangakanani kwezemfuyo* ________ (1) Full time/*sonke izikhathi* (2) part time/ *ngezikhathi ezithile*
20. What do you think can be done to improve contribution by chickens in your household?/ *Yini ocabanga ukuthi ingenziwa kangcono ekuthuthukiseni izinga lokuhlomula ezinkukhwini zesiNtu?* ____
____
21. In which seasons do you experience **most** of the challenges for indigenous chicken? (Tick as many as possible then rank the most 3) *Yisiphi isiphi isikhathi sonyaka lapho ubhekana nezingqinamba ekufuyeni izinkukhu zesiNtu?(maka izinginamba bese uhlela ezintathu ezibalulekile 1-3)*

Challenges	Seasons							
	Hot Wet *ihlobo*	Rank *hlela*	Hot Dry *intwasahlobo*	Rank *hlela*	Cool Dry/*ubusika*	Rank *hlela*	Post-Rainy/*yikwindla*	Rank *hlela*
Disease/*izifo*								
External parasites/*izilwanyana zanga phandle*								
Internal parasites/*izilwanyana zangaphakathi*								
Theft/*ukwebiwa*								
Predation/*ukudliwa yizilwane*								
Limited market access */ukutholakala kwemakethe*								
Feed shortage/*ukushoda kokudla*								
Housing/*umpheme*								

Other/*okunye* (specify/*cacisa*)								

22. Predation as a cause of chicken loss/*Ukuzingelwa kwezikunkukhu* (Tick and rank 1-3 most -least important/Hl*ela ubungozi bazo*

Predators /*izilwane* ezizingelayo	**Tick /*Maka***	**Rank /*Hlela***
Snake/*inyoka*		
Mongoose/u*chakide*		
Dog/*Inja*		
Eagle /*Ukhozi*		
Wild cat/*imbodla*		
Other/o*kunye*(s) specify/*cacisa*		

23. Tick the most important predator of the following chickens/*Maka izilwane eziyingozi kulezinkukhu ezilandelayo*.

Izinkukhu/*umkhiqizo wezinkukhu*	Snake/*inyoka*	Mongoose/*Imbodla*	Dog/*inja*	Eagle/u*kheshan e*	Wild cat/*Imbodla*	Others/*okunye*
Eggs/*amaqanda*						
Chicks/a*machwane*						
Growers and adults/*ezinkukhu ezsakhula nezindala*						

24. Type of chicken farming system do you practice/*hlobo luni enilusebenzisayo ukufuya izinkukhu* (1) Extensive /*ziyadedelwa zidle noma ekephi(*2) Intensive/*ziyavalelwa ubusuku nemini ziphakelwe ukudla* (3) Semi-intensive/*zibiyeliwe kunezindawo zokudla* (4) Other /*okunye*(specify/*cacisa.*
25. Do you house chickens at night/*ingabe iyazivalela izinkukhu ntambama*? (1) Yes/*Yebo* (2) No/*Cha*
26. If yes/*Uma uthi yebo*, where do you house them/*uzuvalelakephi*? (1) human dwellings/*ezindlini lapho kuhlala abantu* (2) In the trees/*ezihlahlen*i (3) In cages/e*kheyijini* (5) Chicken house built for them/*endlini yezinkukhu* (5) other /okunye(specify/*cacisa*)
27. Materials used to make chicken house/*izinto enekha ngazo indlu yezinkukhu* (1) woods and Mud/*udaka nezinkuni* (2) woods and nets/*izinkuni ne-nethi* (3) Zinc metals /*othayela* 4) Bricks/*ngamabhulokisi* (5) other/*okunye* (specify*/cacisa*)
28. Do you clean chicken houses/*Ingabe niyaklina indlu yezinkukhu*? (1) Yes/*Yebo* (2) No/*Cha*
29. How often to do you clean chicken house/*ingabe niyiklina ngakhi indlu yezinkukhu*? Code: 1. once a week/*kawodwa esontweni*, 2. twice a week/*kabili esontweni*, 3. once a month/*kawodwa enyangeni*, 4. twice per month/*kabili enyangeni* 5. When we remember /*uma sekhumbulile*

