Effects of hydric stress on the growth, blood chemistry and meat quality characteristics of indigenous chickens

By

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List of abbreviations

*a**	Colour ordinate: Redness value
Ad lib	Ad libitum
ADFI	Average daily feed intake
ADG	Average daily gain
ALB	Albumin
ALP	Alkaline phosphatase
ALT	Alanine aminotransferase
AOAC	Association of Official Agricultural Chemists
AST	Aspartate aminotransferase
*b**	Colour ordinate: Yellowness value of meat
CIE	Commission International De I' Eclairage
CREAT	Creatinine
DM	Dry matter
DWI	Daily water intake
EDTA	Ethylene diamine tetra acetic acid
RBC	Red Blood Cell count (Erythrocyte count)
FAME	Fatty acid methyl esters

Individual FAME:

Abbreviation	*Common name*	*Complete formula*	*Systematic (IUPAC) name*
C14:0	Myristic	C14:0	Tetradecanoic
C15:0	Pentadecylic	C15:0	Pentadecanoic
C15:1	Pentadecaenoic	C15:1*c*9	Pentadecenoic
C16:0	Palmitic	C16:0	Hexadecanoic
C16:1	Palmitoleic	C16:1*c*7	*cis*-7-Hexadecenoic
C16:1	Palmitoleic	C16:1*c*9	*cis*-9-Hexadecenoic
C17:0	Margaric	C17:0	Heptadecanoic
C18:0	Stearic	C18:0	Octadecanoic
C18:1c9	Oleic	C18:1*c*9	*cis*-9-Octadecenoic
C18:1t9	Elaidic	C18:1*t*9	*trans*-9-Octadecenoic
C18:2	Linoleic	C18:2*c*9,12(ῳ-6)	*cis*-9,12-Octadecadienoic
C18:3n-3	Linolenic	C18:3*c*9,12,15(ῳ-3)	*cis*-9,12,15-Octadecatrienoic
C19:0	Nonadecanoic	C19:0	Nonadecanoic
C20:0	Arachidic	C20:0	Eicosanoic
C20:1	Eicosenoic	C20:1*c*11	*cis*-11-Eicosenoic
C20:2	Eicosadienoic	C20:2*c*11,14(ῳ-6)	*cis*-11,14-Eicosadienoic
C20:3n-3	Eicosatrienoic	C20:3*c*11,14,17(ῳ-3)	*cis*-11,14,17-Eicosatrienoic
C20:4	Arachidonic	C20:4*c*5,8,11,14(ῳ-6)	*cis*-5,8,11,14-Eicosatetraenoic
C22:1	Erucic	C22:1*c*13	*cis*-13-Docosenoic
C22:5	Docosapentaenoic	C22:5*c*7,10,13,16,19(ῳ-3)	*cis*-4,7,10,13,16-Docosapentaenoic
C22:6	Docosahexaenoic	C22:6*c*4,7,10,13,16,19(ῳ-3)	*cis*-4,7,10,13,16,19-Docosahexanoic

FCR	Feed conversion ratio
GLM	Generalised linear model

GLOB	Globulin
HDLC	High density lipoprotein cholesterol
*L**	Colour ordinate: Lightness (brightness) value
LDLC	Low density lipoprotein cholesterol
MCV	Mean corpuscular volume
MUFA	Monounsaturated fatty acids
ω-3	Omega-3 fatty acids
ω-6	mega-6 fatty acids
NNK	Naked Neck chickens
OVB	Ovambo chickens
PCV	Packed cell volume
PUFA	Polyunsaturated fatty acids
SAS	Statistical Analysis Systems
SEM	Standard error of the mean
SFA	Saturated fatty acids
TC	Total cholesterol
WBC	White Blood Cell count (Total leucocyte count)
MUFA	Total monounsaturated fatty acids
PUFA	Total polyunsaturated fatty acid
TP	Total protein
SFA	Total saturated fatty acids
TGA	Triglycerides
UA	Uric acid

WBSF	Warner Bratzler shear force
WFR	Water to feed ratio
WHC	Water holding capacity

Abstract

Effects of hydric stress on the growth, blood chemistry and meat quality characteristics of indigenous chickens

By

N. Chikumba

The broad objective of the study was to determine the effects of restricted water intake on the growth, blood chemistry and meat quality characteristics of indigenous chickens in semi arid environments. A total of 15 flocks in communal villages and 12 flocks in resettlement schemes of Msinga District in South Africa were monitored for 30 months to determine the effects of production system and season on flock size, dynamics and constraints faced by indigenous chicken producers. As a follow up, 281 and 233 chicks hatched in November 2011 from 18 and 9 households in communal villages and resettlement schemes, respectively were monitored using a structured checklist to determine survival and causes of mortality from hatching up to 12 weeks of age. Kaplan-Meier survival distributions and the odds ratios for effects of potential risk factors were determined using survival analysis and logistic regression models, respectively.

Flock composition and structure were significantly affected by production system and month. Farmers in resettlement schemes had approximately one cock and three hens more ($P < 0.05$) than those in communal villages. The number of growers and chicks were similar ($P > 0.05$) between the two production systems but chicks were the predominant age group (38 %) of each flock. The cock to hen ratio in households in communal villages was 1:3.5, while that in resettlement schemes was 1:3.7, suggesting that inbreeding might have been reducing flock productivity. Flock sizes in communal villages peaked in March (45.1 ± 3.02) during the post

rainy season and declined steadily to a low of 34.7 ± 3.63 in September during the hot-dry season. The largest flock sizes in resettlement schemes were observed in January (52.4 ± 5.09) during the hot-wet season and the smallest in August (36.1 ± 5.98) during the cold- dry season. Households in communal villages had more chicks ($P < 0.05$) than cocks, hens and growers throughout the year except in June when the number of growers was equal to that of chicks. In resettlement schemes, the number of chicks was lower ($P < 0.05$) than the number of hens and growers, except in June and July when it was equal to that of growers. Total entries were not affected ($P > 0.05$) by production system. Hatched chicks were the major mode of entry, accounting for more than 97 % of entries into flocks. The contribution of purchases, gifts and exchanges was negligible. Mortality was the main cause of exits from flocks, accounting for 70 and 63 % of total exits among households in communal villages and resettlement schemes, respectively. The major causes of mortality were aerial predators, sub-optimalnutrition and inclement weather conditions, which were similar between production systems. The number of birds that exited flocks through slaughter for household consumption was higher ($P < 0.05$) among households in resettlement (34% of total exits) than communal villages (21 % of total exits). The proportion of chickens exiting flocks through sales was higher in communal (9 %) than resettlement (4.3 %) households.

Chick survival from hatching to 12 weeks was higher ($P < 0.05$) in communal villages (55 ± 3.14 %) than in resettlement schemes (41 ± 4.19 %). Mean chick survival time did not differ ($P > 0.05$) between communal (56 ± 3.30 days) and resettlement (49 ± 3.23 days) flocks. Provision of water *ad libitum* and treatment of sick birds were important covariates in prolonging the survival time of chicks.

The effects of restricted water intake on growth performance, blood chemistry, physicochemical properties, and sensory characteristics of meat from Naked Neck (NNK) and Ovambo (OVB) chickens were also assessed. In the experiment, 54 pullets of each strain with an average weight of 641± 10g per bird were randomly assigned to three water restriction levels for 60 days in a completely randomized design. The treatments were *ad libitum*, 70% of *ad libitum* and 40% of *ad libitum* water intake. Each treatment group was replicated three times. The *pectoralis* (breast) muscle was sampled for meat quality, fatty acid composition and sensory quality analyses. Ovambo chickens had superior body-weight at 16 weeks of age, average daily gains (ADG) and average daily water intake (ADWI) than NNK chickens. Body weight of birds at 16 weeks of age, ADG, average daily feed intake (ADFI), ADWI and water to feed ratio (WFR) declined progressively ($P < 0.05$) with increasing severity of water restriction, while food conversion ratio (FCR) values increased ($P < 0.05$) as the severity of water restriction increased. Naked Neck chickens had better FCR at the 40 % of *ad libitum* water intake level than OVB chickens. The dressing percentage per bird was higher ($P<0.05$) in water-restricted birds than those on *ad libitum* water consumption, irrespective of strain. Heart weight was significantly lower in birds on 40% of *ad libitum* water intake than those on *ad libitum* and 70% of *ad libitum* water intake, respectively. Packed cell volume was higher ($P < 0.05$) in NNK than OVB chickens offered water*ad libitum,* but similar in birds offered 70 and 40 % of *ad libitum*. There were no differences in erythrocyte count (RBC) and mean corpuscular volume (MCV) values between strains, but MCV was higher in birds on 40 than 70 % of *ad libitum* water intake, irrespective of strain. Naked neck chickens had higher ($P < 0.05$) white blood cell count (WBC) values than OVB chickens at 40 % restriction level, but lower WBC than OVB at 70 % water restriction level. Uric acid, creatinine, triacylglycerides, total cholesterol, low density lipid cholesterol, total protein and globulin increased ($P < 0.05$) with each increment in water restriction, but the increase in creatinine and total cholesterol was more pronounced in OVB than NNK chickens. The opposite was observed for uric acid. Alanine transaminase, alkaline phosphatase and aspartate transaminase activities were not influenced by strain and water restriction. It was concluded that the two strains could withstand up to 40 % of *ad libitum* water restriction, but NNK chickens tolerated water stress better than OVB chickens.

Water intake levels of 40% of *ad libitum* produced meat with significantly lower ($P < 0.05$) cooking loss, and higher ($P < 0.05$) redness (a*) values in NNK chickens compared with OVB chickens. Water intake level had no effect ($P > 0.05$) on lightness (L*) and yellowness (b*) values, shear force, moisture and protein contents in both strains. The fat content of NNK meat was 41 % lower ($P < 0.05$) than that of OVB meat at 70 % of *ad libitum*, but 31 % higher at 40 % of *ad libitum* water intake. The ash content was significantly elevated ($P < 0.05$) in birds on 70 % of *ad libitum* compared to those on *ad libitum* and 40 % of *ad libitum* water intake, which had similar ($P > 0.05$) ash contents. Birds on 40 % of *ad libitum* water intake had significantly higher ($P < 0.05$) proportions of octadecanoic acid (C18:0), *cis*, *cis*-9,12-octadecadienoic acid (C18:2 ῳ-6), *cis*-8,11,14,17-eicosatetraenoic acid (C20:4 ῳ-6), *cis*-7,10,13,16-docosatetraenoic acid (C22:4 ῳ-6), *cis*-4,7,10,13,16,19-docosahexaenoic acid (C22:6 ῳ-3), total polyunsaturated fatty acid (PUFA), total omega-3 PUFA and total omega-6 PUFA proportions, but lower ($P < 0.05$) *cis*-7-hexadecenoic (C16:1*c*7), *cis*-9-octadecenoic (C18:1c9), *cis*-11-octadecenoic acid (C18:1*c*11), *cis*-13-docosenoic acid (C22:1*c*13), total monounsaturated fatty acids than those on the 70% of *ad libitum* and *ad libitum* water intake, respectively. The proportion of *trans*-9-octadenoic acid (C18:1*t*9) was higher ($P < 0.05$) in NNK chickens on 40 % of *ad libitum* water

intake than OVB chickens. It was concluded that water restriction at 40 % of *ad libitum* water intake resulted in favourable cooking loss values and meat redness (a*) values, omega-3 and 6 PUFA proportions and a high ω-*6*/ω-*3* ratio. The high fat content of NNK chickens at 40 % of *ad libitum* water intake compared to OVB chickens suggests a superior adaptation to hydric stress.

Naked Neck breast meat had higher initial impression of juiciness scores than that from OVB chickens, but only in birds on *ad libitum* and 70 % of *ad libitum* water intake. Sensory scores for first bite, connective tissue and tenderness decreased with increasing severity of water restriction ($P < 0.05$). Aroma, flavour and atypical flavour were not affected by strain or water restriction level ($P > 0.05$). There were significant strain differences for sustained impression of juiciness and tenderness, with the highest scores occurring in NNK chickens ($P < 0.05$). Aroma had a significant influence on the flavour of breast meat ($P < 0.05$). Fat content was significantly correlated with initial impression of juiciness, first bite and sustained impression of juiciness of breast meat. It was concluded that water restriction up to 40 % of *ad libitum* had a significant and adverse impact on juiciness and first bite scores of meat.

Publications

1. Chikumba, N., Swatson, H and Chimonyo, M. 2013. Haematological and serum biochemical responses of chickens to hydric stress. Animal 7 (9): 1517-1522.

2. Chikumba N. and Chimonyo, M. 2013. Effects of water restriction on the growth performance, carcass characteristics and organ weights of Naked Neck and Ovambo chickens of Southern Africa. Asian-Australasian Journal of Animal Science (http//dx.doi/10.5713/ajas.2013.13383).

3. Physicochemical properties of breast meat from water-restricted Naked-Neck and Ovambo chickens. British Poultry Science (In press).

Dedication

To God the Almighty

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Table of Contents

List of Tables

List of Figures

List of Appendices

CHAPTER 1: General Introduction

1.1. Background

The raising of indigenous chickens is an integral part of the farming systems and a critical source of livelihood in many developing countries. Indigenous chickens are widely and equitably distributed among the rich, poor and marginalized members of rural society than any other livestock (Gondwe and Wollny, 2007). Indigenous chickens are also known as rural, scavenging, traditional or family chickens, and have various names in local languages (Ahlers *et al*., 2009). In Southern Africa, indigenous chickens are reared under scavenge-based free range production system and to a lesser extent under the backyard systems, where birds are part-confined within a fenced yard (Kitalyi, 1998). In both systems, management intervention in the form of feed and water supplementation, overnight housing and health care is minimal. Consequently, the productivity of indigenous chickens is low as a result of exposure to sub-optimal rearing conditions. The challenges of raising indigenous chickens are likely to be aggravated by the increasing frequency of droughts due to climate change.

Climate change is expected to impact free-ranging indigenous chickens through altering the quantity and quality of feed available, heat stress and changes in water availability (Thornton and Herrero, 2008). Under global warming, water scarcity will be the main common weak point in all livestock systems (Nardone *et al*., 2010). Livestock, including chickens, are likely to need more water as temperatures increase and coupled with potential reductions in water availability, this could pose a serious challenge to livestock development. Droughts and extreme rainfall variability can trigger periods of severe feed scarcity, especially in dryland areas, with devastating effects on livestock populations (Gregory, 2010). Although, the future impacts of climate change on livestock in the tropics are less certain (Easterling *et al*., 2007), the phenomenon is expected to reduce food security, undermine the contribution of indigenous chickens to rural livelihoods and exacerbate poverty among the poor (Bates *et al*., 2008). Livestock producers, in arid and semi-arid regions of Southern Africa will have to adapt to changes in climatic systems by either adapting the environment to the need of the animals or rearing animals that are adapted to the respective environment (Mirkena *et al*., 2010). Chicken genotypes that maintain a frugal water economy in a harsh and rapidly changing environment need to be identified. However, prior to their identification, it is crucial to have knowledge of existing production systems, management practices, flock dynamics and the constraints facing the chicken producers. The objectives of indigenous chicken producers for raising chickens and the constraints they face tend to vary depending on the socioeconomic circumstances of households.

1.2. Justification

Chicken flock productivity, management practices and constraints faced by resource-poor indigenous chicken producers in drought-prone areas are poorly understood. Such information is critical for empowering extension agencies to deliver informed advice, development agents to prioritize funding of appropriate technologies and policy-makers to implement policies that promote sustainable indigenous chicken production and subsequently, improve livelihoods of resource-constrained indigenous chicken producers.

To guide the evolution of indigenous chicken production systems under the increase of temperature and water scarcity, there is need to identify and characterise drought-tolerant breeds or ecotypes. Identification of indigenous chicken genotypes that can maintain a frugal water economy and remain productive under conditions of extreme heat and drought is a prerequisite for their conservation for posterity. Preserving such unique qualities in indigenous chickens ensures a wealth of genetic resources for future use in basic scientific research and the advancement of the agricultural sciences. Drought-tolerant indigenous chicken genotypes may also support government planning of utilization of limited water resources and contribute to food security of poor rural households if they are properly integrated into rural development programmes.

1.3. Objectives

The goal of the study was to generate information that would contribute towards sustainable livelihoods in drought-prone rural areas through increased production of adapted village chicken ecotypes.The broad objective of the study was to determine the effects of restricted-water intake on the growth, blood chemistry and meat quality characteristics of indigenous chickens in semi-arid environments.

The specific objectives are to:

1. Establish farmer management practices, flock dynamics, and production constraints in communal and resettlement schemes;
2. Determine the incidence and causes of mortality in free-ranging indigenous chickens in communal and resettlement schemes;
3. Determine the growth and physiological responses of different indigenous chicken genotypes to graded levels of water restriction; and

4. Investigate the effects of graded levels of water restriction on carcass and meat quality attributes of indigenous chickens.

1.4. Hypotheses

The following alternative hypotheses were tested;

1. Farmer management practices, flock use and dynamics, and production constraints in indigenous chicken production differ between households in communal and resettlement schemes;
2. The incidence and causes of mortality among free-ranging indigenous chicken flocks in communal and resettlement schemes differ;
3. Water restriction reduces the growth performance, and evokes haematological and biochemical responses consistent with stress in indigenous chickens; and
4. Water restriction reduces the carcass and meat quality of indigenous chickens.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Climate change is expected to impact free-ranging indigenous chickens through altering the quantity and quality of feed available, heat stress and changes in water availability (Thornton and Herrero, 2008). Livestock, including chickens, are likely to need more water as temperatures increase and coupled with potential reductions in water availability, this could pose a serious challenge to livestock development. Droughts and extreme rainfall variability can trigger periods of severe feed scarcity, especially in dryland areas, with devastating effects on livestock populations. These changes are expected to increase food insecurity, undermine the contribution of indigenous chickens to rural livelihoods and exacerbate poverty among the poor (Bates *et al*., 2008). The future impacts of climate change on these valuable indigenous animal genetic resources in the tropics are less certain (Easterling *et al*., 2007). Identification of drought-tolerant indigenous chicken genetic resources that maintain a frugal water economy in harsh environments is, therefore, imperative.

The review describes the dominant indigenous chicken genetic resources in Southern Africa, discusses the nutritional, economic and sociocultural roles played by chickens in rural livelihoods, and highlights the constraints faced by village chicken producers. The effects of water scarcity on chicken performance and quality of indigenous chicken products, and how these chickens cope with water scarcity are reviewed.

2.2. Characteristics of indigenous chicken genetic resources of Southern Africa

Indigenous chickens are invaluable reservoirs of genes for adaptive and economic traits that provide a diversified genetic pool (Muchadeyi *et al*., 2007b). These genotypes can help in meeting future challenges resulting from possible changes in production environments (e.g. global warming and changes in disease pressure) and consumer requirements (e.g. fatty acid composition in poultry products) (Simianer, 2005). Six major categories are present: normal feathered, naked neck, frizzle, silky, dwarf and the feathered feet (Mtileni *et al*., 2012). The types and varieties of indigenous chickens found in Southern Africa are usually differentiated by adult body weight, egg weight, reproductive performance and morphological features such as plumage colour, skin colour, shank colour, ear lobe colour, beak colour, comb shape and colour, and feathered-shank (ptilopody). Table 2.1 summarises the characteristics of indigenous chicken populations found in Southern Africa.

In South Africa, the predominant breeds are the Potchefstroom Koekoek, Lebowa-Venda, Naked Neck, Ovambo, Natal Game, Zulu, Nguni and their crosses (Van Marle-Koster and Casey, 2001; Grobbelaar *et al.,* 2010). Although there is no information to show whether these various types are of different genetic formation, the chickens are generally active, hardy and have better ability to withstand disease challenges associated with backyard conditions than imported chickens (Horst, 1988). They are also aggressive and highly protective of their young from predators, possess excellent brooding and foraging ability, and can utilise high fibre diets, in addition to being tolerant to extreme temperatures (Fraga, 2002). Other positive attributes of indigenous chickens are the yellow colour of their egg yolks, probably due to xanthophylls obtained through scavenging and foraging green grass (Safalaoh, 1997).

Table 2.1: Phenotypic characteristics of common indigenous chicken populations in Southern Africa

Characteristic	Description
Phenotypes	Normal feathered, frizzled, naked neck, dwarf, silky feathered feet
Plumage colour	Waxy black, white, brown, reddish brown, grey or spotted or mixture of these.
Colour of comb and wattles	Red, red with white and black spots
Beak colour	Black and dark grey
Skin colour	White, yellow and reddish
Colour of feet and toes	Black and cream
Age at sexual maturity (days)	140 -170
Egg production per year	35 - 45
Egg weight (g)	33 – 55
Egg hatchability (%)	50 - 75

Adapted from Mtileni *et al*. (2012).

Despite all these good attributes, the productivity of indigenous chickens leaves a lot to be desired.They are characterised by slow growth rates, small body size, low egg production and low hatchability (Safalaoh, 1997). Egg size is usually below 40g while total production is usually less than 120 eggs per annum. Other parameters such as egg length and diameter, albumen height and diameter and yolk height have also been reported to be lower in indigenous chicken than other improved breeds (Yeasmin *et al*., 1992). Market weights of more than 1 kg are attained at more than twenty weeks of age (Safalaoh *et al*., 1996). Although the productivity of indigenous chickens is low as a result of the suboptimal rearing conditions, the chickens make a very valuable contribution to the nutritional, economic and sociocultural needs of the rural poor.

2.3. Contribution of indigenous chickens to rural livelihoods

Most indigenous chickens are raised in the rural areas where the poor and malnourished masses reside. Meat and eggs from indigenous chickens therefore provide a readily available, high quality source of proteins, vitamins and micronutrients (Ahlers *et al*., 2009). Eggs are an excellent source of iron, zinc and vitamin A, all of which are essential to health, growth and well being of humans (Ahlers *et al*., 2009). Chickens and eggs therefore contribute to a nutritious balanced diet, which is especially important for children, nursing mothers and people who are ill.

Indigenous chickens can also be sold or bartered to meet family needs such as medicines, medical costs, school fees and village taxes. In this way, they act as a ready source of cash for sustaining livelihoods, meeting emergencies and purchasing small household requirements (Mtileni *et al*., 2012). Indigenous chickens also provide manure which is a valuable organic fertilizer that can be applied to fruit trees and vegetables in gardens and serve as an efficient waste disposal system converting kitchen scraps and every left-over grain into valuable protein for the owners (Muchadeyi *et al*., 2005). Indigenous chicken are also useful in the control of weeds through their foraging habit. Chicken litter, offals and feathers present an attractive and novel ruminant feed source that can be used to supplement protein after treatment to eliminate pathogenic bacteria (Mapiye *et al*., 2008). They are therefore an important component in an integrated farming system (Barua and Yoshimura, 1997).

Improvement in the production and commercialization of indigenous chickens can create employment for people as individuals are hired to process and sell the chickens and their products. In addition to provision of tangible products, the chickens contribute towards the livelihoods of the poor through risk mitigation and accumulation of wealth (Guèye, 2003b). Therefore, indigenous chickens are an ideal vehicle for generating cash returns to meet food security needs and improve welfare among communal households.

Indigenous chickens also have social, cultural and symbolic roles in human society that transcend their practical use as food or commodities. For example, birds are given away as gifts or they are consumed as part of ritual and secular celebrations, thereby strengthening important social bonds (Naidoo, 2003; Aklilu *et al.*, 2007a). In some societies, chickens may be used to foretell the future through divination rites. Naidoo (2003) described how chickens of different colour, sex and age may be used for purposes such as assuring good harvest returns and for honouring ancestors or spirits.

Despite the important contribution that chickens make to the livelihoods of those who keep them, their economic potential has not been fully exploited due to a number of constraints. The constraints are complex and vary among households due to the different environmental, biological, social and economic factors that influence production methods and consequently, productivity levels (Mwalusanya *et al*., 2002).

2.4. Constraints to indigenous chicken production

The productivity of indigenous chickens in communal areas is low and inefficient (Kusina and Kusina, 1999; Mwalusanya *et al*., 2002). Understanding the constraints facing indigenous chicken producers in communal areas is crucial before recommendations for improving viability of indigenous chicken enterprises are implemented (Mapiye *et al*., 2008). The major constraints faced by indigenous chicken producers include high mortality and reproductive wastage, poor health management practices, low levels of nutrition, poor housing, inbreeding as well as socioeconomic and institutional constraints embracing poor market organisation, lack of institutional support and adverse policies. It is important to note that these constraining factors act in combination, and should therefore be tackled, as much as possible, in unison. In tackling these constraints a holistic and participatory approach which instils a sense of ownership and responsibility among producers to improve productivity of indigenous chickens is advocated.

2.4.1. High mortality and reproductive wastage

High mortality, especially among chicks, was observed to be the major limitation to indigenous chicken production in communal production systems (Pedersen *et al*., 2002; Maphosa *et al*., 2004; Mtileni *et al*., 2009). Mortality was reported to account for a larger proportion of exits in flocks than exits through sales, consumption, gifts and exchanges between flocks (Muchadeyi *et al*., 2005). It is, however, difficult to associate the high mortality among indigenous chickens with a single factor, as it is due to a number of factors such as diseases, parasites, predation, accidents and inclement weather, among other factors. Empirical evidence of the contribution of each of these factors to overall mortality among household flocks is lacking and difficult to obtain because death events are rarely documented. Reports from different countries show that 50 to 70 % of indigenous fowl chicks die between hatching and the end of brooding. Mortality rates of chicks of 50 % up to eight weeks of age in Burkina Faso (Wilson *et al*., 1987), 66 % by 12 weeks of age in Senegal (Gueye, 1998), 30-50 % by four weeks of age in Mali (Gueye, 1998), 68 % up to six weeks in Nigeria (Ologhobo, 1992), and 53 % up to four weeks of age in Cameroon (Agbede *et al*., 1995) have been reported. Under free range management conditions, newly hatched chicks have access to the same feed resource-base with stronger and more vigorous members of the flock, with whom they are unable to compete. The low protein and energy content of the available feed, low hatching weight of the chicks, high ambient temperatures and other associated factors contribute to the losses, both directly, and also by increasing vulnerability to predation and susceptibility to disease (Sonaiya *et al*., 1999). The high mortality rate necessitates a rigorous replacement strategy, which, in turn affects the potential egg output and off-take rate. Disease periodically decimates flocks and consequently more than 50 % of the eggs produced are incubated in order to replace birds that have died. A laying hen needs about 120 to 130 days to accomplish one production cycle, that is, 40 to 50 days of laying, 21 days to incubate eggs and 60 days of brooding the small chicks (Tadelle *et al*., 2003). The time taken by the laying hen to incubate eggs and to brood chicks, that may eventually die, represents a considerable loss of eggs that would have been consumed or sold.

2.4.2. Poor health management

Poor health management of indigenous chickens resulting in high mortality rates and poor productive performance characterise most communal production systems in Southern Africa (Kusina *et al*., 2001). Disease outbreaks such as Newcastle disease, fowl typhoid, Gumboro, Marek's disease and fowl pox have been found to account for over 50 % of the indigenous chicken losses in Zimbabwe (Pedersen *et al*., 2002), Botswana (Moreki *et al*., 2010), Namibia (Bamhare, 2001) and Malawi (Gondwe and Wollny, 2007). The high mortality due to diseases is in part attributed to the extensive system of production, which is characterised by free mixing of both wild and domestic birds during scavenging and the exchange of live birds in the form of breeding stock, which increases the likelihood of infection and transmission of diseases (Abdelqader *et al*., 2007; Olwande *et al*., 2010). To overcome high mortalities due to diseases, proper health control mechanisms and vaccination programmes on indigenous chickens coverage need to be developed. To have a positive impact on household economies, the health intervention strategies should address the aspirations of different gender groups and stakeholders working on indigenous chicken development programmes. Such programmes have improved smallholder chicken production in Pakistan (Javed *et al*., 2003). The use of ethno-veterinary medicine has also been recommended, but, it might not be sustainable because there is continuous loss of local indigenous knowledge through generations, deforestation and climate change, which might result in extinction of some herbs being used (Mwale and Masika, 2009). Breeding for disease resistance is a better option of disease control in that once achieved, it is expected to be permanent and passed on to future generations. Enhanced genetic resistance through selective breeding represents an under-exploited low-cost opportunity for disease control in low-input indigenous chicken production systems. However, improvement in resistance should be undertaken whilst enhancing productivity.

2.4.3. Feeding and watering management

Improved feeding is seen as one intervention that could improve productivity of household chicken flocks. Most smallholder chickens scavenge for feed and water for an average of 11 hours per day between 0500 and 1800 hours (Maphosa *et al*., 2004). Muchadeyi *et al*. (2004) reported that in a bid to protect their crops during the planting season, farmers detain their chickens in coops until midday with little or no supplementary feed. The practice limits the scavenging time to the hotter parts of the day and exerts tremendous physiological stress on the birds leading to under-nutrition. Furthermore, where supplementary feed is provided, the amount is not measured and feeding is indiscriminate such that all age groups compete for the supplement, resulting in the weaker members of the flock such as chicks getting suboptimal nutrition (Tadelle and Ogle, 2003). It is well known that the nutrient requirements of chickens vary depending on the age, sex and physiological status of birds (King'ori *et al*., 2007). It is not clear whether indigenous chickens get enough nutrients under these production systems. Improving the diet of scavenging chickens is complicated by the fact that the type and quality of feed consumed by the birds is not known. The proportion of feed that comes from the environment varies with activities such as land preparation, sowing, harvesting, grain availability in the household, the life cycles of insects or other invertebrates, and the biomass of the village flock, making it difficult to design appropriate supplementation programmes (Gunaratne *et al*., 1993; Mwalusanya *et al*., 2002). Water is rarely provided, where it is made available, it is usually available to all forms of livestock and wild animals, with significant health risks on both the chickens and consumers of chickens (Mlambo *et al*., 2011). The variable supply of nutrients and water restricts the productive potential of local birds (Tadelle and Ogle, 1996a). It is imperative, therefore, that any attempt to supplement local chickens considers what the birds actually consume. Research on the types and quality of feed resources upon which indigenous chickens subsist is lacking. Information on the inventory and quality of the scavenging feed resources is important in the formulation of supplementation strategies that would enhance chicken productivity. Assessing the seasonal variation in the composition and quality of the diet of indigenous chickens through crop content analysis is, therefore, warranted.

2.4.4. Poor housing and sanitation

Good housing is a prequisite for any viable and sustainable poultry project. Most farmers in Southern Africa provide shelter for their chickens and few farmers leave their chickens to roost in trees and nearby grass bushes at night (Mapiye *et al*., 2008). Mtileni *et al*. (2009) reported that households that did not provide proper shelter experienced high mortality rates in their flocks. Lack of proper housing allows free movement of birds and exacerbates the spread of diseases and parasites, and predisposes birds to predation (Muchadeyi *et al*., 2007b). Where housing is provided, poor sanitation practices result in high infestation with external parasites, which have a negative effect on the growth of chickens. Fleas and mites suck blood from the birds, causing irritation and anaemia, and brooding hens may abandon nests, resulting in poor hatchability and death of chicks (Mtileni *et al*., 2012).

2.4.5. High levels of inbreeding

Inbreeding, a manifestation of mating closely related individuals, is a challenge for many communal indigenous chicken flocks. It results in low growth rates, egg production, and disease resistance, among other negative effects (Barua and Yoshimura, 1997). Inbreeding depression is exacerbated by the small flock sizes, confinement of indigenous chickens during the cropping season and the long periods that cocks stay in the flocks before they are culled (Faranisi, 1995). Exchange of cocks between farmers from different villages can reduce inbreeding (Mapiye and Sibanda, 2005). The levels of inbreeding among indigenous chicken flocks in communal areas need to be investigated.

2.4.6. Poor marketing management

The demand for indigenous chickens is expected to grow given the increasing population growth, urbanization, economic development and the increased demand for organic poultry products in Southern Africa (FAO, 2010). The increasing numbers of supermarkets in urban centres offer opportunities for producers to fetch premium prices for their products. However, a majority of producers are still not able to capture a share of this market due to the very high quality conditions required. There is ample evidence that producers' willingness to increase productivity is closely linked to existence of efficient markets for their produce (Gausi *et al*., 2004). However, very little market research and advocacy on indigenous chickens has been done in most developing countries (Magothe *et al*., 2012). Formal indigenous chicken marketing, in most communal areas of Southern Africa is non-existent (Kusina and Kusina, 1999). Instead, communal farmers resort to the informal marketing of their indigenous chickens where pricing is based on an arbitrary scale, with reference to visual assessment of the birds. The existence of middlemen who purchase live birds from farmers for resale in other areas, such as towns and schools has been observed in some countries (Mtileni *et al*., 2012). Unfortunately, most, if not all, of these transactions are not captured in official statistics leading to underestimation of production and consumption of indigenous chicken meat in Sub-Saharan Africa (Magothe *et al*., 2012).

Creation of partnerships between producers, traders and market outlets has been hailed as a significant first step towards improving the marketing of indigenous chickens (Gueye, 2002). Business contracts can be established between traders and producers. The producers would undertake to supply a given quantity of eggs or live birds to a particular trader or traders at specific timeframes, while the traders would undertake to collect the products at an agreed price. This should then be replicated along the marketing chain up to the retailers. To meet the quantity agreed upon, each producer within a group can specialize in production of one type of product, either eggs or live birds. This calls for effective sensitization and capacity building through training (Copland and Alders, 2005; Alders and Bagnol, 2007). With specialisation, meeting the quality that consumers demand would be easy and a stable regular market would thrive, leading to increased income for the producer.

2.4.7. Low levels of literacy among farmers

Education is one of the major factors affecting adoption of new technologies (Saha *et al*., 1994). Generally farmers with higher education have better access to knowledge and information that is beneficial to farm management and hence profitability. Close to 70% of indigenous chicken producers in Southern Africa, as in other developing countries, are illiterate, but rich in indigenous knowledge (Njenga, 2005; Halima *et al*., 2007). This hinders efficient communication thus limiting their bargaining potential during trade and the ability to train in animal management and other related aspects. There is a need to focus on farmer's education and training in the areas of chicken breeding, feeding, diseases and parasite control and treatment and marketing. Training and education should be tailored to both sexes but the major focus should be on women as they play a major role in indigenous chicken production systems (Halima *et al*., 2007; Olwande *et al*., 2010). Bottom-up training approaches, simple and unconventional teaching methods such as songs, theatre and learning by doing should be used to pass simple extension messages (Guèye, 2002).

2.4.8. Poor infrastructure

Indigenous chicken production is mainly concentrated in the rural areas (Ndegwa *et al*., 1998; Okitoi *et al*., 2000a). These areas are characterised by poor infrastructural facilities, such as road and telecommunication networks. Installation of these facilities would open up these areas for development (Kilungo and Mghenyi, 2001) and enhance ease of access by the producers to markets and input supplies. Construction of roads would help the extension service providers to reach as many producers as possible, allowing training on new production technologies which will result in increased productivity of the indigenous chickens. Climate change is expected to have a profound effect on water availability, among other resources, yet water for chickens is seldom considered in rural planning in most developing countries. Water scarcity spurred by increased incidence of droughts will have devastating effects, not only on humans, but also on indigenous chickens which subsist on waste-water from households.

2.5. Effects of water scarcity on growth performance, physiological parameters and meat quality of chickens

Water intake is a determinant of indigenous chicken performance, as it influences bird health and welfare status (Brooks, 1994; Soares *et al*., 2007). Thus, water availability is essential to achieve efficient production. Indigenous chickens may be deprived of water because over 80% of producers live in fragile and marginal environments where lack of adequate potable water for both human and livestock consumption is being exacerbated by climate change (Thornton and Herrero, 2008). The challenge for water availability is great during the hot dry season when the availability of water and succulent scavenging resources declines. Consequently, the amount of water supplied to the birds is determined by the quantity available in the household and the judgment of the attendant, which often results in an undersupply and deprivation (Bawa *et al*., 2006). Coupled with excessive heat during these seasons, erratic and inadequate water supplies impose a considerable degree of dehydration and physiological stress on the chickens. Poor watering practices in chicken enterprises in the tropics have been attributed to ignorance and inexperience about the water requirements of free-ranging chickens on the part of the farmers and limited research on the effects of water scarcity on the performance, health and welfare of birds (Abdelsamie and Yadiwilo, 1981).

Water effects are particularly difficult to study as deficiency symptoms are not easily determined unless water insufficiency is extreme. Efficient production of indigenous chickens requires knowledge of the effects of inadequate water intake on the growth performance, health and welfare of the birds.

2.5.1. Feed intake

Research has demonstrated that there is a relationship between feed and water consumption. In laying hens, Savory (1978) found a positive correlation between food and water intake on a daily basis and that restricting the daily water supply of each bird to 90 % of its *ad libitum* intake, for a period of 6 weeks, caused a predicted reduction in daily food intake. Similar studies suggest that removal of water reduces feed consumption and that removal of feed reduces water consumption compared to *ad libitum* presentation of both feed and water (Abdelsamie and Yadiwilo, 1981; Miller *et al*., 1988). It is, therefore, inevitable that any factor influencing water intake will consequently affect feed intake and *vice-versa* (Leeson and Summers, 1997). Depressed feed intake during water restriction has been attributed to a number of factors influencing feed intake, including the rate of emptying of the crop which, in turn, is influenced by the rate of movement of the ingesta through the alimentary tract. Insufficient water in the tract leads to a reduction in the fluidity of ingesta and thus retarding its passage rate (Kese and Awuah, 1982). On the other hand, Knowles *et al*. (1995) postulated that the high plasma specific gravity caused by water restriction reflected a high substrate concentration which would continuously stimulate the brain satiety centre and reduce feed intake.

2.5.2. Growth rate

Several studies have examined the effects of restricted access to water on body weight gain for broilers, laying hens and broiler breeders. However, results of these studies are conflicting. Research on intermittent watering of White Leghorn layers showed a consistent improvement in feed efficiency and hence body weight (Spiller *et al*., 1976). On the contrary, Viola *et al* (2009) reported a linear reduction in weight gain as water restriction increased from 0 to 40 % of *ad libitum* water allocation in Ross 308 male broilers. Nilipoul and Butcher, (1998) also demonstrated that water-restricted birds, even if restricted for a few hours, stopped growing. These findings are in basic agreement with classical studies of Marks (1980), Abdelsamie and Yadiwilo (1981) and Kese and Awuah (1982) who observed that both volumetric and temporal water restriction caused a significant depression in body weight gain in broilers. On the other hand, Gerry (1980) found no significant effects on body weight of cage-reared broilers when water was available for as little as 5 minutes in each hour. Likewise, Miller *et al*. (1988) reported that cyclic watering of broilers for 30 minutes in each 4-hour cycle had no significant effect on body weight gain. Hocking (1993) also noted that body weight of broiler breeders was not significantly higher when the intake of water was limited than when it was freely available. The variability of results regarding the effects of water restriction on body weight highlights the need for further research on the subject. It is essential that the scope of research is broadened to include indigenous, slow-growing coloured-feather breeds that are widely distributed in rural areas set in marginal and drought-prone environments.

2.5.3. Feed conversion efficiency

Feed conversion efficiency was not altered at any age by the cyclic presentation of water as opposed to *ad libitum* watering (Miller *et al*., 1988). A non-significant effect of water restriction on feed conversion rates by birds was also reported by Skomorucha *et al*. (2006). Kese and Awuah (1982) noted a slight depression in efficiency of feed conversion as the level of water restriction increased from 15 to 45 % of *ad libitum* allocation in broiler chickens from one day old to eight weeks. It is not known whether a similar situation obtains in indigenous chickens.

2.5.4. Haematological and serum biochemical parameters

The effects of hydric stress on haematological and biochemical parameters of broilers and layers have been studied extensively (Mmereole, 2009; Ahmed and Alamer, 2011). Changes in haematological and serum biochemical parameters have been used as proxies for the resilience of livestock species to environmental, nutritional and pathological stresses (Kral and Suchy, 2000). Drought-resilient chickens are expected to manifest the least changes in haematological and biochemical parameters when subjected to stressful situations relative to those under optimal production conditions (Takei *et al*., 1988). Reference values of haematological, electrolyte and serum biochemical parameters of clinically healthy chickens are shown in Table 2.2. Water restriction increases packed cell volume and erythrocyte counts (Iheukwumere and Herbert, 2003), increases serum uric acid and creatinine due to impaired renal function (Lumeij *et al*., 1987), elevates levels of total protein, albumin and globulin due to concentration in a reduced volume of plasma (Cork and Halliwell, 2002). Peebles *et al.* (2004) reported increased serum triglycerides and cholesterol levels in water-restricted Single Comb White Leghorn hens and attributed it to increased fat mobilization for metabolic water production. In addition, tissue and organ damage due to water restriction increases activities of alkaline phosphatase (ALP), alanine transaminase (ALT) and aspartate transaminase (AST) (Fasina *et al.*. 1999; Sokunbi and Egbunike, 2000). There is, however, a dearth of information on reference values for haematological and serum biochemical parameters of healthy indigenous chickens in South Africa, which makes prediction of their resilience to hydric stress difficult. Information on the haematological and biochemical responses of indigenous chickens to hydric stress is useful, not only in assessing bird welfare and developing management strategies that minimize stress, but also in identifying genotypes that should be prioritized in conservation efforts.