SECTION B: Non-Conventional protein sources/*ukudla okusha ukunamaprotheni*

1. Do you feed your chicken/*uyaziphakela izinkukhu zakho*? (1) Yes/*Yebo* (2)No/*Cha*
2. If yes to/*uma uthi Yebo ku* (Q1), state the method of feeding/*isho indlela oziphakela ngayo* . (1) Broadcast into the ground/*ukuhlwayela egcekeni* (2) feeders/*izitsheni zokudla* (3) Other/*okunye*(specify/*cacisa*)
3. If you offer feed to your chickens, how do you provide feed/*Uma uziphakela izinkukhu zakho,isho uhlelo oziphakela ngalo* ? (1) Feeding altogether/ *ngiziphakela ndawonye* (2) feeding chicks only/*ngiphakela amachwane wodwa* (3) feeding hens and chicks/*ngiphakela amachwane nezikhukhukazi*
4. Do you practice supplementary feeding of your chicken with available feed resources/*niyaziphakela izinkukhu ngokudla okutholaka endaweni enihlala kuyo*? (1) Yes/*Yebo* (2) No/*Cha*
5. Which season do you mostly provide an extra feed for chickens/*esiphi isikhathi sonyaka lapho enithola khona ukudla okuningi kwezinkukhu*? (1) Hot dry season/*Ntwasahlobo* (2) Rainy season/*Ehlobo* (3) Cool dry season/*Ebusika* (4) Post rainy season/*Ekwindla*
6. Do chickens finish feed being supplemented to them/ *Ingabe izinkukhu ziyakuqeda ukudla eziphakelwe zona*
7. When do you normally the supplement chicken/*niziphakela nini izinkukhu*? (1) In the morning before they scavenge/*Ekuseni ngaphambi kokuthi ziziqhwishele* (2) in the mid-day during savaging/*Emini Zisaqhwisha* (3) In the evening after scavenging/*Ntambama emuva kokuqhwisha* (4) in the afternoon while scavenging/

Ntambama zisaqhwisa (5) Any time during day times/ *Noma inini osukwini* (6) others/*okunye* (specify/*cacisa*)\

8. If No to, *Uma uthe Cha ku* (Q4) what is the reason for not supplementing/*isiphi isizathu sokungazondli izinkukukhu*? (1) Unavailability of feed resources/*ukungatholakali kokudla* (2) Expensive feed resources/*ukubiza kokudla* (3) Ignorant about feeds/*ukunganaki ngokudla kwezinkukhu* (d) shortage of finance/*ukushoda kwezimali* (e) other /*okunye*(specific/*cacisa*)
9. If yes to/*Uma uthe yebo ku* (Q4) How many times per day do you supplement chickens with these feed resources/*niziphakela kangakhi ngosuku*?

   (1) Once/*kanye* (2) twice/*kabili* (3) three times/*kathathu* (4) none/*asiziphakeli*

11. Do you perform flock grading when feeding/*Niyazihlunisa izinkukhu uma niziphakela*? (1) Yes/*Yebo* (2) No/*Cha*

12. What do you think are the main constraints in chicken feeding/*ingabe iziphi izigqninamba ekondleni izinkukhu*? (1) Limited access/*ukungathokali kokudla* (2) Cost of feed/*ukubiza kokudala* (3) shortage of water/*ukushoda kwamanzi* (4) Other /*okunye*(specify/cacisa)

13. Have you experienced any shortage of feed for chickens in the past 12 months*/ Ingabe nike nihlangabezane nesimo sokushoda kokudla kwezinkukhu kusukela ezinyangeni eziyi-12 ezedlule* ? (1) Yes*/Yebo* (2) No/*Cha*

14. If yes/ *uma uthi yebo*, which season(s) do you experienced feed shortage of chickens*/ kweziphi izikhathi zonyaka lapho nishodelwa ukudla*? (1) Hot dry season/*Ntwasahlobo* (2) Rainy season/*ehlobo* (3) Cool dry season/*ebusika* (4) Post rainy season/*Enkwindla*

15. Do you give water to your birds/*Ingabe niyazipha amanzi izikukhu*? 1. Yes/*Yebo* 2.No/Cha (why/*Isizathu*) --

16 Do you know that chickens scavenge for non-conventional animal protein such as insects and worms? Ingabe unalo ulwazi ukuthi izinkukhu ziqhwisha ukudla okufana neminyundu nezimbuzane? 1. Yes/Yebo 2.No/Cha

16. Do you use available non-conventional proteins to supplement indigenous chickens/*Ingabe niyalisebenzisa uhlobo olusha lokudla olunama-phrothe*ni? (1) Yes/*Yebo* (2) No/*Cha*

17. If no/ *uma uthi cha*, why/*isizathu*? (1) Unawareness/*ukunganaki* (2) unavailability/*ukungatholakali kwazo* (3) No time for collecting them/*ukungabibikho kwesikhathi sokuizihlanganisa* (2) lack of collecting resources/*ukungabi nazo izimfanelo zokuhlangasa ukudla*(e) other/*okunye* (specify/*cacisa*)

18. Source of the feed resource/*nikutholla kanjani ukudla kwezinkukhu*. 1) purchasing/*siyakuthenga* 2) homemade/*siyazitshalela/siyazenzela 3)* other/*okunye*

10. If yes to/*Uma uthe Yebo ku* (Q 4), Indicate feed resources that you use for supplementing/*Isho ukudla enikusebenzisayo ukuphakela izinkukhu.*

Feed resources /*Ukudla*	Most Available feed resources in your area/*ukudla okuxhaphakile endaweni enihlala kuyo Tick (√)as many as you can/*	Since January 2013 to this day, did you supplemented chickens with the following feed resources./*Kusukela ngoMasingana kulonyaka, ingabe nike nazipha izinkukhu ngalokudla*? Codes (1)yes/yebo (2)No/Cha	Tick (√) the seasonal availability of feed resources/*Maka ukutholakala kokudla kwezikhukhu ezikhathani zonyaka*								Rank the feed resources that you most used for supplementing from 1-3. From most to least used/Hlela ngokubaluleka kwazinhlobo zokudla enizisebenzisayo.1 -3 kusukela kokubaluleke kakhulu kuya kokungabalulekanga kakhulu
			Cooldry season/*Ebusika*		Hot dry season/*ntwasahlobo*		Rainy season /*Ehlobo*		Post rainy /*Inkwindla*		
			High/*kuni gni*	Low/*kun cane*	High/*kuningi*	Low/*kuncane*	High/*kunngii*	Low/*kuncane*	High/*kunigni*	Low/*kuncane*	
Kitchen waste/ *izinsalela zokupheka*											
Whole Maize/*umbila*											
Crushed Maize/*Umbila ogayiwe*											
Sorghum/*Amabele*											
Millet/*imfe*											
Wheat/*Kolweni*											
Rice/*rayisi*											
Leavesand shrubs/*utshani namaqabunga*											
Fruits seeds/*imbewu yama-fruit*											
Commercial ration/*Ukudla kwasizitolo*											
Crop residues/*izinsalela zezimvuno*											

18. Indication of the non-convectional that one use for supplementing/*Veza izinhlobo zokudla ezintsha enizisebenzisayo ukuphakela izinkukhu*

Non-conventional protein sources/*Ukudla okungakasetshenziswa okunama-protheni*	Most Available non-conventional protein in your area/*Ukudla kwezikhukhu okunama-phroteni okungajwayelekile kodwa okuxhaphakile endaweni Tick (√)as many as you can/Maka*	Rank the availability of non-conventional protein, (1) most available (2) moderately available (3) least available/*hlela ukutholahala kwalokudla okunama-phrotheni kwezikhukhu endaweni.1-kuningi 2- kuphakathi nendawo 3-itholaka kancane*	Non-conventional proteins do you use to supplement chickens/*Ikuphi Ukudla okunamaphrotheni enikusebenzisayo ukuphakela izinkukhu.*	Tick (√) the seasonal availability of non-conventional protein/*maka ngokutholakala kokudla ukunamaphotheni ezikhathin zonyaka.*								Rank the Non-conventional protein that you most used for supplementing from 1-3. From most to least used/*hlela usesetshenziswa kokudla okumaphrotheni ukondla izinkukhu.* 1- *Kusetshenziswa kakhulu* 2- *Kusetshenzuswa kahle* 3- *Kusetshenziswa kancane*
				Cooldry season/*Ebusika*		Hot dry season/*ntwasahlobo*		Rainy season /*Ehlobo*		Post rainy /*Inkwindla*		
				Low/*kuncane*	High/*kuningi*	Low/*kuncane*	High/*kuncane*	Low/*kuncane*	High/*kuningi*	Low /*kuncane*	High/*kuncane*	
Earthworms/*Iminyundu*												
Maggots/*Izimpethu*												
Flies/*Izimpukane*												
Termites/*amatshekethshe*												
Flying termite/*Izinkulungane*												
Crickets/*izintobolo*												
Locusts/*amaqhwagi /intethe*												
Snails/*iminenke*												
caterpillar/*acimbi*												
Cockroaches/*amaphela*												
Grasshopper /*intothoviyane*												

19. Which seasons are non-conventional proteins feeds abundantly available/*Eziphi izikhathi zonyaka lapho ukudla okunaphrotheni kuxhaphakile*? (1) Hot dry season/*Entwasahlobo* (2) Cool dry season/*Ebusika* (3) Rainy season/*Ehlobo* (4) Post rainy/*Enkwindla*