Table 2.2: Reference values of selected haematological, electrolyte and serum biochemical parameters in clinically healthy chickens

Parameter	Unit	Reference values	Source
Haematological values			
Haemoglobin	g/dl	7.0 -13	Jain (1993)
Total erythrocyte (RBC) count	$x10^6/\mu l$	2.5 – 3.5	Jain (1993)
Packed cell volume (PCV)	%	22 – 35	Jain (1993)
Mean corpuscular volume (MCV)	femtoliters(fl)	90 – 140	Jain (1993)
MCH[1]	pg	33 – 47	Jain (1993)
MCHC[1]	g/dl	26 – 35	Jain (1993)
Total leucocyte count (WBC)	$x10^4/\mu l$	1.2 -3.0	Jain (1993)
Heterophils (H)	%	15 – 40	Jain (1993)
Lymphocytes (L)	%	45 – 70	Jain (1993)
Eosinophils	%	1.5 – 6.0	Jain (1993)
Monocytes	%	5.0 – 10	Jain (1993)
Basophils	%	rare	Jain (1993)
Serum electrolyte and biochemical values			
Potassium	mmol/l	1.7 -4.2	Clinical Diagnostics Division (1990)
Sodium	mmol/l	139 - 155	Clinical Diagnostics Division (1990)
Chloride	mmol/l	108 – 124	Clinical Diagnostics Division (1990)
Calcium	mg/dl	8.1 – 12	Clinical Diagnostics Division (1990)
Total protein	g/dl	70 -88	Iheukwumere and Herbert (2003)
Albumin	g/dl	24-30	Iheukwumere and Herbert (2003)
Globulin	g/dl	30 -64	Iheukwumere and Herbert (2003)
Glucose	mg/dl	197 - 299	Clinical Diagnostics Division (1990)
Uric acid	mg/dl	1.9 – 12.5	Clinical Diagnostics Division (1990)
Creatinine	mg/dl	1.4 – 1.5	Peters *et al*. (2010)
Cholesterol	mg/dl	129 - 297	Clinical Diagnostics Division (1990)
Alanine transaminase (ALT)	(U/l)	18 -22	Iheukwumere and Herbert (2003); Fasina *et al*. (1999)
Alkaline phosphatise (ALP)	(U/l)	10 - 106	Clinical Diagnostics Division (1990)
Aspartate transaminase (AST)	(U/l)	26 -31	Iheukwumere and Herbert (2003); Fasina *et al*. (1999)

[1]MCHC: mean corpuscular haemoglobin concentration; MCH:mean corpuscular haemoglobin

2.5.5. Behaviour and welfare of chickens

Swarbrick (1986) defined welfare as the external environment around the animals, many aspects of which can be objectively and easily assessed and measured. One of the objective methods of assessing welfare is to look for abnormal behaviour. Abnormal behaviour is a persistent, undesirable action, shown by a minority of the population which is not due to any obvious neurological lesion and it is not confined to the situation that originally elicited it (Appleby and Hughes, 1991). Under abnormal behaviour there is a category of behaviour called stereotypies. Stereotypies are known as repetitive actions that are fixed in form and orientation and serve no obvious purpose (Savory, 1995). Viola and colleagues (2009) showed that broiler chickens submitted to water restriction showed abnormal behaviour. Without water, chickens did not eat and were sleepy. In the presence of humans, the birds were excited, running, and jumping into the cages. When water was offered to birds, some started to peck other chicken's toes and tried to drink it all very fast. Yu and Robinson (1992) and Brooks (1994) also described similar behaviors in chickens submitted to water restriction.

2.5.6. Meat quality

When dehydrated, the body tries to maintain its homeostatic balance by ingesting water and by reducing water excretion or using interstitial and intracellular fluids (Bruno *et al*., 2000). However, birds submitted to water restriction utilize tissue substances, in particular fat reserves, for metabolic water production to maintain hydrational homeostasis (Warriss *et al.*, 1988; Pires *et al*., 2007; Viola *et al*., 2009). These changes, in turn, influence the ultimate physicochemical and sensory properties of meat such as pH, water-holding capacity, colour, tenderness, fat content and composition, juiciness, flavour and palatability (Debut *et al*., 2003; Skomorucha *et* *al*., 2006; Barbut *et al*., 2008; Dadgar *et al*., 2012). However, the impact of water restriction on the physical and chemical properties of meat from local unimproved strains of chickens in South Africa has not been evaluated.

2.6. Adaptation of indigenous chickens to water scarcity

The hot conditions in many communal areas, coupled with the scarcity of drinking water, create the potential for physiological problems associated with inadequate hydration. Indigenous chickens adapted to semi-arid areas are able to survive and even thrive, despite extreme temperatures and scarce-water by tolerating these conditions using behavioral, morphological, and physiological adaptations (Schmidt-Nielsen 1997).

2.6.1. Behavioural adaptations

Free-ranging indigenous chickens reduce heat loads and maintain water balance using daily timing of activity, diet selection and microhabitats. Although described separately here, behavioural adaptations function in combination with both morphological and physiological adaptations.

Timing of daily activities can reduce heat loads and minimize evaporative water loss. During the hottest, driest periods of the year, indigenous chickens reduce diurnal activity and become more crepuscular, foraging and moving during the cooler periods of the day and thereby reducing daily heat loads (Williams *et al*., 1995). In addition to the thermoregulatory benefits of restricting activities to cooler periods of the day, free range chickens in some areas also increase the intake of preformed water by foraging before sunrise (Tieleman and Williams, 2000). Furthermore, the general behaviour of selecting forage plants with higher moisture content, regardless of time of day, may provide a means to reduce the amount of free water needed to maintain water balance (Maclean, 1996).

The use of cooler microclimates also reduces heat loads and the need for evaporative cooling, thus conserving water. Use of shaded, lower temperature microhabitats is a common behaviour during midday when temperatures are highest, and has been observed in free ranging chickens (Wolf *et al*., 1996; Shobrak, 1998; Williams *et al*., 1999). During hot days chickens press the ventral parts of the body against cool surfaces to conduct away heat without excessive loss of water for evaporation. Chickens often fashion small cups in the sand against tufts of grass that provide shade, pressing their ventral surface against the cool substrate. Occasionally chickens lie with their wings spread on the shrubs, apparently benefiting from the relatively cool, damp foliage (Shobrak, 1998).

2.6.2. Morphological adaptations

Chickens adapted to hot-dry and water-scarce environments possess a variety of morphological adaptations that aid in the reduction of heat loads and minimize water loss. Morphological adaptations that reduce heat loads and minimize water loss include body size and shape and patterns of fat deposition (Louw and Seely, 1982).

2.6.2.1. Body size

Major morphological characteristics that regulate heat gain and water loss in birds are body size and shape. Large-bodied chickens such as improved exotic strains gain heat from the environment at a slower rate than do smaller sized unimproved breeds because they have a lower surface-area-to-volume ratio and higher thermal inertia (Wolf *et al*., 1996; Williams *et al*., 1999). The relatively small surface area of large birds reduces the proportion of the animal exposed to solar radiation, thereby reducing potential environmental heat loads. Although their overall energy requirements are higher, large birds also have lower mass specific metabolic rates than do small birds; these low metabolic rates contribute relatively less metabolic heat to the total heat load (Louw and Seely, 1982; Schmidt-Nielsen, 1984a). While having a large body reduces the rate at which heat is gained from the environment, it is disadvantageous because it also reduces the rate of heat loss to the environment and shaded microclimates of sufficient size are often more limited in areas that are sparsely vegetated or lack other types of cover (Louw and Seely, 1982).

2.6.2.2. Body shape and appendages

The shape of the body and appendages also influences the rates of heat gain and loss in birds; thin appendages minimize radiant heat gain and maximize convective heat loss (Louw and Seely, 1982). Compared to birds inhabiting mesic areas, species inhabiting semi-arid regions often have longer, thinner appendages with a higher surface-to-volume ratio that facilitates heat loss (Philips and Sanborn, 1994). Changes in the rate of blood flow from the body core to the surface by vasodilatation and vasoconstriction affects the rate of heat loss from the body surface. Thus, areas of the body surface where the changes in blood flow occur are analogous to windows that can be opened or closed to regulate heat loss (Stewart *et al*., 2005).

2.6.3. Physiological adaptations

Physiological adaptations function to minimize cutaneous and pulmonary water loss and water loss in faeces and urine. Physiological mechanisms used by chickens adapted to semi-arid environments to minimize water loss include adaptive heterothermy, changes in metabolic rate, reduction in renal and digestive water loss, and reduction in pulmonary evaporative water loss by cooling exhaled air (McNab, 1988). The location of fat deposition also affects rates of heat loss and gain. Fat stored subcutaneously throughout the body may inhibit the loss of heat to the environment (Louw and Seely, 1982). The storage of fat in localized areas may be an adaptation to reduce the impact of fat reserves on a bird's ability to lose heat to the environment by minimizing the insulative effect of fat to small areas of the body, thus facilitating heat lost over other body surfaces.

2.7. Summary of literature review

Indigenous chickens have the potential to contribute positively to the nutritional status of resource-poor communities of Southern Africa. Indigenous chicken production in these communities is hampered by numerous constraints. The major constraints that affect indigenous chicken production include high reproductive wastage and mortality, high prevalence of diseases and parasites, inbreeding, low levels of nutrition and poor husbandry and poor market organization. The impact of these constraints varies with geographical areas, communities, socio-economic backgrounds of the households and changes in climate systems, among other factors. Water scarcity is projected to increase and dehydration occasioned by water scarcity is likely to have a profound effect on the productivity, meat quality and welfare of livestock including chickens. Drought-tolerant chicken genotypes, therefore, need to be identified and characterised. The broad objective of the current study was, therefore, to determine the effects of restricted water intake on the growth, physiological parameters and meat quality of indigenous Naked Neck (NNK) and Ovambo (OVB) chickens in a semi-arid environment.

CHAPTER 3: Flock dynamics and utilization patterns of indigenous chickens in a semi-arid environment

Abstract

Flock dynamics in 15 and 12 communal and resettlement households, respectively of Msinga were monitored for 30 months to determine trends in flock size, dynamics and constraints. Households in resettlement schemes had on average three chickens more ($P < 0.05$) than those in communal villages. The cock to hen ratio was 1:3.5 and 1:3.7 in communal and resettlement households, respectively. Hatched chicks accounted for 97% of total entries. Most chicks were hatched in November (8.3 ± 1.65 per household) in communal villages and January (14.6 ± 2.79 per household) in resettlement schemes. The highest number of exits per household in communal (8.9 ± 1.31) and resettlement households (8.9 ± 2.15) occurred in September. Chick mortality was the major route of flock exits contributing over 90% of total exits and was highest during the hot-wet seasonin both study sites. Aerial predators and inclement weather conditions were the major causes of chick mortality. Home consumption of indigenous chickens per month per household was higher in resettlement schemes (2.2 ± 0.17) than communal villages (1.4 ± 0.11) while sales of chicken were higher in communal (0.6 ± 0.09) than resettlement schemes (0.3 ± 0.15). It was concluded that changes in flock sizes are influenced by the rates at which chicks are hatched and mortality. The contribution of indigenous chickens to household nutrition and income in both production systems could be increased if chick survival is given appropriate attention.

Keywords: flock attrition; free range; chicken use patterns.

3.1. Introduction

In many developing countries, over 80 % of rural households rear indigenous chickens *(Gallus domesticus)* (Swatson, 2003). Indigenous chickens are adaptable and compatible to both the semi-arid environment and activities of the owners (Pedersen *et al*., 2002). They are raised under a low-input production system with little investment on disease control and prevention, supplemental feed and housing (Gondwe and Wollny, 2007). Mortality rates of up to 75 %, especially among juvenile stock are common and vary, depending on the farmers' geographic location and socioeconomic circumstances (Maphosa *et al*., 2004). High mortality rates coupled with the small flock sizes encountered in the scavenging production system cast doubt on the level of contribution that such flocks make to satisfy the multiple nutritional, economic and cultural needs of resource-poor households.

Temporal variations in populations are influenced by various biological, cultural, social and economic factors prevailing at household and community levels. For example, entries of chickens into flocks are determined by the reproductive potential of hens which, in turn, is influenced by the strains kept, their nutrition and health. Socio-cultural relationships, which depict the degree of social cohesion in communities, and investment priorities of farmers, also influence movements of chicken into and out of flocks (Aklilu *et al*., 2007). The availability of scavenging feed resources (insects, seeds, and household food leftovers), and incidence of diseases and parasites vary with seasons and consequently influence changes in chicken populations (Mapiye *et al*., 2008).

In Africa, most resource-poor farmers live in marginalized areas, where natural resources are limited. Agricultural production in rural areas is predominantly rain-fed and therefore seasonal (ODI, 2009). Consequently, households are prone to seasonal starvation. In an effort to ease congestion in communal villages and reduce pressure on fragile natural resources, most governments in Africa are acquiring land and resettling people in resettlement schemes. It is, however, not clear whether production practices in the resettled areas are better than those in densely populated communal villages. Since chickens are closely associated with livelihoods in these farming systems, it is, therefore, necessary to understand changes in key production parameters, uses and constraints in flocks in these farming systems in order to develop intervention strategies that enhance productivity and knowledge bases that can be used for mitigation and emergency response planningby relief agencies.

The objective of the study was to determine flock dynamics, use patterns and factors that affect efficient production of indigenous chickens in communal villages and resettlement schemes in a semi-arid region of South Africa. The hypothesis tested was that flock dynamics, use patterns and constraints differ among households in communal villages and resettlement schemes.

3.2. Materials and Methods

3.2.1. Description of study site

The study was undertaken in Msinga local municipality (28°10'S 30°15'E), a rural area located in Umzinyathi District in the KwaZulu-Natal Midlands of South Africa. Msinga is located in a dry to semi-arid zone at an altitude of 800 m above sea level. Temperatures vary between -2 and 44°C, with an average of 24°C. The annual rainfall is low and highly variable in space and time, ranging from 500 to 700 mm and often occurs as high intensity storms. As a result, agricultural production is more suited to livestock grazing systems than crop production. The area was specifically selected for study because of the significant contrasts in the vegetation cover between densely populated communal villages and relatively lightly settled resettlement schemes. In communal areas, much of the native woody species vegetation has disappeared as more land is being used for human settlement and arable cropping whilst the vegetation in resettlement areas is relatively undisturbed and ranges from valley bushveld to mixed grass-tree savannah, with excellent value as grazing in the dry winter months. The dominant tree species is *Acacia karroo*.

3.2.2. Household selection and data collection

Selection of farmers was based on willingness to participate in the longitudinal study and presence of a literate member in the household who would be able to keep accurate records. Selection of the farmers was done with the assistance of local animal health assistants working for Mdukatshani Rural Development Trust (MRDT). Three households were selected from each of four resettlement areas namely Ncunjane, Lower Ncunjane, Nkaseni and Nomoya, and four communal villages namely, Ngqongeni, Jolwayo, Mhlangane, Ngubo and Emkhamo.

Baseline data on household characteristics, integration of chickens to other livestock enterprises, feed, water, breeding and health management practices were captured using a structured questionnaire (Appendix 1). Data on indigenous chicken flock inventory and flock dynamics were recorded at the end of every month from January 2009 to June 2011. Data collected included flock size, flock structure (cocks, hens, growers and chicks), entries and exits. The entries recorded were hatchings and purchases, whilst exits comprised of birds that were slaughtered, sold, and those that were killed by predators and diseases, or were stolen. Exchanges, gifts and chickens entrusted were recorded as either entries or exits depending on whether the chickens involved were joining or exiting the flock.

3.2.3. Statistical analyses

The PROC FREQ procedure of Statistical Analyses System SAS (2003) was used to determine the frequency of qualitative household attributes. The association between type of land holding and qualitative household attributes were determined using the chi-square test. The effect of type of land holding and month on quantitative household characteristics such as household size, cattle herd, goat, and chicken flock size, flock structure, entries and exits were determined using the PROC GLM procedure of SAS (2003). Flock size per household at the beginning of the study was fitted as a covariate. The PDIFF statement was used for mean separation when a significant effect of type of land holding and month was detected.The linear model used was:

$Y_{ijk} = \mu + L_i + M_j + (L \times M)_{ij} + E_{ijk}$

where

Y_{ijk} = response variable;

μ = constant mean common to all observations;

L_i = effect of type of land holding (i = communal and resettlement);

M_j= effect of month (*j*= January, February…December);

$(L \times M)_{ij}$= interaction of type of landholding and month; and

E_{ijk} = random residual error, assumed to be normally distributed.

3.3. Results

3.3.1. Socioeconomic characteristics, livestock species kept and chicken management practices

The demographic and socio-economic characteristics of households, livestock species kept and chicken management practices are shown in Table 3.1. Most households in communal villages were headed by women compared to resettlement schemes where household heads were predominantly male. Most male household heads were resident on the farms. The average household size was larger in resettlement than in communal areas.A significant majority of household heads in communal villages were younger than 60 years and dependent on social grants from the government. On the other hand, most household heads in resettlement schemes were older than 60 years and depended on pensions for income. The level of literacy and numeracy among farmers in both study sites was low. Over 50 % of the farmers indicated that they did not receive basic primary education. Land holdings per household were larger in resettlement schemes than in communal villages. Over 50 % of the farmers in resettlement schemes practiced mixed farming with a strong market gardening component.

There were fewer farmers dependent on market gardening in communal areas. Cattle, goats and chickens were the major livestock species kept by the farmers. Mean cattle herds and goat flocks per household were larger ($P < 0.05$) in resettlement than communal villages. Indigenous chickens were the most popular livestock species in both study sites.

Table 3.1: Socioeconomic characteristics, livestock species kept and chicken management practices in communal and resettlement areas

Item	Communal (n=15)	Resettlement (n=12)	Test	
	Percent	Percent	χ^2	P-value
Female household heads	71[a]	27[b]	4.81	0.03
Female owners of chicken	65	85	1.49	0.22
Farmers older than 60 years	24	46	2.58	0.63
Did not receive primary education	50	62	2.06	0.56
Farmers dependent on social grant	50	25	1.27	0.53
Dependent on crop sales	25	57	3.75	0.29
Provided housing	43	55	0.33	0.56
Used bought in concentrate feed	0[b]	7[a]	6.79	0.03
Used waste water from washing dishes or bathing	50	77	3.73	0.16
Adlib water provision	6	0	1.50	0.68
Females responsible for purchases	64	64	0.001	0.97
Females responsible for sales	31	36	0.08	0.77
Females responsible for breeding	75	73	1.22	0.54
Females responsible for feed and water	29	55	1.73	0.63
Females responsible for health	64	82	1.87	0.39
Access to state veterinarian	6[a]	0[b]	14.50	0.006
Used traditional medicine to treat sick birds	41	39	0.81	0.846
	Mean ± SE	Mean ± SE	F-test	P-value
Household size (persons/household)	8 ± 1.03	10 ± 1.16	0.95	0.34
Land size (ha)	0.8 ± 0.64[b]	3 ± 0.72[a]	3.07	0.04
Cattle herd (per household)	3 ± 3.17[b]	13 ± 3.58[a]	4.90	0.04
Goats (per household)	19 ± 4.58	26 ± 5.16	1.09	0.31

[ab] Means in the same row without common superscript are different at $P<0.05$; SE: Standard error.

All the chickens were raised under the free range production system and over 50% of respondents did not provide housing for their flocks, irrespective of production system.Although the scavenging system was the most dominant feeding system in both communal villages and resettlement schemes, the majority of respondents (96%) provided supplementary feed.However, the quantities provided were not recorded. Yellow maize was the predominant feed supplement for chickens (86%), followed by kitchen waste (7.3%). Use of bought-in concentrates was more prevalent in resettlement than communal households ($P < 0.05$). The use of water left-over from washing dishes or bathing was more common in resettlement than communal households. In the majority of cases, farmers indicated that the water was of poor quality, based on colour and smell. Seventy six and 85% of farmers in communal villages and resettlement schemes, respectively, indicated that the water provided to chickens was muddy, soapy and smelly. The types of container used for providing water to chickens showed a wide range between the production systems and included plastic containers, used tyres, metal containers, and old clay pots. All the farmers indicated that the water troughs were accessible to all forms of livestock and that the containers were rarely washed. Women and children were responsible for most of the indigenous chickens' daily management activities while decisions about selling were mostly made by men. Animal health service delivery was generally poor, with 6% and 0% of indigenous chicken farmers in communal and resettlement areas, respectively, served by State Veterinary Services. About 40% of the farmers in both communal and resettlement production systems reported that they used traditional medicines to treat sick birds. About 50% of the farmers bought drugs for sick chickens from veterinary drug suppliers while about 8% indicated that they did nothing. The major veterinary drugs bought were Newcastle disease (ND) and fowl pox vaccines.

3.3.2. Household flock composition and dynamics

Farmers in resettlement schemes had approximately one cock and three hens more ($P < 0.05$) than those in communal villages (Table 3.2). The number of growers and chicks was, however not different ($P > 0.05$) between the two production systems. Chicks formed the largest proportion (38 %) of flocks followed by breeding hens (32 %). The sex ratio (cock:hen) was 1:3.5 and 1:3.7 in communal and resettlement households, respectively. Besides production system, month had a significant effect on the number of growers and chicks (Figure 3.1). Flock sizes in communal villages peaked in March (45.1 ± 3.02) during the post rainy season and declined steadily to a low of 34.7 ± 3.63 in September during the hot-dry season. The largest flock sizes in resettlement schemes were observed in January (52.4 ± 5.09) during the hot-wet season and the smallest in August (36.1 ± 5.98) during the cold-dry season. Households in communal villages had more ($P < 0.05$) chicks than cocks, hens and growers throughout the year except in June when the number of growers was equal to that of chicks, and during the period June to September (cold-dry to hot dry season) when there were more hens than chicks. In resettlement schemes, the number of chicks was lower ($P < 0.05$) than the number of hens and growers, except in June and July when it was equal to that of growers. The number of chicks for farmers in resettlement schemes was, however, higher than the number of cocks throughout the year except in October and November during the hot-dry and hot–wet seasons, respectively. The number of cocks in both communal and resettlement households showed little variation throughout the seasons.

Table 3.2: Average household flock size (± standard error) and flock structure of indigenous chickens in communal villages and resettlement schemes of Msinga

Category of chicken	Production system		
	Communal (n=538)	Resettlement (n=201)	Overall (n=739)
Flock size	39.1 ± 1.04[b]	44.2 ± 1.64[a]	41.3 ± 0.10
Cocks	3.1 ± 0.13[b]	4.0 ± 0.21[a]	3.2 ± 0.10
Hens	12.5 ± 0.41[b]	16.4 ± 0.64[a]	13.3 ± 8.36
Growers	8.8 ± 0.47[a]	8.9 ± 0.74[a]	9.3 ± 0.40
Chicks	14.9 ± 0.67[a]	15.0 ± 1.06[a]	15.5 ± 0.58
Sex ratio (cock:hen)	0.29 ± 0.01[a]	0.27 ± 0.02[a]	0.26 ± 0.01
Total entries	7.0 ± 0.47	7.4 ± 0.74	7.3 ± 0.38
Hatched chicks	6.8 ± 0.47	7.3 ± 0.74	7.1 ± 0.38
Purchases	0.056 ± 0.020	0.064 ± 0.033	0.063 ± 0.016
Gifts	0.022 ± 0.012	0.020 ± 0.019	0.016 ± 0.009
Exchanges	0.044 ± 0.013	0.025 ± 0.021	0.032 ± 0.01
Total exits	6.6 ± 0.38	7.0 ± 0.59	6.9 ± 0.30
Sales	0.6 ± 0.09	0.3 ± 0.15	0.56 ± 0.074
Gifts out	0.07 ± 0.02	0.09 ± 0.031	0.078 ± 0.015
Slaughters	1.4 ± 0.11[b]	2.2 ± 0.17[a]	1.58 ± 0.085
Mortality	4.6 ± 0.31	4.4 ± 0.50	4.8 ± 0.25

[ab] Means in the same row without common superscript are different at $P<0.05$

n= number of month-flock observations

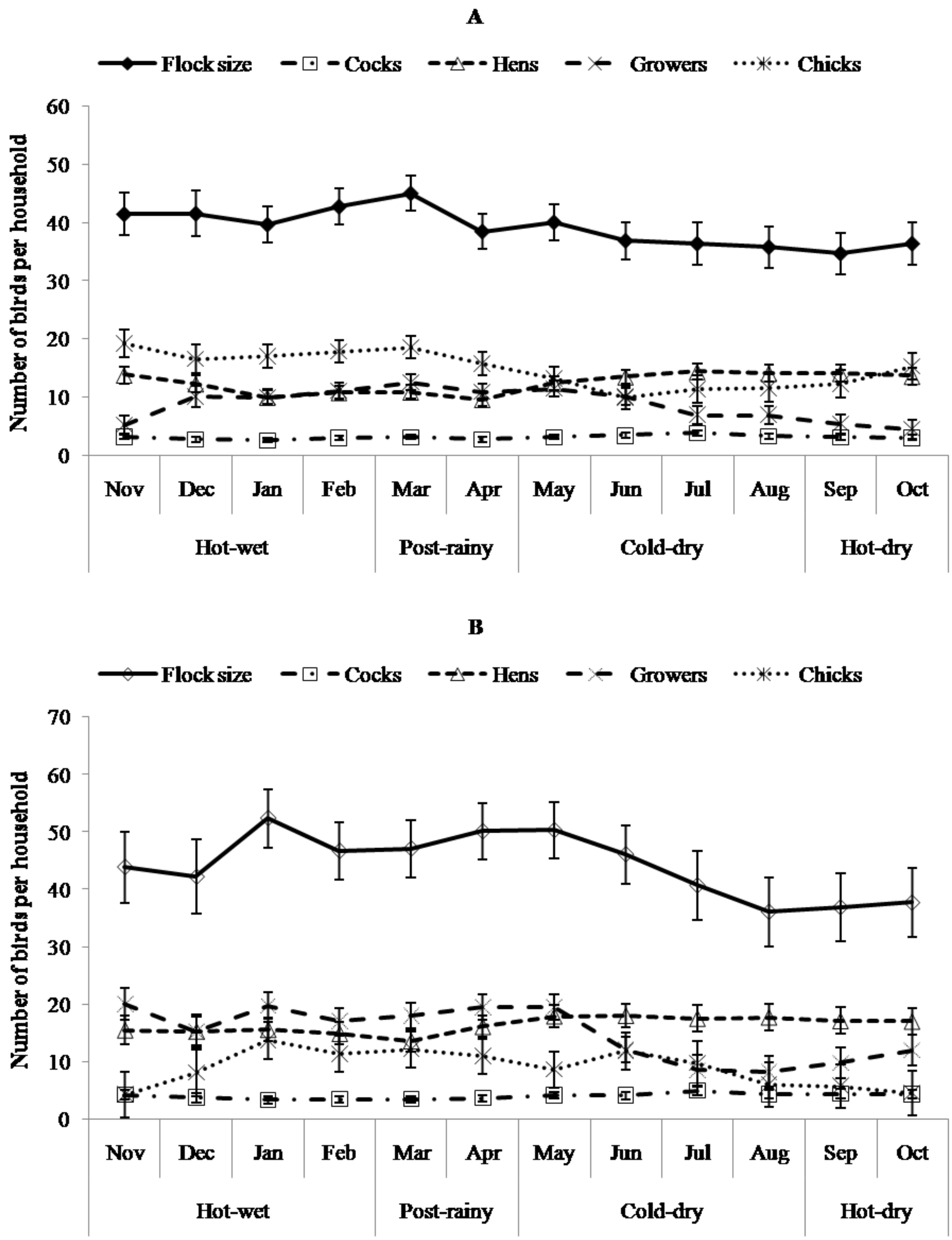


Figure 3.1: Least square means ((±standard error) of monthly flock dynamics and composition in communal (A) resettlement (B) households

3.3.3. Entries

Total entries were not affected by production system ($P > 0.05$; Table 3.2). However, households in resettlement schemes had 0.4 more entries than those in communal villages. Hatched chicks were the major mode of entry, accounting for more than 97% of entries into flocks. The contribution of purchases, gifts and exchanges was negligible.

Month had a significant effect on total entries and the number of hatched chicks ($P < 0.05$).The numbers of chickens that joined flocks through purchases, exchanges and gifts were not affected ($P > 0.05$) by month. Changes in total entries and number of hatched chicks in communal villages and resettlement schemes are shown in Figure 3.2. In communal villages, a major peak in total entries per household occurred in February (9.3 ±1.39) during the hot-wet season. The highest number of total entries per household was observed in November (14.6 ± 2.80). Minor peaks in total entries per household occurred in January (12.8 ± 2.30), March (10.7 ± 2.24) and September (9.6 ± 2.70) during the hot-wet, post-rainy and hot-dry seasons, respectively. The pattern of hatched chicks per household closely followed the pattern of total entries in both study areas as depicted in Figure 3.2. The number of birds entering flocks through purchases, gifts and exchanges in the study areas was low and remained constant throughout the study period.

3.3.4. Exits

The least square means of the main causes of exits between households in communal villages and resettlement schemes are shown in Table 3.2. There were no differences in the number of total exits between households in communal villages and resettlement schemes. Mortality was the main cause of exits from flocks, accounting for 70 and 63% of total exits between households

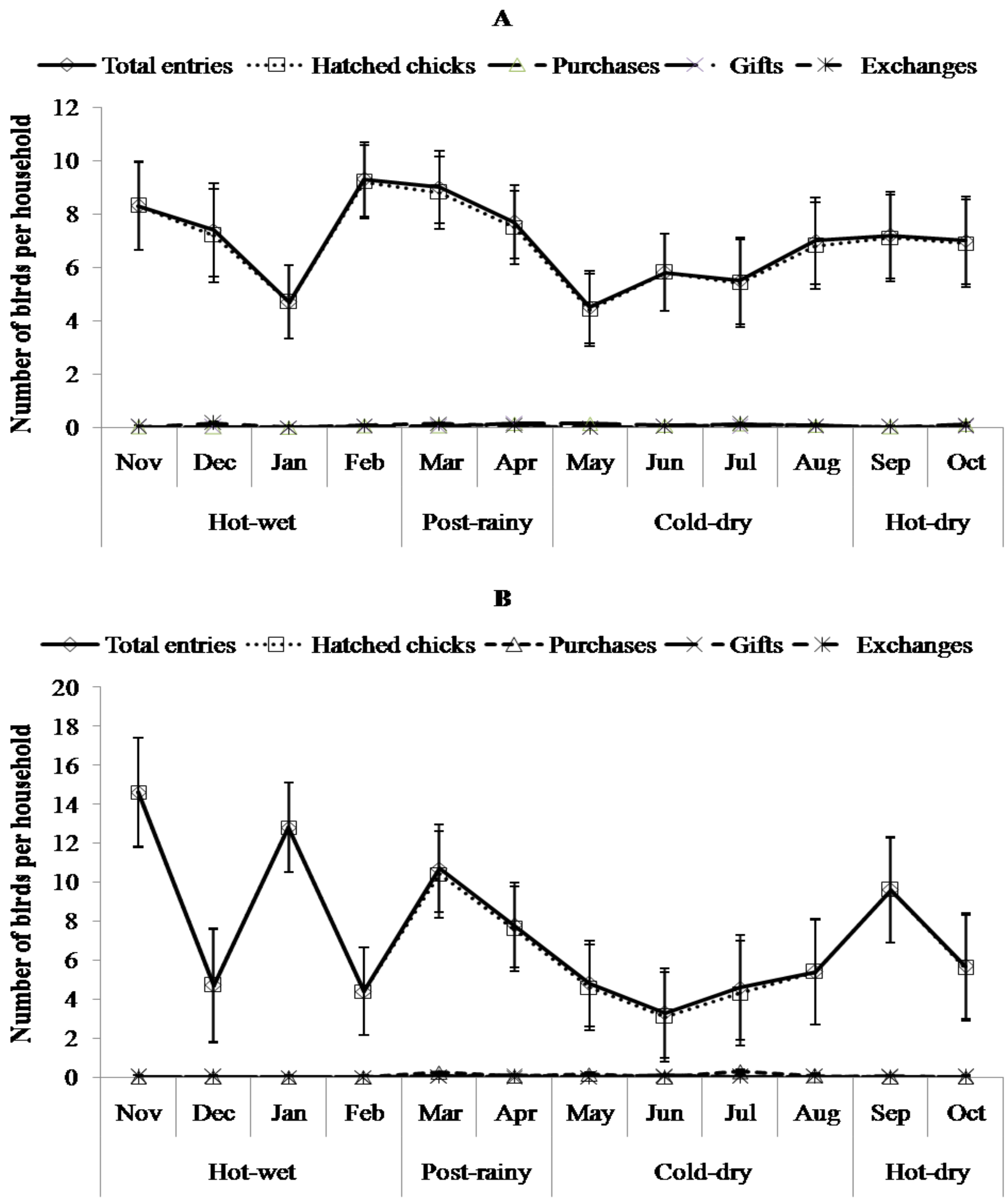


Figure 3.2:Monthly least square means of total entries, hatched chicks, purchases, gifts and exchanges in communal villages (A) and resettlement schemes (B)

in communal villages and resettlement schemes, respectively. The number of birds that exited flocks through slaughter was higher (P < 0.05) between households in resettlement than communal villages and accounted for 34 and 21 % of total exits in the former and latter, respectively. Exits through gifts were negligible and accounted for 1 and 1.3 % of total exits between households in communal villages and resettlement schemes, respectively. The proportion of chicken exiting flocks through sales was higher (9 %) in communal than resettlement (4.3 %) households.

Total exits and exits through sales, gifts, slaughters and mortality between households in communal villages and resettlement schemes were not affected (P > 0.05) by month. However, total exits per household between communal households peaked in September (9.0 ± 1.31) during the hot-dry season (Figure 3.3). Subsequent but minor peaks occurred in January (7.7 ± 1.10 and April (8.4 ± 1.10 during the hot-wet and post-rainy seasons, respectively. A similar trend was observed for households in resettlement areas except that minor peaks occurred in February and June during the hot-wet and cold-dry seasons, respectively. The number of chickens slaughtered for home consumption between communal households was higher than the number of birds sold or presented as gifts throughout the study period, except in March, May and August when it was equal to the number sold. The number of birds slaughtered for home consumption between households in resettlement schemes, however, remained higher than the number sold or presented as gifts. No clear pattern of sales and gifts could be established in both study areas, but as and when a sale was commissioned, chickens were sold for R30 to R35 (US$3.75 to US$4.375:1US$ = R8.00) per bird. Theft of adult chickens, in particular cocks and hens, was a major concern in densely populated communal villages than in the lightly settled resettlement schemes (Figure 3.4). Mortality of chicks was the major cause of exits between flocks and it followed closely the pattern of total exits in both communal villages and resettlement schemes. Out of a total of 4563 recorded deaths in communal households, chicks, growers, hens and cocks accounted for 94, 4.0, 2.0 and 0.5 %, respectively. Although there were fewer deaths between flocks in resettlement schemes than communal villages, death of chicks, growers, hens and cocks accounted for 90, 5.5, 4.0 and 0.7 %, respectively. The major causes of mortality in communal and resettlement flocks are shown in Figure 3.4. The number of chickens exiting as gifts was negligible and remained constant throughout the study period.

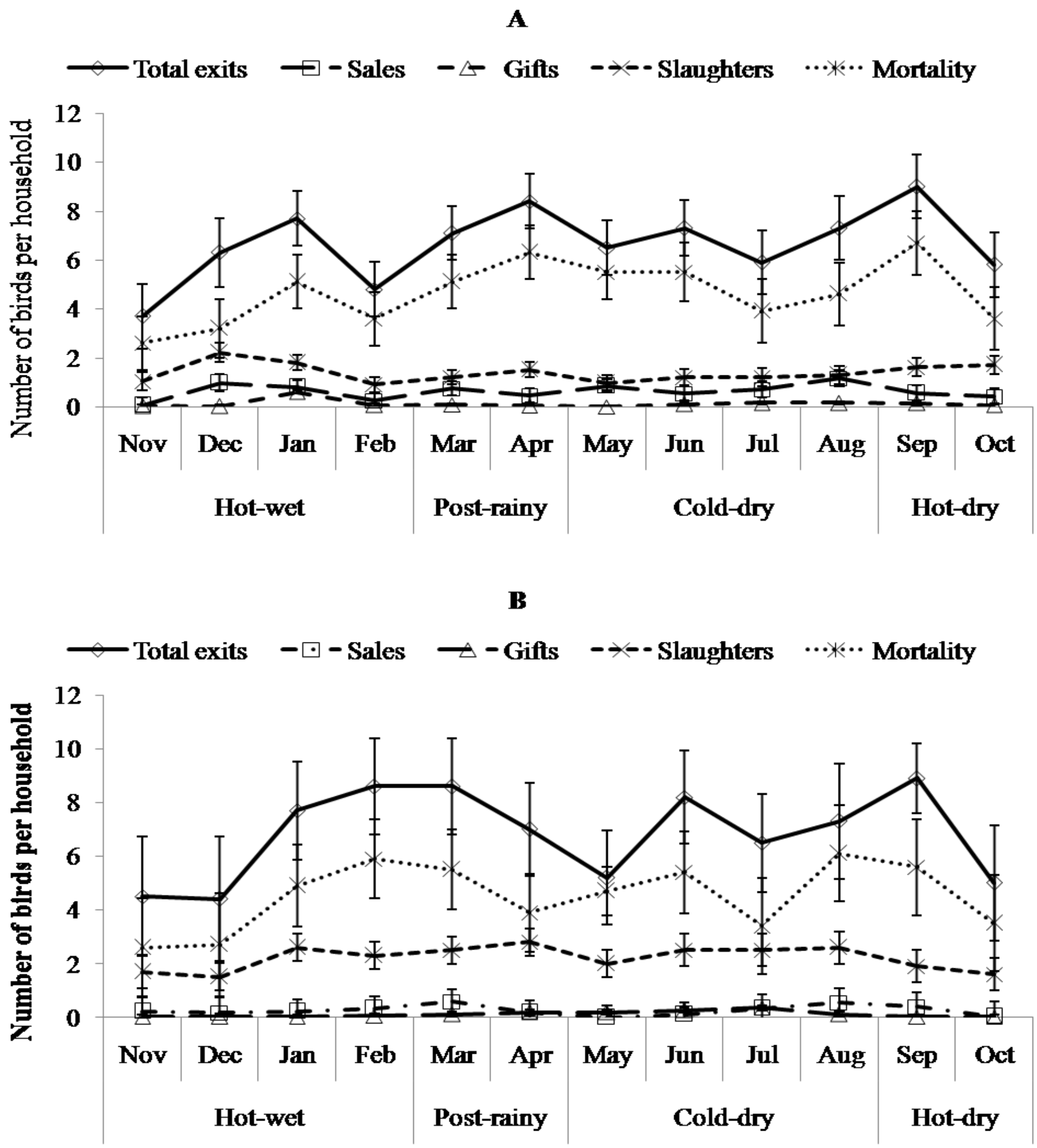


Figure 3.3: Monthly least square means of total exits and number of birds that left flocks through sales, gifts, slaughters and death in communal (A) and resettlement (B) households

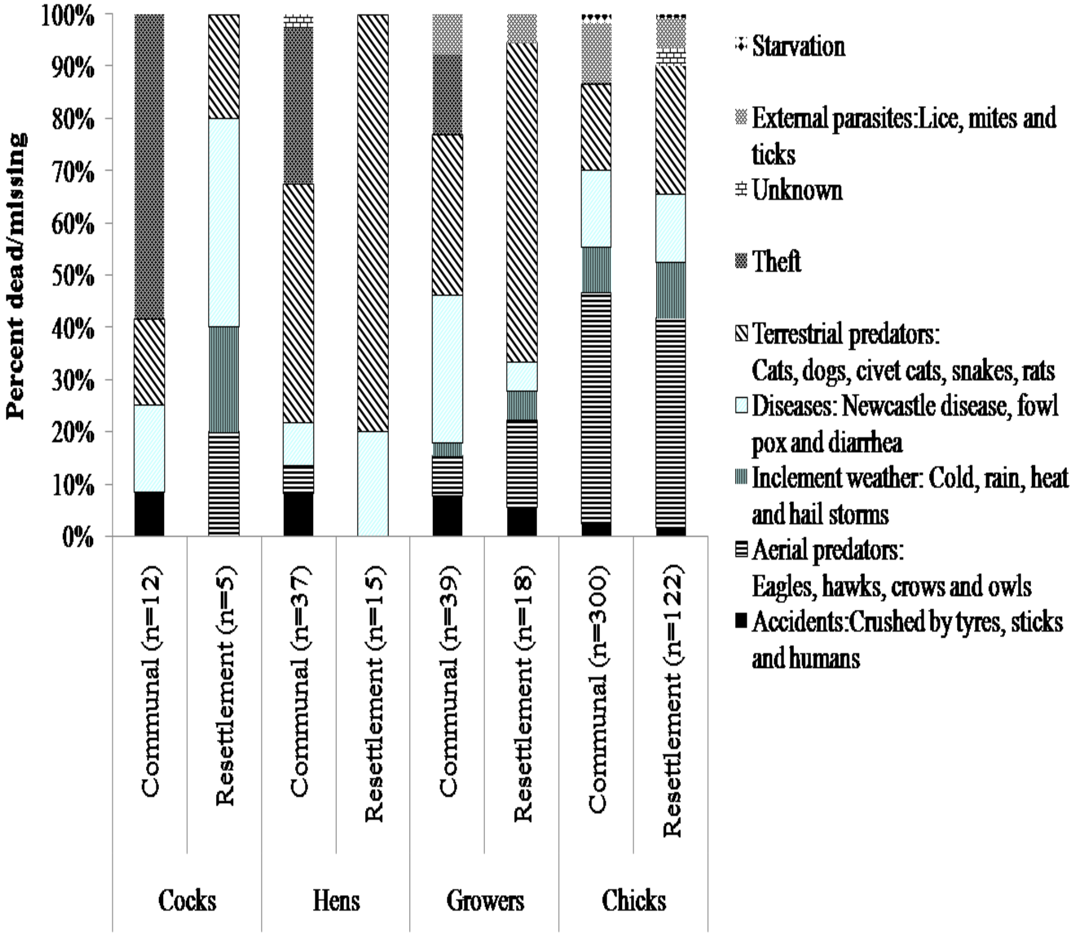


Figure 3.4: Causes of attrition among the different age groups of indigenous chickens in communal villages and resettlement schemes

3.4. Discussion

The observation that women constituted the large majority of household heads in communal villages is typical of most rural areas in Southern Africa where most adult men have either left the village to find work in big cities and hardly ever return due to the cost, or have died of AIDS (Mwale and Masika, 2009). The high percentage of resident male household heads in resettlement schemes can be attributed to the high numbers of retired professionals, who subsist on life savings and pensions. Agricultural production in resettlement schemes was relatively more intensive, with a strong commercial bias than found in communal villages.