20. How many times per day do you supplement chickens with non-conventional protein/ *niziphakela kangakhi ngokudla okunama-phrotheni*? (1) Once/*kanye* (2) twice/*kabili* (3) three times/*kathathu* (4) none/*asiziphakeli*

21. If you do not supplement/ *uma ungaziphakeli ngokudla okunama-phrotheni*, which non-conventional proteins do you recommend to be fed to chickens /*ikuphi ukudla okusha okunama-phrotheni ongakukhetha ukuthi kuphakelwe izinkukhu zakho ?*

Non-conventional protein sources	Recommended non-conventional proteins /*Ukudla okunama-phrotheni ongakukhetha* *Tick (√)as many as you can/maka noma okungakhi*
Earthworms/I*minyundu*	
Maggots/*izimpethu*	
Flies/*izimpukane*	
Termites*/amatshekethe*	
Flying termites/iz*inkulungwane*	
Crickets/iz*intobolo*	
Locusts/*amaqhwagi/intenthe*	
Snails/*iminenke*	
Grasshopers/*intothoviyane*	
caterpillars*/Amicimbi*	
Cockroaches/*Amaphela*	

22. Reason for recommendation/ *Isizathu sokukhetha loluhlobo lokudla okunama-phrotheni* (1) Abundantly available in the area/*kuxhaphakile* (2) They are inexpensive/*kushibhile* **(**3) other/*okunye* (specific/*cacisa*)

23. If your answer in question 2.1 is yes/ *uma impendulo yakho kumbuzo 2.1 ithi Yebo,* how do you gather/collect non-conventional protein/ *Ingabe ukuqongelela kanjani Ukudla okunama-photheni* ?

Trapping	Tick/*maka* (√)
sticky tape/*theyiphu*	
casual collection/*ngiqongelela ngezandla*	
scoop net/*ngenethi*	
Other/o*kunye* (specify/*cacisa*)	

Thank you very much for your time and contribution/ *Siyabonga kakhulu ngosizo lwakho nangesikhathi sakho* .Do you have any question(s)/*Ingabe ikhona imibuzo*?

____
____
____

Appendix 2: Questionnaire for household demography and chicken management

1. What is the age of the farmer? ____
2. What is your marital status? 1-single 2-married 3-divorced 4-widowed 5-cohabiting 6-other (specify)
3. What is your main occupation? 1-Farming 2-Livestock rearing 3-Unemployed 4-Pensioner 5-Casual work 6-Self-employed 7-Formal work 8-Student 9- None
4. What are the major sources of income in this household? 1- formal work2- casual work3-hawking4- old-age grant5- child support6- other(specify
5. Please circle the most main source of income. 1- formal work 2- casual work 3-hawking 4- old-age grant 5- child support6- other(specify
6. What is you religious system? 1- Christian 2- tradition-based3- other(specify)
7. Do you house chickens at night/*ingabe iyazivalela izinkukhu ntambama*? (1) Yes/*Yebo* (2) No/*Cha*
8. If yes/*Uma uthi yebo*, where do you house them/*uzuvalelakephi*? (1) human dwellings/*ezindlini lapho kuhlala abantu* (2) In the trees/*ezihlahlen*i (3) In cages/e*kheyijini* (5) Chicken house built for them/*endlini yezinkukhu* (5) other /okunye(specify/*cacisa*)
9. If yes, do you clean chicken?
10. What are the common chicken breeds?
11. What time do chickens scavenge?
12. What time do come from scavenging at night?
13. Do you know what chickens are getting under scavenging?
14. Do you know feed materials commonly found in the crop and gizzard?
15. The most important livestock in the household is (1) scavenging chickens (2) cattle (3) sheep (4) goats
16. What are major challenges to chickens production (1) disease (2) poor feed quality and availability (3) predation (4) marketing (5) theft (6) housing

Appendix 3: Ethical clearance from University of KwaZulu Natal

UNIVERSITY OF KWAZULU-NATAL

INYUVESI YAKWAZULU-NATALI

26 May 2014

Mr Cyprial Ndumiso Ncobela (209508208)
School of Agricultural, Earth & Environmental Sciences
Pietermaritzburg Campus

Protocol reference number: HSS/0584/013M
Project title: Impact of non-conventional protein supplements on the performance of scavenging chickens

Dear Mr Ncobela,

Full Approval – Expedited Application

In response to your application dated 24 July 2013, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol have been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Dr Shenuka Singh (Chair)

/ms

Cc Supervisor: Prof Michael Chimonyo and Prof Ignatius Nsahlai
Cc School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee
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