The observed household sizes were both higher than the national average of 4.11 persons per household and values reported for similar rural communities in South Africa (Mwale and Masika, 2009). The higher than national average household sizes among the farmers were not unusual as most of the farmers belong to the Zulu tribe, which condones polygamy. Low levels of awareness of family planning have also been cited as a reason for the large household sizes. The age composition of households also resembled the typical population pyramid of most developing countries, where most rural heads of households fall into the dependent age group aged above 60 years (Swatson, 2003).The observed low levels of education might explain the reliance on indigenous knowledge for management by indigenous chicken keepers.The average farm size in both communal villages and resettlement schemes was small (0.9 and 2.3 ha/household, respectively). Similar farm sizes were reported in rural areas of North-West Ethiopia (Halima, 2007) and Zimbabwe (Maphosa *et al*., 2004). Due to limited land the majority of farmers in communal areas own fewer ruminants than chickens. The majority of the farmers owned other livestock species, such as cattle and goats. The coexistence of indigenous chicken production with other livestock enterprises on the farm increased diversity to the farming system helped farmers to meet their multiple obligations and reduced vulnerability during periods of food shortages.

Provision of supplementary feed to flocks by both communal and resettlement farmers was also reported in other African countries (Dessie and Ogle, 2001; Kondombo *et al*., 2003). The dominant feed given to the birds was maize. The birds got some protein from scavenging on insects, snails and leguminous grains. There was no preferential treatment for chicks during supplementary feeding, contradicting reports of Kitalyi (1998) and Kondombo *et al.* (2003), who observed that supplementation was mainly provided to chicks. Maize was also used as a tool to attract the birds to shelter at sunset and when farmers needed to take stock of their flock. Despite some variations in the sources of water and frequency of watering, almost all of the respondents provided water to their chickens. The water quality was, however, doubtful and a potential health risk. Detailed studies to monitor the frequency and adequacy of water supply as well as the chemical and microbial quality of the water are required to reduce the spread of water-borne diseases and to safeguard the health of consumers of indigenous chicken and their products.

The observation that women were responsible for most of the activities like provision of water and supplementary feed to chicken is consistent with findings of Gueye (1998), who indicated that due to various historical and social factors, management of village chicken is highly associated with women. Mapiye and Sibanda (2005) also reported that women, in Rushinga district of Zimbabwe, dominated in most of the activities on village chicken production like; feeding (37.7 %), watering (51.2 %), treatment of chickens (40 %) and cleaning of bird's house

(37.2 %) while men assist in shelter constructions (60 %). Our study reaffirms these assertions and calls for a purposeful targeting of the women when introducing technologies in free-range chicken management as an entry point to poverty alleviation in the rural communities.

The poor state of animal health service delivery by State Veterinary Services observed in the study confirm earlier statements by Chiduwa *et al*. (2008) that veterinary support for most indigenous livestock species in rural areas of most Southern African countries is weak. The low levels of veterinary support can be attributed to lack of information about populations and the distribution of indigenous chickens, due to lack of detailed livestock census in rural areas. Such information is important for planning purposes and allows policy makers and donor agencies to prioritize allocation of funds to develop this livestock sub-sector. In order to maintain health, in the face of poor animal health service delivery, farmers resort to ethnoveterinary practices (Mwale and Masika, 2009). Newcastle disease (NCD) vaccination was effective and enabled adult chickens to survive through the cold-dry and hot-dry seasons, which are NCD infection periods. This corroborates the importance of NCD vaccination in rural poultry production as reported earlier (Mwalusanya *et al*., 2002). However, despite successful NCD prevention among adult birds in the study sites, it was unclear whether the high mortality observed among chicks was due to the prevalence of other diseases and parasites, or whether chicks hatched between vaccinations and thus were not protected. Similar health problems in NCD-vaccinated flocks in Zimbabwe have been reported (Pedersen, 2002). There is need to investigate the epidemiology of other diseases and parasites in NCD-vaccinated flocks in order to design strategic measures of intervention.

The large flock sizes observed in resettlement schemes than communal villages could be attributed to differences in land-holding sizes. Land is generally available in relative abundance in the lightly-settled resettlement schemes, and thus larger areas for the chickens to scavenge. In contrast, communal villages are relatively densely populated and congested leaving out very little land for the chickens to scavenge. It is therefore reasonable to assume that competition for scavenging resources was high in communal villages than resettlement schemes and hence the small flock sizes. Differences in flock sizes at household, community and regional levels have been attributed to the size and diversity of the scavenging feed resource base, among other factors (Goromela *et al*., 2006). The observed flock sizes were comparable with flock sizes of 35 chickens reported by Maphosa *et al*. (2004) in a small-scale commercial farming area in Zimbabwe, but larger than the usual flock sizes of 5 to 20 birds per household reported in Malawi (Gondwe and Wollny, 2007) and other countries in Africa (Sonaiya *et al*., 2004; Halima, 2007). The relatively large mean flock sizes can also be attributed to the inclusion of young chicks as part of the flock, unlike in some parts of Africa, where owners never include chicks when they refer to flock size, due to very high mortality in this age group.

Flock structure in both study areas was consistent with findings of Tadelle and Ogle (1996a) who reported that chicks account for the largest proportion of the indigenous chicken flocks in the central highlands of Ethiopia followed by mature hens. The higher proportion of hens could be an indication of a strong desire for egg and chick production or a deliberate attempt by farmers' to increase egg production and securing sources of replacement. Lack of strong selection and culling against hens and build up of old and unproductive hens in flocks has also been cited as a reason for higher proportions of hens among indigenous chicken flocks (Meseret, 2010). The larger number of growers per household compared to cocks could be a copping mechanism adopted by farmers to replace mature birds reduced by selling, consumption and loss due to other reasons (Aboe *et al*., 2006). A high selection intensity on hens could explain the low cock: hen ratio.

The observation that hatched chicks were the main mode of entry into flocks, accounting for over 95 % of all entries into flocks is consistent with previous reports indicating that farmers rely on the reproductive performance of their foundation stock for replacement stock (Gondwe and Wollny, 2007; Olwande *et al*., 2009). The purchase or exchange of breeding chickens to reduce inbreeding and/or to acquire different strains among farmers is rare because of both financial constraints and the traditional practice of restocking flocks using existing birds (Henning *et al*., 2007). The marked decline of hatchlings during the cold dry season could be attributed to inclement weather conditions, feed shortages and the effect of decreasing day length, which stimulated broodiness that directly affected the reproductive performance of hens. The peak flock sizes observed in September was mainly due to high numbers of hatched chicks during this period. Maphosa and colleagues (2004) attributed this to the effect of increasing day length, which stimulated many hens to lay. In contrast, Moreki (2000) reported that cold-dry season was the most prolific breeding time for village chickens because of low incidence of Newcastle disease, low predation rates and abundance of harvest waste in Serowe-Palapye district of Botswana.

The proportion of exits, especially chicks, due to death was significant compared to sales, consumption and gifts. The high mortality (>90 %) observed in this study could limit the availability of adult birds for replacements which could be a handicap for the sustainability of the village chicken production system. Similar results were obtained by Olwande *et al*. (2009), who reported that deaths from diseases especially Newcastle and fowl typhoid and predation among chicks accounted for over 50% of exits and emerged to be the most important across the various age groups of indigenous chickens. High mortality (75 %) in young birds up to onset of laying, was also reported by Maphosa *et al*. (2004) under traditional management in a community in Zimbabwe.

High chick mortality during the hot-dry season could be attributed to an increase in the number of aerial and terrestrial predators, and feed and water shortages. It appears the range of prey for aerial and terrestrial predators in the wild declines at these times of the year, forcing them to exploit food resources within human settlements. Most rural households run out of food and food reserves from harvested crops during the hot-dry season (September to October) and subsequently there are fewer household left-overs and by-products available to supplement the chicks. The ensuing excessive heat and water shortages impose a considerable degree of dehydration and physiological stress on the birds, leading to death. As such, provision of proper shelter and adequate feed and water supplies for young chicks to protect them against extreme weather conditions and predators alike would be beneficial. Provision of shelter for young chicks considerably improved survival (Lañada *et al*., 2002). Cold and wet conditions during the cold-dry and hot-wet seasons, respectively also explain peaks in chick mortality.

Migration of chickens out of flocks also demonstrated the primary functions of indigenous chickens. The functions of chickens were similar in both study sites, indicating that they might hold the same socioeconomic value. The functions were dominated by use as a source of animal protein for households, followed by sales. Participation in socio-cultural ceremonies, such as gifts to distinguished guests, and initiation and sacrificial ceremonies ranked third. The findings agree with those of many authors in different countries in Africa and elsewhere. However, the order of importance of various functions differs among authors. For example, Swatson *et al.* (2001) reported equal importance of use of indigenous chickens for rituals, sale and consumption, as perceived by farmers in KwaZulu-Natal. Despite differences in the order of importance of the roles played by local chickens in rural communities, the multifunctional use of local chickens is obvious.

3.5. Conclusions

The contribution of chickens to household nutrition and income in communal and resettlement production systems of Msinga was generally low.Chick mortality was the major factor limiting indigenous chicken production in both production systems. Anecdotal evidence suggested that aerial predators and inclement weather conditions were the main causes of exits out of flocks, including chick mortality. Empirical evidence of chick survival rates and causes of mortality in the production systems was generally lacking and difficult to obtain because death events were rarely documented and based on farmer recall. Longitudinal studies to follow up and document survival rates and causes of mortality of representative samples of chicks from hatching to weaning (usually up to 3 months of age) are warranted. Identifying the causes of chick mortality, when and how they occur, assists in designing appropriate intervention strategies and approaches to enhance chick survival, and consequently ensure a sustained contribution of indigenous chickens to rural livelihoods.

CHAPTER 4: Survival and risk factors for chicks in free-ranging indigenous chicken production systems in semi arid environments: A lifetest analysis

Abstract

Low survival rate of chicks is one of the major challenges to the economic efficiency of indigenous chicken enterprises and a major setback to current conservation efforts in communal production systems. A longitudinal study was conducted to determine the survival and causes of mortality for indigenous chicks from hatching up to 12 weeks of age in a semi-arid farming area of South Africa. Chicks hatched in November 2011 in communal (n = 281) and resettlement (n = 233) areas, respectively were monitored. Data on date of hatching, date of death and probable cause of death of individual chicks were collected using a structured checklist. Kaplan-Meier survival distributions and the odds ratios for effects of potential risk factors were determined using survival analysis and logistic regression models, respectively. Chick survival from hatching to 12 weeks was higher in communal villages (55 ± 3.14 %) than in resettlement (41 ± 4.19 %) schemes ($P < 0.05$). Mean chick survival time did not differ between communal (56 ± 3.30 days) and resettlement (49 ± 3.23 days) flocks ($P > 0.05$). Aerial predators were the major cause of chick mortality (over 60 %), followed by terrestrial predators (30 %) in both study sites. The probability (odds ratios < 1) of chick mortality decreased as the chicks grew older. Provision of water *ad libitum* and treatment of sick birds were important covariates in prolonging the survival time of a chick. It was concluded that pre-weaning chick management was better in communal than resettlement areas. Irrespective of farming area, reduced mortality rate would significantly increase replacement stock output and the contribution of chickens to livelihoods.

However, isolated efforts to solve this problem are likely to have limited impact. Instead, an integrated approach to minimise the impact of underlying factors is advocated.

Keywords: Chick survival, Causes, Risk factors, Free-range chickens, Semi arid areas

4.1. Introduction

Indigenous chickens, *Gallus domesticus,* are reared in many parts of the world irrespective of the climate, traditions, life standard, or religious affiliation (Tadelle *et al.*, 2003). Recognition of their importance as assets and a means of improving livelihoods of resource-poor farmers is increasing amid growing calls to conserve indigenous animal genetic resources. Indigenous chickens are adapted to local production conditions and are compatible with the activities of most resource poor farmers. They are tolerant to most endemic diseases and parasites (Minga *et al*., 2004), can endure long periods of feed and water deprivation than exotic chickens (Goromela *et al*., 2006). More importantly, they are prolific, easy to rear and their output can be generally expanded more rapidly and easily than that of other livestock (Kitalyi, 1998; Pedersen *et al*., 2002). The taste of their meat and eggs is also preferred by a majority of consumers over those of exotic chickens (Moreki, 2006). Improving the productivity of indigenous chickens in communal areas, therefore, constitutes the key for effective poverty eradication, and should be given special attention.

Despite the merits of indigenous chickens, the enterprise is plagued by numerous constraints that interact to undermine their contribution to human livelihoods (Permin *et al*., 2000). As reported in Chapter 3, the constraints, however, vary depending on the region and the socioeconomic circumstances of the farmers. Farmers in rural areas rely on the reproductive performance of their flocks to maintain productivity, but high mortality rates of chicks and juvenile stock, limit the availability of adult birds for replacements and threaten the productivity and sustainability of indigenous chicken enterprises. Predation along with diseases, and low food and water availability, are common explanations of mortality for chicks under free range production systems (Chapter 3; Olwande *et al*., 2010). It has been observed in other studies that women and children are more involved in chicken production (McNaish et al., 2004; Gondwe, 2004). The gender bias in chicken production implies some variation in valuing of and management of chickens in male and female headed households of the society (Muchadeyi, 2007). Studies have also shown that predator density is strongly correlated with vegetation density in village chicken production systems in the central highlands of Ethiopia (Tadelle *et al*., 2003). It is therefore possible that with wholesale resettlement of resource-poor farmers onto commercial farm land deemed underutilised, loss of chicks due to predation is likely to be significant due to increased vegetation cover in these areas. Empirical evidence of chick survival rates and causes of mortality in sparsely vegetated communal and densely vegetated resettlement schemes is lacking and difficult to obtain because death events are rarely documented. A worthy proposition to close this information gap is to follow up and document survival rates and causes of mortality of a representative sample of chicks from hatching to weaning at 12 weeks in these production systems. As indicated in Chapter 3, such information is useful in developing apposite intervention strategies to enhance chick survival and increasing the contribution of indigenous chickens to household food and financial security through increased replacement stock output.

The objective of the study was, therefore, to determine chick survival and rates of loss caused by different factors among indigenous chicken flocks in communal villages and resettlement schemes in a semi-arid area of South Africa. The hypothesis tested was that chick survival rates in resettlement schemes and communal villages were similar.

4.2. Materials and Methods

4.2.1. Study sites

The study was undertaken from November of 2011 to March of 2012 in six communal and five resettlement villages in Msinga local municipality (28°10'S 30°15'E) located in Umzinyathi District in the KwaZulu-Natal Midlands of South Africa.Details on the site are given in Section 3.2.1.

4.2.2. Selection of flocks and data collection

Eighteen and nine households in communal and resettlement areas, respectively were purposively selected to participate in the study based on their willingness to participate and availability of at least four hens that were due to hatch during the month of November 2011. All the hatched chicks were tagged with different coloured knitting yarn by the farmers with assistance of researchers and trained assistants. Chick mortality from day old to 12 weeks of age was assessed by recording chick identity, date of death, and probable cause of death on a structured check-list provided (Appendix 2). Data recorded by the farmers were verified weekly by trained assistants. Feeding and management, including vaccination and medication, were left to the farmers. On each visit, the trained assistants captured data on the potential risk factors associated with chick mortality such as the presence or absence of medication, water, concentrate feed, housing and presence of other species of poultry at each household.

4.2.3. Statistical analyses

The PROC FREQ procedure of Statistical Analyses System (SAS, 2003) was used to generate frequencies of ownership of chickens by gender and management practices that directly influence chick mortality (potential risk factors) such as presence or absence of veterinary care, water, concentrate feed, housing and other species of poultry at each household in communal and resettlement production system. The association between production system and potential risk factors was determined using the Chi-square test. The influence of production system and gender of chicken owner on the number of hatched chicks and percent survival of chicks were determined using the PROC GLM procedure of SAS (2003).The linear model used was:

$$Y_{ijk} = \mu + L_i + G_j + (L \times G)_{ij} + \varepsilon_{ijk}$$

where

Y_{ijk} = number of hatched chicks and chick survival percent;

μ = constant mean common to all observations;

L_i = effect of production system (i = communal and resettlement);

G_j = effect of gender (j= female and male);

$(L \times G)_{ij}$= interaction of production system and gender; and

ε_{ijk}= random residual error, assumed to be normally distributed.

The effects of production system and age of chicks and the interaction between production system and age on chick mortality were also determined using the PROC GLM procedure of SAS (2003). The model used was;

$Y_{ijk} = \mu + L_i + W_j + (L \times W)_{ij} + \varepsilon_{ijk}$

where

Y_{ij} = number of dead chicks;

μ = constant mean common to all observations;

L_i = effect of production system (i = communal and resettlement);

W_j = effect of age (*j*= 0-2, … 11-12 weeks);

$(L \times W)_{ij}$ = interaction of production system and age; and

ε_{ijk}= random residual error, assumed to be normally distributed.

The PDIFF procedure of SAS (2003) was used for mean separation.

Mean and median survival times of chicks as influenced by production system and potential risk factors were determined using the PROC LIFETEST procedure of SAS (2003). Kaplan-Meier survival distributions for different strata of potential risk factors were compared using the PROC LIFETEST procedure of SAS (2003).The PROC FREQ procedure of SAS (2003) was used to generate frequencies on the causes of chick mortality. The association between age of chick, production system and cause of death was determined using the Chi-square test.

An ordinal logistic regression was used to determine the probability of a household experiencing a chick death. The logit function was used to model the relationship between the probability of a death occurring and production system, gender, the presence or absence of medication, water, cleaning of containers, housing and other species of poultry at each household.

The logit model used was:

$Log_{10} (P/(1-P)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 ... + \beta_7 X_7 + \varepsilon$

where:

P	= probability of a chick death occurring;
[P/1-P]	= odds ratio, which referred to the odds a chick death occurring;
β_0	= intercept;
$\beta_{1 ......} \beta_7$	= parameter estimates of type of landholding, gender, water provision, medication, cleaning of container, provision of supplement feed, housing and other species of poultry at each household.
$X_{1 ......} X_7$	= explanatory variables type of landholding, gender, water provision, medication, cleaning of container, provision of supplement feed, housing and other species of poultry at each household
.ε	= random residual error.

Estimates of model parameters ($\beta_{0,}$ $\beta_{1,}$ β_2 .... β_7) were obtained by maximum likelihood estimation. Predicted probabilities (P) were calculated using the following formula: $P = e^{\beta 0 + \beta 1X1 + \beta 2X2 ...+ \beta 7X7} / (1+ e^{\beta 0 + \beta 1X1 + \beta 2X2 ...+ \beta 7X7})$. The odds ratio [P/1-P] was interpreted as the probability of a chick death occurring. Odds ratios greater than one indicate that chick mortality is more likely to happen than not and odds ratios less than one indicate that chick mortality is less likely to happen than not.

4.3. Results

4.3.1. Socio-economic characteristics associated with chick mortality

About 88 % of chicken owners were women. All the participating farmers in resettlement areas indicated that they provided water to their chicks at least once a day, while 29 % of farmers in communal production systems provided water once after every other day. There was a significant association between production system and source of drinking water for chickens. The number of farmers using tap (12 %) and domestic waste water (71 %) was higher ($P < 0.05$) in communal than resettlement (0 and 44 %, respectively) production systems. Farmers in resettlement areas relied more on river (22 %) and borehole (22 %) water for their chickens than communal farmers (12 and 6 %, respectively). About 77 and 65 % of farmers in resettlement and communal production systems, respectively, indicated that they cleaned the water containers daily. There was a significant association between production system and the type of feed given to chicks ($\chi^2 = 6.80$; $P < 0.05$). The number of farmers providing maize grain to their chicks was significantly higher in communal (77 %) than resettlement (22 %) production systems, while the number of farmers providing kitchen waste (67 %) and chick mesh (11 %) was higher in resettlement than communal (18 and 6 %, respectively) production systems. The majority of farmers in communal (77 %) and resettlement (67 %) production systems did not confine their chicks; instead care of the chicks was left to brooding hens. A significant association was noted between production system and health care for the chicks. The number of farmers providing medication, including vaccination against Newcastle disease, to their chicks was higher ($P < 0.05$) in resettlement areas (67 %) than in communal (47 %) production systems.

4.3.2. Hatched chicks

The number of chicks per hen per clutch was influenced ($P < 0.05$) by production system. The average number of chicks per hen per clutch was significantly higher in resettlement (14.3 ± 0.44) than in communal villages (12.3 ± 0.37). Gender of the person responsible for tending to the chickens had no effect ($P > 0.05$) on clutch size.

4.3.3. Chick survival

Chick survival from hatching to 12 weeks, calculated as the total number of chicks alive at 12 weeks of age, divided by the total number of hatched chicks per production system and expressed as a percentage, was higher in communal villages (55 ± 3.14 %) than resettlement (41 ± 4.19 %) schemes ($P < 0.05$).

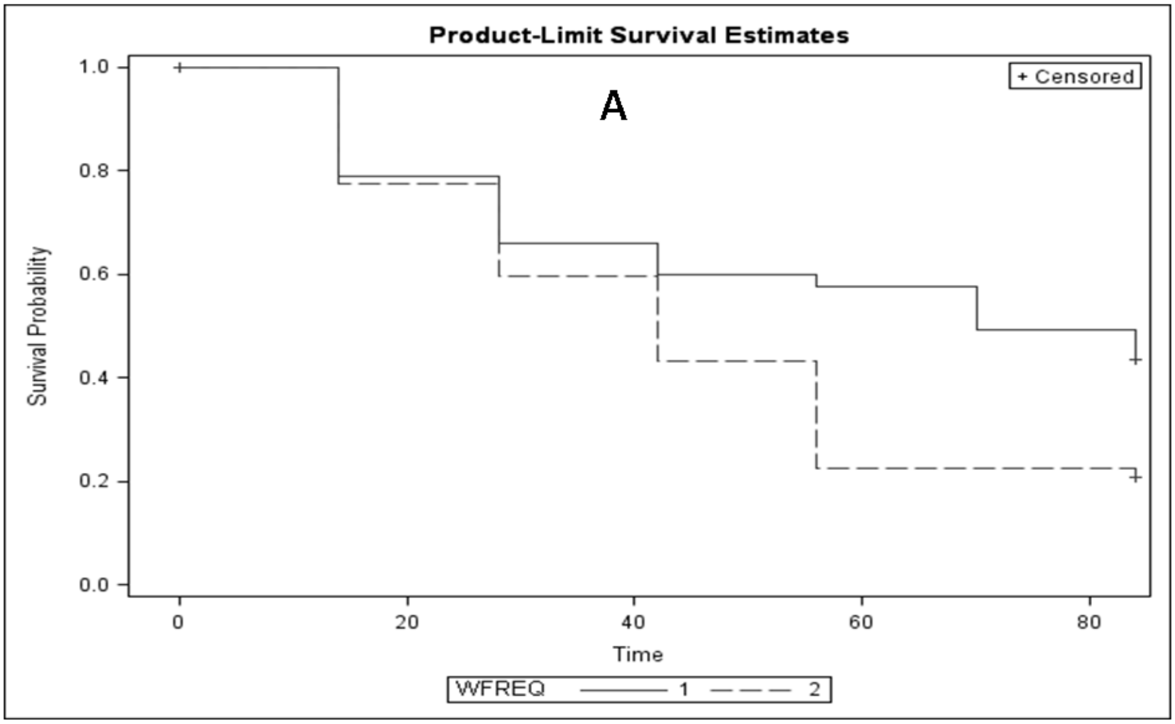
4.3.4. Mean and median survival times and effects of risk factors on chick survival

The survival times of chicks as influenced by production system, housing, water provision, cleaning of water container, provision of medication and the presence of other poultry species strata are shown in Table 4.1. The log rank test showed no influence of production systems onchick survival. Frequency of water supply and regular veterinary care of sick birds, however, significantly influenced survival times (Table 4.1). The survival time to 12 weeks for chicks receiving water *ad libitum* were higher than that for chicks watered intermittently ($\chi^2 = 8.30$; $P < 0.05$). Mean and median survival times were also higher among flocks receiving regular veterinary care against diseases than those not receiving any veterinary care ($\chi^2 = 4.36$; $P < 0.05$). The survival curves up to 84 days of chicks as influenced by frequency of water supply and veterinary care are depicted in Figure 4.1.

Table 4.1: Survival times of chicks as affected by location, housing, water provision, hygiene, medication and other poultry species

Fixed effect	Strata	N	Mean survival time(± SE) (days)	Median survival time (days)	95% CI		Log-rank test	
					Lower	Upper	χ^2	P-value
Production system	Communal	281	56.2 ± 3.30	56	42	84	1.56	0.211
	Resettlement	233	49.0 ± 3.23	42	28	56		
Housing	Present	121	54.1 ± 4.77	56	42	84	0.04	0.849
	Absent	393	51.8 ± 2.67	49	42	70		
Water provision	*Ad libitum*	289	57.6 ± 3.27	70	42	84	8.30	0.004
	Intermittent	225	45.5 ± 3.11	42	28	56		
Cleaning of	Yes	457	53.3 ± 2.49	56	42	70	2.33	0.1269
container	No	57	44.5 ± 6.31	28	28	70		
Vet care	Yes	376	61.3 ± 4.17	70	56	84	4.36	0.0367
	No	138	49.1 ± 2.73	42	28	56		
Other poultry	Present	71	54.0 ± 6.36	42	42	84	0.008	0.930
	Absent	443	52.0 ± 2.51	56	42	70		

SE: Standard error; CI: Confidence interval



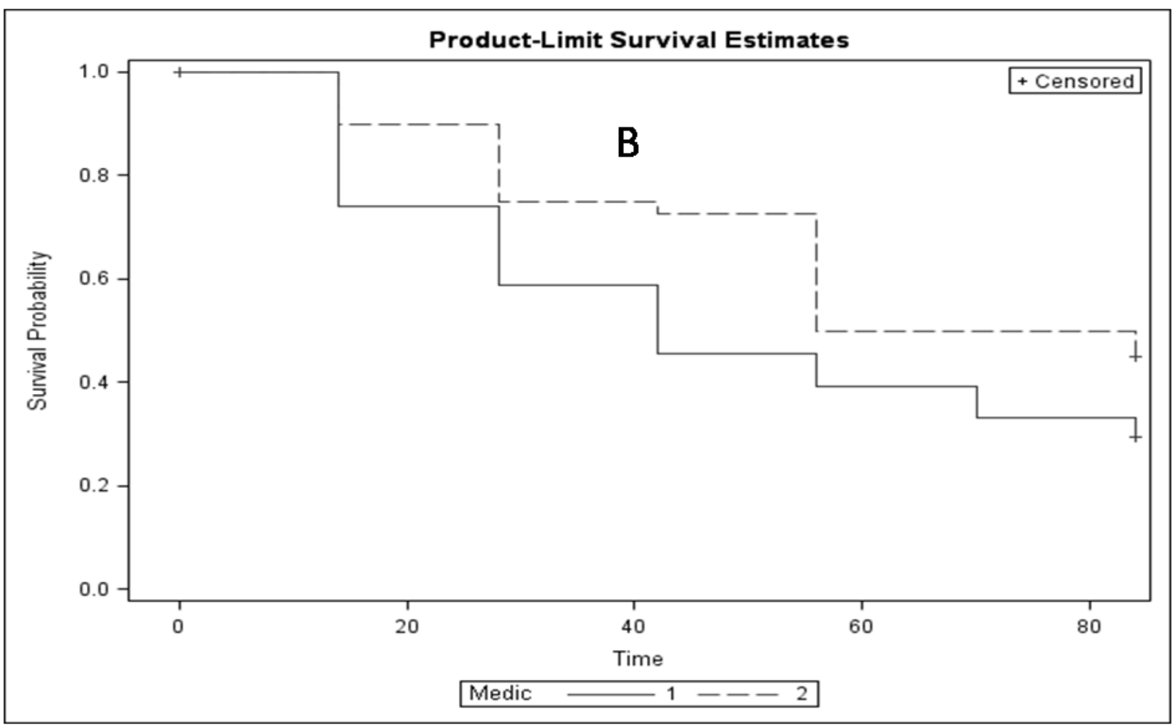


Figure 4.1: Kaplan-Meier survival curves of chicks up to 84 days of age as influenced by A) a*d libitum* water provision (WFREQ 1) vs intermittent water provision (WFREQ 2), and B) veterinary care provision (Medic 1) vs no vet care provided (Medic 2)

4.3.5. Causes of chick mortality

The incidence of mortality per clutch was affected by age of chick ($P < 0.05$). Chick mortality was higher in resettlement than communal systems throughout the study ($P < 0.05$) except between the 3 to 4, and 7 to 8-week old chicks, when it was similar to communal areas (Figure 4.2). Aerial predators, mainly birds of prey such as eagles, hawks, crows and owls were the major causes of chick mortality (Figure 4.3). Chick mortality due to birds of prey was significantly higher between 3 to 4 and 9 to 10 week old chicks than other age groups. Terrestrial predators including cats, dogs, civet cats, snakes and rats were the second most important cause of chick mortality. Accidents, inclement weather conditions and external parasites were the other causes of chick mortality.

4.3.6. Relationship between causes of mortality and production system, gender, and management factors

The odds ratio estimates for the effects of risk factors associated with mortality of chicks are shown in Table 4.2. The probability of a household in communal villages experiencing the death of a chick was 65.3% lower than in resettlement areas. Female farmers were 1.102 times more likely to experience chick mortality than males, while farmers who regularly cleaned their drinkers were 14.8% less likely to experience chick death than those who did not clean. Chicks receiving water *ad libitum* were 52% less likely to die than those watered intermittently. The odds of chick mortality for households who sought treatment for sick birds and those who did not confine their chicks were approximately half of the odds for households that treated sick birds and housed their chickens, respectively.

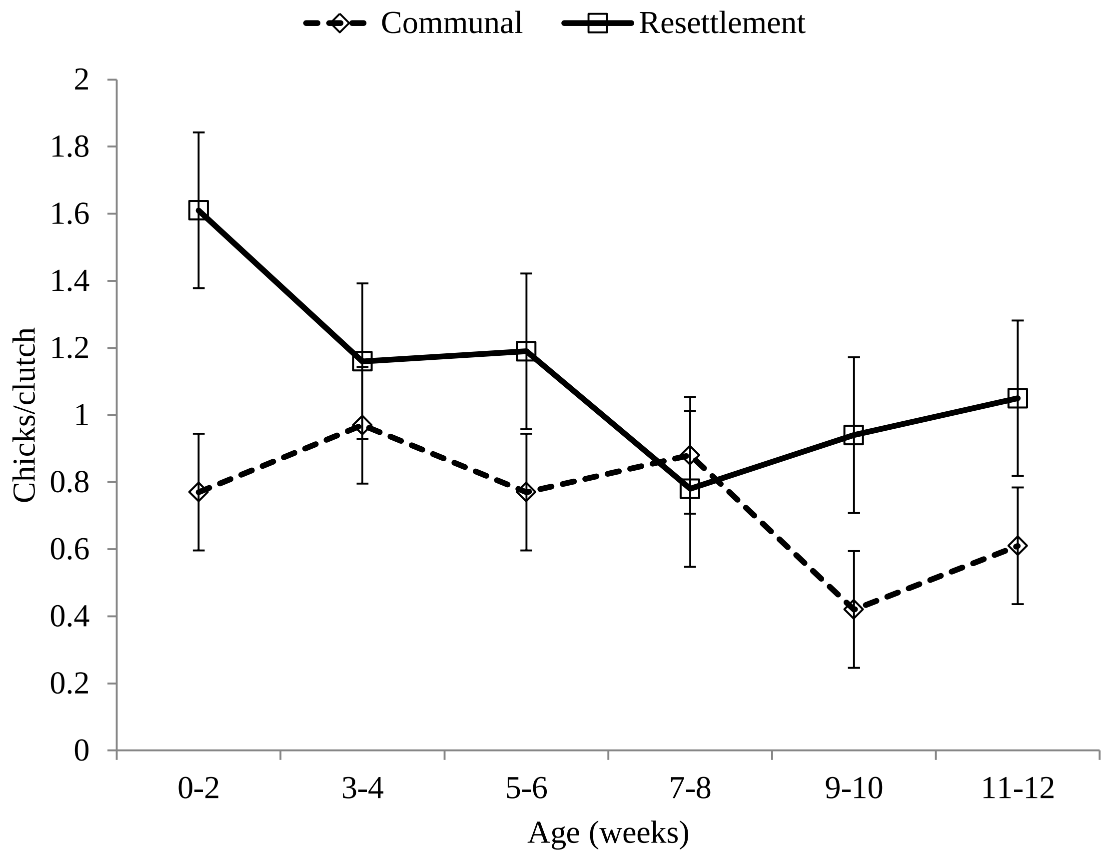


Figure 4.2: Biweekly chick mortalities (mean ± se) per clutch as influenced by production system during the first 12 weeks

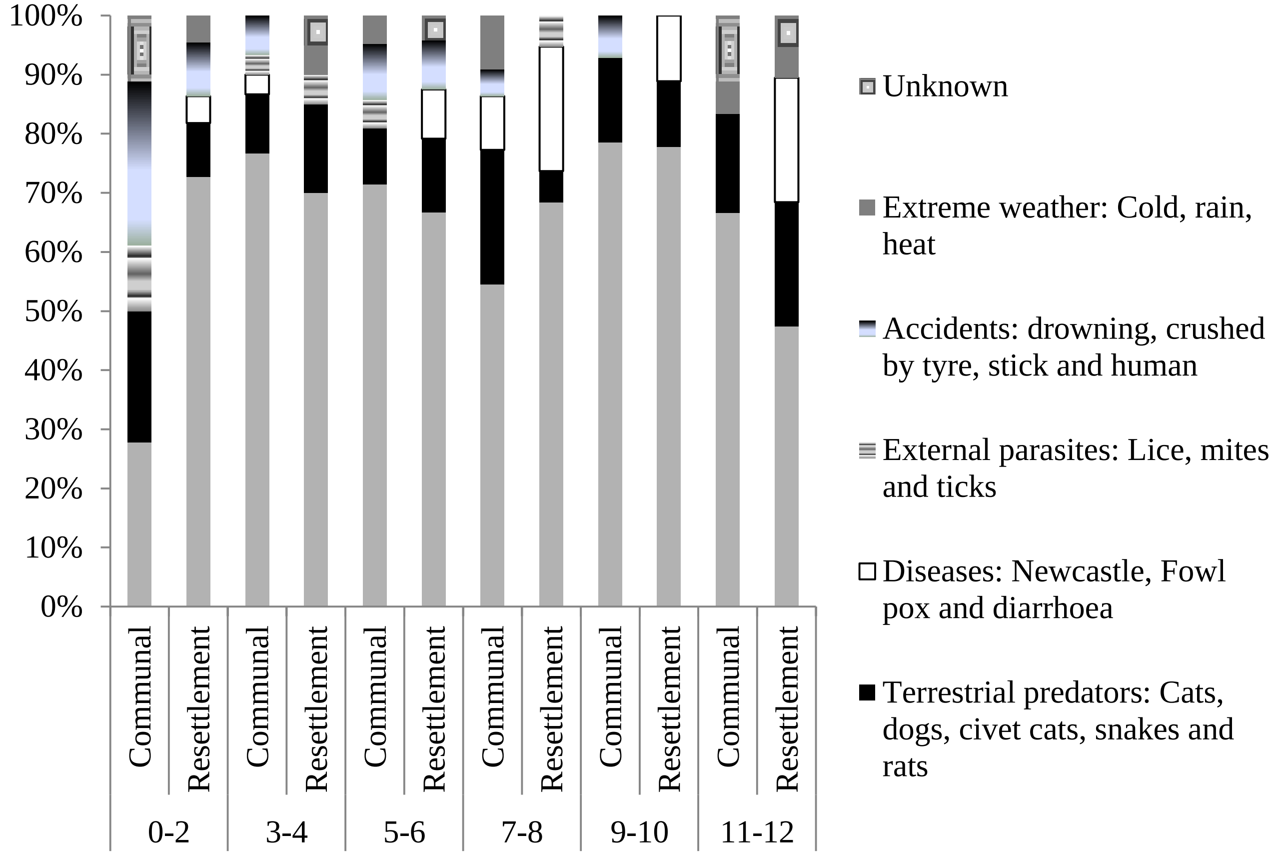


Figure 4.3: Chick mortality and associated causes from hatching to weaning at 12 weeks in communal and resettlement production systems

Table 4.2: Odds ratio estimates for chick mortality

Chick mortality	Odds ratio	95% Wald confidence limits		P-value
		Lower	Upper	
Production system (Communal vs Resettlement)	0.347	0.236	0.509	0.001
Gender of chicken farmer (female vs male)	1.102	0.765	1.586	0.220
Water provision (*ad libitum* vs intermittent)	0.483	0.151	1.547	0.006
Cleaning of container (yes vs no)	0.852	0.268	2.713	0.051
Provision of medication (yes vs no)	0.461	0.086	2.475	0.037
Availability of housing (yes vs no)	0.476	0.129	1.760	0.849
Availability of other poultry species (yes vs no)	0.863	0.418	1.781	0.044
Age in weeks: 3-4 vs 0-2	2.998	0.741	12.119	0.012
5-6 vs 0-2	0.973	0.194	4.876	0.973
7-8 vs 0-2	0.853	0.169	4.297	0.847
9-10 vs 0-2	0.954	0.161	5.652	0.959
11-12 vs 0-2	1.382	0.259	7.385	0.037

4.4. Discussion

All farmers aspire to increase the size of their flock so that they can enjoy the benefits tenable from rearing indigenous chickens. However, this goal is seldom realized due to high chick mortality, which affects the sustainability and productivity of the indigenous chicken enterprises. Identifying the causes of chick mortality, when and how they occur, assists in designing appropriate intervention strategies and approaches to enhance chick survival, and consequently ensure a sustained contribution of indigenous chickens to rural livelihoods. Few studies have evaluated the influence of spatial variation in vegetation density between communal and resettlement areas on chick survival to weaning at 12 weeks of age.

The high numbers of hatched chicks per hen in resettlement schemes with dense vegetation cover than sparsely covered communal villages can be attributed to a number of factors, including breeds, management and availability of a larger and diverse scavenging feed resource base. In contrast, the low number of hatched chicks in communal villages can be attributed to the same factors mentioned above or might be an indication that the farmers prefer to sell and/ or consume the eggs rather than hatch chicks.

The low chick survival in resettlement than communal areas could be attributed to vegetation-linked increases in predator density. As a result of large tracts of bush thickets in resettlement areas, birds not only scavenge over a wide territory in search of food items but also stray into dangerous areas where some are caught and eaten by predators (Nsahlai *et al*., 2003). In agreement with our study, Maphosa *et al*. (2004) found birds of prey (hawks, eagles and crows), rats, dogs and wildcats, in that order of importance, to be predators of concern in resettlement schemes of Zimbabwe. In Ethiopia, the link between vegetation cover and predation was also exposed when high incidences of predation were reported during the rainy season, due to high density of vegetation, which attracted and provided cover for both aerial and terrestrial predators (Tadelle *et al.*, 2003). In contrast, Moreki (2006) reported low predation rates of chicks in areas with dense and thick grass cover in Serowe-Palapye district of Botswana and attributed this to the fact that such areas provided sanctuary to chicks from aerial predators which were reported to cause more losses than terrestrial predators. Protection of chicks during the brooding period in resettlement areas of Msinga should reduce losses due to predation. This can be achieved by either confining and feeding or limiting the scavenging area and close monitoring of chicks during the day. Unfortunately, monitoring of chicks is a time-consuming engagement that carries a relatively high opportunity cost, compared with the apparent benefits (Chitate and Guta, 2001).

The mortality rates obtained in this study are comparable with findings of Permin *et al*. (2000) who recorded 50% mortality by the 12th week in Newcastle disease vaccinated flocks in Zimbabwe. Mwalusanya *et al*. (2002) also reported chick mortality rates of 40% before the 10^{th} week of age in Tanzania. Apart from predators, the incidence of death due to accidents, extreme weather, external parasites, diseases, and unknown causes was negligible in both communal villages and resettlement schemes. Accidents were, however, greater in communal villages during the first two weeks of life and compel farmers to be more cautious when handling chicks at this vulnerable age. Disease was more important in resettlement schemes from 7 to 12 weeks of age indicating sub-optimal health management. Diagnosis of diseases based on the symptoms explained by farmers was difficult to verify because no carcasses were submitted for post mortem examination. However, because farmers regularly vaccinated their flocks against

Newcastle disease, fowl pox known locally as *Amaqhuqhumba* and diarrhoea (*Isihudo*) were the most common diseases cited, contradicting previous reports by Sonaiya and Swan (2004) who attributed most chick deaths to Newcastle disease. Although most of the farmers claimed to provide supplementary feed and water, direct observation in various villages revealed that production losses due to poor chicken management especially feeding and watering were prevalent. Water containers were usually empty and chickens, including chicks were commonly seen scratching and picking from the bare ground. Furthermore, most households kept different age groups of chickens together, predisposing the vulnerable and weaker chicks to diseases and malnutrition. Similar observations were noted among indigenous chicken flocks in Namibia (Bamhare, 2001) and Zimbabwe (Mapiye and Sibanda, 2005).

No information on mean and median survival times of free-ranging indigenous chicks is available in published literature. However, the mean survival times of chicks in communal areas obtained in this study were higher than the value of 50.5 days, reported for broody hens reared under a semi-intensive production system in Bangladesh (Biswas et al., 2008). The higher mean survival time of the indigenous chicks reared in the current study compared to those reared under semi-intensive conditions can be attributed to their superior adaptation to the free-ranging environment, including good predator aversion and foraging ability. The observation that provision of water *ad libitum* and regular veterinary care of sick birds were the most important factors associated with longer survival times of chicks in both communal and resettlement households is consistent with findings of Rodriguez *et al*. (1997) who identified the two factors as important factors influencing survival time of local backyard chickens in Mexico. Since predation was the major cause of mortality in this study, it is possible that well hydrated and healthy chicks were better able to evade predators than chicks deprived of veterinary care and water. Although the other management factors that directly influence chick survival such as concentrate feed, housing and presence of other poultry species were not correlated with mortality, specific trials to draw final conclusions about them are required.

4.5. Conclusions

Pre-weaning chick survival was higher in communal villages than in resettlement schemes probably due to differences in vegetation cover. The mean pre-weaning chick survival time of 56 days in communal villages and 49 days in resettlement schemes, suggest that even at 7 weeks of age, indigenous chicks are still vulnerable to the prime causes of mortality. Aerial predators mainly birds of prey such as eagles, hawks, crows and owls were the major causes of chick mortality in both study areas, followed by terrestrial predators, including cats, dogs, civet cats, snakes and rats. Chick mortality due to birds of prey was significantly higher between 3 to 4 and 9 to 10 week old chicks compared to the other age groups. Presentation of water *ad libitum* and provision of regular veterinary care to birds were important covariates in prolonging the survival time of a chick. It is evident that management of indigenous chickens is sub-optimal and characterised by, among other factors, inadequate supply of water to the chickens. It is possible that inadequate supply of water could be one of the factors limiting productivity of these chickens. The effects of restricted water intake on the growth performance, physiological well-being and meat quality of indigenous chickens are, however, not known and warrant investigation.

CHAPTER 5: Effects of water restriction on the growth performance, carcass characteristics and organ weights of Naked Neck and Ovambo chickens of Southern Africa

(*Asian-Australasian Journal of Animal Science;* In Press)

Abstract

In semi-arid areas of Southern Africa, dehydration can compromise the performance and welfare of local chickens, particularly during the growing period when confinement is curtailed and birds are left to scavenge for feed and water. The effect of water restriction on the growth performance was compared in Naked Neck (NNK) and Ovambo (OVB) chickens that are predominant in Southern Africa. A total of 54 eight-wk-old pullets each of NNK and OVB chickens with an initial average weight of 641 ± 10 g/bird were randomly assigned to three water intake treatments, each having six birds for 8 wk. The water restriction treatments were *ad libitum*, 70 % of *ad libitum* and 40 % of *ad libitum* intake. Nine experimental pens with a floor space of 3.3 m^2 per bird were used. The pens were housed in an open-sided house with cement floor deep littered with a 20 cm layer of untreated wood shavings. Feed was provided *ad libitum*. Average daily water intake (ADWI), BW at 16 weeks of age (FBW), ADG, ADFI, feed conversion ratio (FCR) and water to feed ratios (WFR) were determined. Ovambo chickens had superior FBW, ADG and ADWI than NNK chickens ($P < 0.05$). Body weight of birds at 16 weeks of age, ADG, ADFI, ADWI and WFR declined ($P < 0.05$) progressively with increasing severity of water restriction while FCR values increased as the severity of water restriction increased ($P < 0.05$). Naked Neck chickens had better FCR at the 40 % of *ad libitum* water intake level than Ovambo chickens. The dressing percentage per bird was higher in water restricted birds than those on *ad libitum* water consumption, irrespective of strain. Heart weight was significantly lower in birds on 40 % of *ad libitum* water intake than those on *ad libitum* and 70 % of *ad libitum* water intake, respectively. In conclusion, NNK chickens performed better than OVB chickens under conditions of water restriction and would be ideal to raise for meat and egg production in locations where water shortages are a major challenge.

(Key Words: Chickens, Ovambo, Feed intake, Growth performance, Water restriction, Semi-arid areas)

5.1. Introduction

The Ovambo (OVB) and Naked Neck (NNK) chickens are closely associated with rural livelihoods in Southern Africa where they are used to meet nutritional (meat and eggs) and economic needs of households (Mapiye *et al*., 2008). The chickens also have social, cultural and symbolic roles that transcend their practical use as food or commodities. Birds are often given away as gifts, sacrificed to ancestors and divinities, or consumed as part of ritual and secular celebrations, thereby strengthening important social bonds (Aklilu *et al*., 2007).

Ovambo chickens are a small but aggressive, dual-purpose, agile dark-coloured breed, thought to have originated from the northern part of Namibia and Ovamboland (van Marle-Koster and Nel, 2000). Sexual maturity is attained at 143 d with males weighing about 2.16 kg and females 1.54 kg. The NNK chickens are a widely distributed, multi-coloured, relatively light-weight breed kept for meat and eggs for home consumption. Naked Neck chickens reach sexual maturity at 155 d of age, with males weighing about 1.95 kg and females 1.4 kg. Naked Neck chickens possess better post weaning (> 12 weeks of age) heat tolerance than OVB chickens due to the presence of a major gene that causes reduced plumage cover (Cahaner *et al*., 1993). Reduced plumage is effective when temperatures are high and birds have to dissipate excess heat (Deeb and Cahaner, 2001). Adaptation of NNK chickens to water restriction has, however, not been established. Haematological and serum biochemical responses of these strains to water restriction have been reported earlier (Chikumba *et al*., 2013)

Approximately 80 % indigenous chicken producers in Southern Africa live in fragile and marginal environments where there is lack of adequate potable water for both human and livestock consumption (Swatson, 2003). The situation is worsened in the hot dry periods of the year when availability of water and succulent scavenging resources is low. In Chapter 3, it was shown that over 90 % of indigenous chicken producers in communal villages and resettlement schemes of Msinga did not offer water to recently weaned free-ranging chickens, trusting their ability to scavenge for water. Intermittent supply of water also increased the likelihood of chicks dying (Chapter 4). Such management practices result in an undersupply of water and predispose chickens to dehydration. The effects of restricted water intake on the growth performance of indigenous chickens are not known. Information on the effects of restricted water intake on the growth performance of the indigenous chickens could reveal the mechanisms of adaptation to water stress as well as aid in identifying drought-tolerant strains that can be used to enhance food security in drought-prone areas.

The objective of the study was, therefore, to compare the effects of water restriction on body weight gains, feed intake, feed conversion ratio and water to feed ratios of NNK and OVB chickens. It was hypothesized that NNK chickens have a greater ability to withstand higher levels of water restriction than OVB chickens.

5.2. Materials and Methods

5.2.1. Study site and ethical aspects of the study

The study was conducted between January and March 2012 at Cedara College of Agriculture, which is located in the upland savanna zone on latitude 29.53°S and longitude 30.27°E at altitude 613m. The minimum, maximum and average temperature and relative humidity during the experimental weeks are summarized in Table 5.1. The average environmental temperature was 22.3°C and relative humidity was moderate at an average of 65.8 %.

Table 5.1: Average minimum and maximum temperature and average relative humidity from 9 to 16 weeks of age of the trial

Week	Temperature (°C)			Relative humidity (%)
	Mean	Minimum	Maximum	
9	22.4	16.4	28.3	76.6
10	23.5	18.0	29.0	71.8
11	22.9	18.6	27.1	75.6
12	24.4	19.3	29.4	61.3
13	25.4	18.1	32.6	61.8
14	21.8	16.1	27.4	60.5
15	20.5	14.3	26.7	63.0
16	17.9	12.1	23.7	56.3

Care and use of chickens were compliant with internationally accepted standards for welfare and ethics in animals (Austin *et al*., 2004) and were specifically approved by the University of KwaZulu-Natal Animal Ethics Research Committee (Reference Number: 048/12/Animal; Appendix 3).

5.2.2. Birds, water restriction levels and management

A total of 250 day-old chicks each of Ovambo and Naked Neck strains, hatched from parent stock of a conserved population kept at the Agricultural Research Council, Irene, Pretoria, were used in the experiment.

From Day 1 until Day 49, chicks of each strain were reared in separate (2 × 1.5 m) pens at a density of 32 chicks per m^2. Floors were covered with wood shavings. A proprietary broiler starter diet (Table 5.2) was offered *ad libitum* from tube feeders made of standard gutter materials. Water was offered *ad libitum* in 4L plastic founts. Ambient temperature was gradually decreased from 32°C when the birds were 1 day old to 21°C at 21 day old. Light was provided continuously. Birds were vaccinated against Newcastle disease at 10 and 35 days of age. A foot bath drenched with virucidal chemical was placed at the entrance to the brooding house.

At 49 days of age, the birds were weighed, and 54 pullets of each strain with an initial average individual bodyweight of 641 ± 10g per bird were randomly selected and placed in nine experimental pens. The pens were 230 cm long, 143 cm wide and 120 cm high corresponding to three water restriction treatments replicated three times. Each replicate, represented by a pen, had six birds. The water restriction treatments were *ad libitum*, 70 and 40 % of *ad libitum* intake.

Birds were acclimated to the pen environment for seven days prior to the experiment. During this period, all birds were allowed water *ad libitum* and a proprietary grower diet (Table 5.2) was gradually introduced.Thereafter, and depending on the restriction treatment, water was supplied in one instalment daily at 0900h for eight weeks until the birds were 16 weeks old. Water-restricted birds were given 70 and 40 % of the amount that the *ad libitum* group consumed the previous day. Water levels were chosen to represent optimum, moderate and severe water restriction, respectively, which the birds usually encounter under natural conditions (Mupeta *et al*., 2000). The experimental pens were housed in an open-sided house with cement floor, deep littered with wood shavings. The resulting stocking density was 3.5 birds/m^2. All the birds were fed on the same proprietary grower pellets until they were 16 weeks old. Feed was provided *ad libitum* and given from tube feeders made of standard gutter materials measuring 30cm long × 12cm wide × 9cm deep. Wood shavings were changed on a weekly basis and water founts cleaned daily.

5.2.3. Data collection

Average daily water intake (DWI) was determined as the difference between water supplied and water refused after 24 hours. Daily water intake was corrected for evaporative loss, which was determined using two founts of similar design and capacity placed at random points within the experimental facility. Body weight changes were determined by measuring body weight for each bird on a weekly basis starting from week zero of the experiment. Data of weekly body weights were used to calculate average daily gains (ADG g $bird^{-1}day^{-1}$). Feed consumption was measured every week to establish the mean daily feed intake per bird (ADFI g $bird^{-1}day^{-1}$).

Table 5.2: Chemical composition (Label values) of commercial broiler starter and grower feeds used in the study [¶]

Composition	Starter	Grower
Crude protein (g/kg)	200.00	180.00
Metabolisable energy (MJg-1)	12.76	13.00
ME/CP ratio (MJg-1)	0.06	0.07
Fat (g/kg)	25.00	25.00
Fibre (g/kg)	50.00	60.00
Moisture (g/kg)	120.00	120.00
Calcium (g/kg)	12.00	12.00
Phosphorus (g/kg)	6.00	5.50
Lysine (g/kg)	12.00	10.00

[¶]Supplied by Meadow Feeds, Pietermaritzburg, South Africa;

ME/CP= Metabolisable energy/Crude protein;

Feed conversion ratio (FCRgg^{-1}) was calculated as the amount of feed consumed per unit of live weight gain. Water to feed ratio (WFR mlg^{-1}) was calculated as the proportion of water to feed consumed daily during the experimental period. Mortality was recorded as and when it occurred. At the end of the trial, 12 birds from each water restriction treatment i.e four birds from each replication, were randomly selected for carcass characteristics and internal organ weight evaluation. The birds were slaughtered in the early morning (0800 h). After bleeding, the carcasses were scalded in water at temperatures ranging between 70 and 90°C. Feathers were plucked manually. The carcasses were then eviscerated and weighed using a digital electronic scale (Jadever JPS-1050, Micro Precision Calibration Inc, USA). The liver, lungs, heart, kidneys and the gizzard were also collected and weighed. The length of the gastro-intestinal tract from the gizzard was also measured using a flexible tape.

5.2.4. Statistical analyses

The data were analysed using a mixed model with repeated measurements in time (age) by the MIXED procedure of the SAS (2003). The covariance matrix was chosen using the Akaike information criterion to detect the effects of the main causes of variation (strain, water restriction level and age), as well as their interactions. The model used was:

$$Y_{ijkl} = \mu + B_i + T_j + A_k + (B \times T)_{ij} + (B \times A)_{ik} + (T \times A)_{jk} + (B \times T \times A)_{ijk} + \varepsilon_{ijkl}$$

where:

Y_{ijkl} = response variable (ADWI, ADFI, ADG, FCR, WFR, carcass and internal organ weights)

μ = overall mean

B_i = effect of the i^{th} strain, with i = NNK and OVB;

T_j = effect of j^{th} water restriction level, with j = *ad libitum*, 70 and 40% of *ad libitum*;

A_k = age with k = 9, 10... 16 weeks;

$(B \times T)_{ij}$ = interaction of the i^{th} strain and j^{th} level of water restriction;

$(B \times A)_{ik}$ = interaction of i^{th} strain and k^{th} age of bird;

$(T \times A)_{jk}$ = interaction of j^{th} treatment and k^{th} age of bird;

$(B \times T \times A)_{ijk}$ = interaction of the i^{th} strain, j^{th} level of water restriction and k^{th} age of bird; and

ε_{ijkl} = random error term assumed to be normally and independently distributed with mean 0 and variance equal to δ^2.

Least square means were compared using the PDIFF procedure of SAS (2003). Statistical significance was considered at the 5 % level of probability.

5.3. Results

No chick deaths were recorded during the entire experimental period between the different combinations of strains and water restriction levels.

5.3.1. Water intake

Strain had a significant effect on water intake such that OVB chickens with an average daily water intake of 113.6 ± 6.08 $mlbird^{-1}day^{-1}$ drank more than NNK chickens with 91.1 ± 6.08 $mlbird^{-1}day^{-1}$ ($P < 0.05$). No significant interaction was observed between strain and water restriction level on this parameter (Table 5.3).

5.3.2. Body weight at 16 weeks of age

There were significant differences between strains in the weight of birds at 16 weeks of age. Ovambo chickens with average body weight of 1544 ± 26.2 $gbird^{-1}$ were heavier than Naked Neck chickens with 1323 ± 26.2 $gbird^{-1}$ ($P < 0.05$). Water restriction had a significant effect on the weight of birds at 16 weeks of age. The body weight of the birds at 16 weeks of age declined proportionally as the magnitude of water restriction increased. Body weights were 1710 ± 32.1, 1431 ± 32.1 and 1158 ± 32.1 $gbird^{-1}$, for birds on *ad libitum*, 70 % and 40 % of *ad libitum* water intake, respectively. Although, no interaction between strain and water restriction level was observed ($P > 0.05$), body weights of NNK chickens on 70 and 40 % of *ad libitum* water intake were 16.6 and 34.1 % lower than that of those on *ad libitum* water intake, respectively. Similarly, the body weights of OVB chickens on 70 and 40 % of *ad libitum* water intake were 16.8 and 28.7 % lower than those of birds on *ad libitum* water intake, respectively (Table 5.3).

5.3.3. Average daily gain

There was a significant effect of strain on ADG ($P < 0.05$). The OVB chickens had higher ADG (15.8 ± 0.45 $gbird^{-1}day^{-1}$) than NNK chickens (12.5 ± 0.45 $gbird^{-1}day^{-1}$). The ADG was also influenced by water restriction level ($P < 0.05$) such that birds on 40% of *ad libitum* water intake had the lowest gains (9.6 ± 0.55 $gbird^{-1}day^{-1}$) followed by those that received 70% of *ad libitum* (13.8 ± 0.55 $gbird^{-1}day^{-1}$) while those on *ad libitum* (19.0 ± 0.55 $gbird^{-1}day^{-1}$) water intake had the highest ADG. No significant interaction between strain and water restriction level was observed for ADG (Table 5.3).

Table 5.3: Performance parameters of Naked Neck and Ovambo chickens raised with or without water restriction

Performance parameter (per bird basis)	Strain						SE	Anova (P-value)		
	Naked neck			Ovambo						
	Ad lib	70% of *ad lib*	40% of *ad lib*	*Ad lib*	70% of *ad lib*	40% of *ad lib*		Strain	WRL	Strain×WRL
Birds (n)	18	18	18	18	18	18				
Weight at 16 weeks (g)	1595.8	1334.4	1037.3	1278.6	1528.1	1824.4	45.39	0.001	0.001	0.86
Average daily gain (g/d)	17.3	12.5	7.7	20.6	15.1	11.6	0.77	0.002	0.001	0.69
Average daily feed intake (g/d)	82.1	63.9	39.3	81.7	77.6	70.3	4.30	0.06	0.008	0.29
Feed conversion ratio	4.7	5.2	5.1	4.0	5.2	6.2	0.59	0.09	0.001	0.30
Average daily water intake (mL/d)	129.9	91.2	52.0	162.5	113.5	64.9	10.5	0.02	0.001	0.66
Water:feed ratio (mL:g)	1.6	1.4	0.9	2.0	1.5	0.9	0.15	0.18	0.002	0.45

Means within a row followed by different superscript are significantly different ($P < 0.05$); SE: standard error; WRL: Water restriction level;

5.3.4. Average daily feed intake

No significant effect of strain was observed on ADFI ($P > 0.05$). Water restriction level, however, affected ADFI ($P < 0.05$). Birds subjected to *ad libitum* water intake had the highest ADFI (81.9 ± 3.04 $gbird^{-1}day^{-1}$), followed by those on 70 % of *ad libitum* (70.7 ± 3.04 $gbird^{-1}day^{-1}$) and 40 % of *ad libitum* (65.9 ± 3.04 $gbird^{-1}day^{-1}$) water intake, which were not significantly different ($P > 0.05$). Even though no significant interaction was observed between strain and water restriction level on feed intake ($P > 0.05$), feed consumption of NNK chickens on *ad libitum* water consumption was 52 and 8 % higher than that of birds given water at 40 and 70 % of *ad libitum*, respectively, while for OVB it was 23 and 8 % higher, respectively (Table 5.3).

5.3.5. Feed conversion ratio

Water restriction level had a significant effect on the FCR ($P < 0.05$). Birds on 40 % of *ad libitum* water intake had the highest FCR of 7.2 ± 0.41 gg^{-1}, followed by those on 70 % of *ad libitum* water intake with 5.2 ± 0.41 gg^{-1}, while those on *ad libitum* water intake with 4.4 ± 0.41 gg^{-1} had the lowest. Strain of chicken had no effect on FCR ($P > 0.05$). Although the interaction between strain and water restriction level was not significant, NNK chickens subjected to 40 % of *ad libitum* water intake had a lower FCR compared to OVB chickens (Table 5.3).

5.3.6. Water: feed ratio

Strain of chicken did not affect the average water: feed ratios, but there was a progressive decline due to water restriction ($P < 0.05$). The highest water:feed ratio was observed in birds on *ad libitum* (1.8 ± 0.11 mlg^{-1}) water followed by those on 70 % of *ad libitum* (1.5 ± 0.11 mlg^{-1}) while those on the 40 % of *ad libitum* (0.9 ± 0.11 mlg^{-1}) water intake had the lowest. There was no interaction between strain and water restriction level on water: feed ratio (P > 0.05); Table 5.3).

5.3.7. Carcass characteristics and organ weights

Strain of chicken had no effect on the weight of organs (P > 0.05). However, there was a significant reduction in the dressed weight and liver, lung and heart weights due to water restriction. Birds on the 40 % of *ad libitum* water intake had the lowest (824 ± 47.7 gbird^{-1}) dressed weights compared to those on 70 % of *ad libitum* (991 ± 47.7 gbird^{-1}) and *ad libitum* water intake (1017 ± 47.7 gbird^{-1}), which were not significantly different. Heart weight was significantly lower in birds on the 40 % of *ad libitum* water intake (8 ± 0.4 gbird^{-1}) than those on the 70 % of *ad libitum* (10 ± 0.4 gbird^{-1}) and *ad libitum* water intake (10 ± 0.4 gbird^{-1}), which were also similar. The highest liver weights were recorded in birds on *ad libitum* (35 ± 1.9 gbird^{-1}) followed by those on 70 % of *ad libitum* (30 ± 1.9 gbird^{-1}) and 40 % of *ad libitum* (27 ± 1.9 gbird^{-1}), in that order. A similar trend was observed for lung weight where birds on the 40 % of *ad libitum* had the lowest (9 ± 0.8 gbird^{-1}) followed by 70 % of *ad libitum* and *ad libitum* water intake each with 11 ± 0.8 gbird^{-1}. There was no significant interaction between strain and water restriction level for all the carcass and internal organ parameters measured (Table 5.4).

Table 5.4: Carcass and internal organ weights of 16 week old female Naked Neck and Ovambo chickens raised with or without water restriction

Carcass and viscera parameter (per bird)	Strain						±SE	Anova (P-value)		
	Naked neck			Ovambo						
	Ad lib	70% of *ad lib*	40% of *ad lib*	*Ad lib*	70% of *ad lib*	40% of *ad lib*		Strain	WRL	Strain×WRL
Birds (n)	12	12	12	12	12	12				
Cold dressed mass (g)	1050.1	994.0	827.3	965.9	940.8	886.4	67.48	0.66	0.10	0.49
Dressing percentage	65.2	74.6	76.9	53.8	63.6	68.8	5.50	0.05	0.06	0.94
Liver (g)	34.4	31.8	28.8	34.5	27.5	26.7	2.97	0.42	0.08	0.72
Lung (g)	9.3	11.7	9.0	11.4	10.3	9.3	1.22	0.79	0.34	0.32
Heart (g)	10.0	10.1	8.7	10.0	9.4	8.2	0.56	0.40	0.04	0.73
Kidney (g)	10.5	10.1	8.8	10.2	10.1	8.4	0.96	0.78	0.19	0.98
Gizzard (g)	41.7	40.1	33.3	39.8	35.8	33.7	3.26	0.50	0.11	0.74
GIT (cm)	127.8	127.9	129.5	121.0	120.9	132.0	6.19	0.49	0.51	0.64

Means within a row followed by different superscript are significantly different ($P < 0.05$); SE: standard error; WRL: Water restriction level

5.4. Discussion

In this study, the lower water intake of NNK chickens on *ad libitum* water intake could be a reflection of either lower water requirements, a greater dependence on metabolic water to maintain hydrational homeostasis or a higher capability of budgeting body water more economically than OVB chickens. Similar differences in efficiency of water utilization among chicken strains were reported by Ahmed and Alamer (2011), who reported that Saudi local chickens had lower water requirements than fast-growing Hisex commercial layers.

At 40% water restriction, the decline in body weight reflected a superiority of NNK over OVB chickens in water expenditure and utilization, since water consumption of the former was lower than that of the latter. It could be postulated that NNK chickens were able to budget their water balance efficiently than OVB chickens. Strain differences in body weight loss were previously reported by Arad (1982) who noted significantly higher rates of weight loss in commercial Leghorns compared to native chickens during water deprivation under hot conditions. The decline in body weight of birds fed at 70 % of *ad libitum* was comparable with results of Abdelsamie and Yadiwilo (1981) who reported a drop of 18 % in body weight in broilers maintained on a 25% water restriction under hot conditions.

The finding that there was a progressive decline in ADFI with increasing severity of water restriction concurs with previous studies that showed that birds reduce their feed intake as an important adaptive strategy to preserve body water by reducing faecal water loss together with reducing body heat increment (Pires *et al*., 2007; Viola *et al*., 2009). Our results, however, contradict findings of Ahmed and Alamer (2011), who reported no significant effect of water restriction on feed intake in local Saudi layer breeds subjected to 40 % water restriction. Kellerup *et al.* (1965) also noted no significant decrease in food consumption when water was restricted in broilers. The high feed intake observed by these authors during water deficiency could also be an important adaptive mechanism employed by these chickens to reduce the adverse impact of water scarcity.

The high FCR of OVB chickens subjected to water restriction compared to NNK chickens has important economic implications as the feed consumed reduced ADG significantly compared to birds that drank water *ad libitum.* The better FCR of NNK than OVB chickens under water restriction is consistent with findings of van Marle-Köster and Casey (2001), who found that the former had better FCR and higher growth rates than most indigenous chicken strains found in South Africa under extensive production conditions that characterise most communal areas where they are normally kept.

The WFR of OVB chickens on *ad libitum* intake were within the normal reference range of 2:1 (NRC, 1994), while those of NNK chickens were lower than the normal reference range. Naked Neck chickens appear to have lower water requirements than OVB chickens for the same amount of feed consumed. In agreement with this study, Ahmed and Alamer (2011) determined that the WFR of Saudi local chickens were lower than those of a commercial layer strain. The observed WFR, however, contradicts with Miller *et al.* (1988). Birds are expected to voluntarily reduce their feed intake when the quantity of water is restricted in order to conserve body water. It is, however, worth noting that water consumption by birds is influenced by many factors, including, the age (Leeson and Summers, 2000), genotype (Ahmed and Alamer, 2011), sex (Ziaei *et al*., 2007), stocking density (Feddes *et al*., 2002), health and welfare (Manning *et al*., 2007), ambient temperature (Belay and Teeter, 1993), quality of feed and behavioural patterns such as polydipsia (Proudman and Opel, 1981).

The significant effect of water restriction on dressing percentage could be attributed to differences in live-weight among the different water restriction levels. Saleh (1992) reported a strong relationship between body weight and carcass weight and between carcass weight and dressing percentage. The high dressing percent of water-restricted birds could also be attributed to the fact that water restriction elicited a stronger water saving response that led to attenuation of body water losses, resulting in higher dressing percentage compared to birds on *ad libitum* water intake. Similar observations were made in Saudi local chickens (Ahmed and Alamer, 2011). The low heart weight of birds fed water at 40 % of *ad libitum* is consistent with results reported by Burh et al. (1998) in chicks submitted to food and water deprivation, according to which heart weight decreased with increasing water deprivation. In contrast, Viola *et al*. (2009) observed an increase in relative heart weight in broilers restricted of water for three weeks. The increase in heart weight was attributed to higher blood viscocity caused by water restriction.

5.5. Conclusions

It can be concluded that under thermoneutral conditions and up to 16 wk of age, Naked Neck chickens consume less water than Ovambo chickens, which could be a reflection of their lower water requirements, greater dependence on metabolic water or unsual capability to budget water more economically. The Ovambo had higher weight gain, feed intake and FCR at moderate levels of water restriction, but NNK performed better at the most severe water restriction level.

The low water requirements coupled with high FCR of Naked Neck chickens at the most severe water restriction level makes them ideal to keep for meat production in locations where access to water is limited.

CHAPTER 6: Haematological and serum biochemical responses of chickens to hydric stress

(Published in *Animal*: Appendix 5)

Abstract

Dehydration can be extremely damaging to the performance and welfare of indigenous chickens. The effect of water restriction on haematological and biochemical parameters was compared in Naked Neck (NNK) and Ovambo (OVB) chickens. A total of 54, 8-week-old pullets each of Naked Neck (NNK) and Ovambo (OVB) chickens with an initial average weight of 641.1g per bird were randomly assigned to three water restriction treatments with three replications, each having six birds. The water restriction treatments were *ad libitum*, 70 and 40 % of *ad libitum* intake. Nine experimental cages with a floor space of 3.3 m^2 per strain were used. Feed was provided *ad libitum*. Packed cell volume (PCV), erythrocyte count (RBC), mean corpuscular volume (MCV) and total leucocyte count (WBC), and biochemical parameters (Uric acid (UA), creatinine (CREAT), total protein (TP), albumin (ALB), globulin (GLOB), triglyceride (TGA), total cholesterol (TC), high (HDLC) and low (LDLC) density lipoprotein cholesterol, and activity of alanine transaminase (ALT), alkaline phosphatase (ALP) and aspartate transaminase (AST) were determined from blood collected after 60 days of water restriction. Packed cell volume was higher in NNK than OVB chickens offered water *ad libitum* ($P < 0.05$), but similar in birds offered 70 and 40 % of *ad libitum*. There were no differences in RBC and MCV values between strains, but MCV was higher in birds on 40 than 70 % of *ad libitum* water intake, irrespective of strain. Naked Neck chickens had higher WBC values than OVB at 40 % restriction level, but lower WBC than OVB at 70 % water restriction level ($P < 0.05$). Uric acid, CREAT, TGA, TC, LDLC, TP and GLOB increased ($P < 0.05$) with each increment in water restriction, but the increase in CREAT and TC was more pronounced in OVB than NNK chickens. The opposite was observed for UA. Alanine transaminase activity indicated that liver fuction was not affected by water restriction. It was concluded that the two strains can withstand up to 40% of *ad libitum* water restriction, but NNK tolerated water stress better than OVB chickens.

Keywords: blood profiles, naked neck chickens, ovambo chickens, water stress

6.1. Introduction

Indigenous chickens play an important role in sustaining livelihoods of many indigent communities living in droughtprone and semi-arid areas of Southern Africa (Muchadeyi *et al.*, 2004). Most of these chickens are exposed to various sub-optimal husbandry conditions and stress-provoking situations that negatively affect their productivity. The climatic conditions that prevail for most of the year are hot and dry and coincide with peak periods of water and feed scarcity. Owing to limited water and succulent foraging resources, birds in such regions are prone to dehydration. However, it is not clear whether these chickens have developed adaptations to these harsh conditions.

The effects of hydric stress occasioned by water restriction on haematological and biochemical parameters of broilers and layers have been studied extensively (Mmereole, 2009; Ahmed and Alamer, 2011). Changes inhaematological and serum biochemical parameters have been used as proxies to predict potential resistance of livestock to environmental, nutritional and pathological stresses (Kral and Suchy, 2000). Drought-resilient chickens are expected to manifest the least changes in haematological and biochemical parameters when subjected to stressful situations relative to those under optimal production conditions (Takei *et al*., 1988).

Water restriction results in haemoconcentration reflected by increases in packed cell volume (PCV; Iheukwumere and Herbert, 2003; Mushi *et al*., 1999), and elevated levels of total proteins (TPs), albumin (ALB) and globulin (GLOB; Cork and Halliwell, 2002). Continued water deprivation also leads to increased serum uric acid (UA) and creatinine (CREAT) because of impaired renal function (Lumeij, 1987). Peebles *et al*. (2004) reported increased serum triglycerides (TGAs) and cholesterol levels in water-restricted Single Comb White Leghorn hens and attributed it to increased fat mobilization for metabolic water production. In addition, tissue and organ damage because of water restriction in broilers was associated with elevated enzyme activities of alkaline phosphatase, alanine transaminase (ALT) and aspartate transaminase (Fasina *et al*., 1999).

The Ovambo (OVB) and Naked Neck (NNK) are important chicken ecotypes kept for various functions and purposes in communal areas of Southern Africa. The Ovambo chicken is a multi-coloured, aggressive, light to medium breed that reaches sexual maturity at 143 days of age with males and females weighing about 2.16 kg and 1.54 kg, respectively (Van Marle-Köster and Nel, 2000). The NNK is also a multi-coloured, light-weight, dual-purpose breed kept for meat and eggs for home consumption. The birds reach sexual maturity at 155 days of age, with males weighing about 1.95 kg and females 1.4 kg (Van Marle-Köster and Nel, 2000). Naked Neck chickens exhibit superior heat tolerance than OVB chickens, due to possession of a major gene that causes reduced plumage cover (Cahaner *et al*., 1993). Reduced plumage cover facilitates rapid heat dissipation and is regarded as an effective adaptation to minimize heat stress in chickens (Deeb *et al.*, 2001). Preliminary investigations have suggested that the bulk of the chickens in communal production systems receive between 20 and 70 % of their water requirements (Rwanedzi, 2010; Chapter 3). In Chapter 5, NNK chickens performed better with regard to weight gain, feed intake, feed conversion ratio and average daily water intake than OVB chickens at the most severe water restriction level. Haematological and biochemical responses of these indigenous chicken genotypes to dehydration induced by water restriction are, however, not known. Information on these responses is useful, not only in assessing bird welfare and developing management strategies that minimize stress, but in identifying chicken genetic resources that should be prioritised for *in situ* conservation in drought-prone communal production systems.

The objective of the study was to compare the haematological and biochemical responses of NNK and OVB chickens to graded levels of water restriction. It was hypothesised that there were no differences in haematological and biochemical responses to water restriction between OVB and NNK chickens.

6.2. Materials and Methods

6.2.1. Study site and ethical aspects of the study

The detailed description of the study site, average ambient temperatures and relative humidity during the experimental period, and a statement of ethics are given in section 5.2.1.

6.2.2. Birds, water restriction levels and management

The details on the number of birds used per strain, water restriction levels and management of the birds are provided in section 5.2.2.

6.2.3. Blood collection

On the last day of a 60-day experimental period, two sets of blood samples were taken from four of six randomly selected birds of each strain in each treatment via brachial venipuncture using 5ml syringes and 22 gauge needles. One set of the blood samples (3ml) was collected into purple top 5ml ethylene diaminetetra-acetic acid (EDTA) coated vacutainer tubes for determination of haematological parameters. The other set of blood samples (3ml) was collected into 5 ml red top anti-coagulant free vacutainer tubes, allowed to coagulate at room temperature and centrifuged for fifteen minutes at 1465 x g using a Hettich Zentrifugen (MIKRO 200) centrifuge. The supernatant sera were then stored in a freezer at -20°C for subsequent biochemical analysis.

6.2.4. Haematological parameters

Packed cell volume was measured by the microhaematocrit method. Blood in EDTA coated tubes was mixed by gentle rocking and transferred to a microhaematocrit capillary tube. One end of the tube was sealed and then centrifuged for 3 min (Autocrit Ultra 3 Microhaematocrit Centrifuge, Becton, Dickinson and Co. New Jersey, USA). The PCV was estimated usinga Haematocrit reader. Erythrocyte (RBC) and leucocyte counts (WBC) were measured by an automatic cell counter at the Onderspoort Veterinary Institute, Pretoria, South Africa within 24 hours of blood collection. Mean corpuscular volume (MCV) was calculated from RBC and PCV values, as described by Jain (1986). The following formula was used:

MCV, expressed in femtoliters (fL) = 10 x PCV (%) / RBC count (millions/µl).

6.2.5. Biochemical parameters

Serum lipid profile, total protein and albumin, serum uric acid and creatinine, liver-function enzymes: aspartate transaminase and alanine transaminase, and alkaline phosphate were measured using an automated chemistry analyzer (LabmaxPlenno, Labtest, Lagoa-Santa, Brazil) at the School of Biochemistry, Genetics and Microbiology, University of KwaZulu-Natal (Westville Campus, Durban, South Africa). All reagents were purchased from Capital Lab Supplies, Durban, South Africa and were of analytical grade. Plasma globulin was calculated as the difference between the plasma total protein and plasma albumin. Low density lipoprotein cholesterol (LDLC) was calculated from total cholesterol (TC), triglyceride (TG), and high-density lipoprotein cholesterol (HDLC) according to Friedewald *et al*. (1972) as:

LDLC (mg/dl) = TC-HDLC - TG/5.

6.2.6. Statistical analysis

Haematological and serum biochemical parameters were analyzed using the General Linear Model procedure of SAS software SAS (2003) under a 2 × 3 factorial arrangement of treatments (strain and water restriction level). The model used was:

$$Y_{ijk} = \mu + B_i + T_j + (B\times T)_{ij} + \varepsilon_{ijk}$$

where:

Y_{ijk} = response variable

μ = overall mean

B_i = bird strain effect of the j^{th} strain, with j = NNK and OVB;

T_j = water restriction effect of i^{th} restriction level, with i =*ad libitum*, 70 and 40% of *ad libitum*;

$(B\times T)_{ij}$ = interaction of the i^{th} strain of bird and the j^{th} level of water restriction;

ε_{ijk} = random error term assumed to be normally and independently distributed with mean 0 and variance equal to σ^2.

Differences among means were evaluated using the PDIFF procedure of SAS (2003). Statistical significance was considered at the 5% level of probability.

6.3. Results

6.3.1. Haematological parameters

There was a significant interaction between strain and water restriction on packed cell volume, erythrocyte and leucocyte counts, except for mean corpuscular volume (Table 6.1). The NNK had a higher packed cell volume than OVB chickens at *ad libitum* water consumption, but packed cell volume values of OVB was similar at 70 and 40 % of *ad libitum* water access. The packed cell volume of NNK birds fed 70 and 40 % of *ad libitum* were about 2 % and 11 % higher than those on *ad libitum* water, respectively, while those of OVB chickens were 11 % and 25 % higher than of birds on *ad libitum* water intake. The erythrocyte counts of NNK and OVB chickens on 40 % of *ad libitum* water was 9 % and 11 % higher than the *ad libitum* groups but not significantly different from those on 70 % of *ad libitum* water consumption. Mean corpuscular volume did not differ between OVB and NNK chickens, but, was significantly affected by water restriction such that mean corpuscular volume averaged over strains was higher in birds fed 40% of *ad libitum* intake (121.3 ± 4.07 fL) than 70 % of *ad libitum* (105.8 ±

4.06 fL) and *ad libitum* water intake (106.8 ± 4.07 fL). Naked Neck chickens had a high and low leucocyte counts at 40 and 70 % of *ad libitum* water restriction levels, respectively, than OVB chickens at the same restriction levels.

6.3.2. Serum biochemical parameters

A significant interaction was observed between strain and water restriction level on serum uric acid concentration (Table 6.2). Serum uric acid concentration was higher in NNK than OVB chickens only at *ad libitum* and 70 % of *ad libitum* water consumption. Creatinine concentration was higher in OVB (0.5 ± 0.04 mg/dl) than NNK (0.2 ± 0.04 mg/dl) chickens ($P < 0.05$). No significant effects of water restriction levels or interaction between strain and water restriction level were observed for this parameter (Table 6.2).

Total protein and globulin content were significantly influenced by water restriction level (Table 6.2). Total protein content was higher in birds on restricted water intake than those with free access to water ($P < 0.05$), while globulin content was higher at the most severe water restriction than at 70 % of *ad libitum* and *ad libitum* water intake ($P < 0.05$). No significant effect of strain or interaction between strain and water restriction level was observed on both parameters. Albumin concentration was not affected by strain and water restriction level.

Table 6.1: Effect of water restriction level on haematological parameters of Naked Neck and Ovambo chickens

Parameter	Strain						SEM	Effects		
	Naked neck			Ovambo				Strain	WRL	Strain × WRL
	W-40	W-70	W-100	W-40	W-70	W-100		P – value		
Birds (n)	6	6	6	6	6	6				
Packed cell volume (%)	34.3[b]	30.3[c]	31.0[c]	35.5[a]	31.5[c]	28.3[cd]	0.0082	ns	*	*
Erythrocyte count ($\times 10e^{12}/l$)	3.1[a]	2.8[b]	2.8[b]	3.0[a]	2.8[b]	2.8[b]	0.10	ns	*	*
MCV (fL)	111.1	107.6	109.2	131.5	104.0	104.4	5.75	ns	*	ns
Leucocyte count ($\times 10e^{9}/l$)	13.6[a]	8.2[c]	6.7[d]	10.1[b]	9.2[b]	8.4[bc]	0.38	ns	*	*

WRL= water restriction level;MCV= Mean corpuscular volume;

Values of each parameter in a row with different superscript differ significantly ($P < 0.05$); W-40: 40% of *ad libitum* water consumption; W-70: 70% of *ad libitum* water consumption; W-100: *ad libitum* water consumption; SEM: standard error of mean; ns: not significant at $P < 0.05$; * $P < 0.05$.

Water restriction level had a significant influence on triglycerides and low density lipoprotein concentration (Table 6.2). Triglyceride concentration increased with each increment in water restriction (Table 6.2). Similarly, low density lipoprotein cholesterol increased with increasing water restriction, but, there were no differences between birds on 70 and 40 % of *ad libitum* intake ($P > 0.05$; Table 6.2). Water restriction level had no effect on serum high density lipoprotein cholesterol ($P > 0.05$). A significant interaction was noted between strain and water restriction level for total cholesterol ($P < 0.05$). Total cholesterol increased with increasing water restriction from *ad libitum* to 40 % of *ad libitum* in OVB chickens, but such a response was seen only up 70 % of *ad libitum* water restriction in NNK (Table 6.2). Strain and water restriction had no effect on HDLC and there was no interaction between strain and water restriction level.

There was no significant difference ($P < 0.05$) between the strains for aspartate transaminase and alkaline phosphatase (ALP) activity (Table 6.2). However, ALT activity showed significant differences between strains ($P < 0.05$). ALT concentrations were significantly higher in OVB than NNK chickens (Table 6.2). Conversely, the activities of AST and ALP showed significant differences among water restriction levels (Table 6.2). AST concentrations were higher ($P < 0.05$) in birds fed 70 % of *ad libitum* compared with the rest of the other water restriction levels, which were similar. In contrast, the lowest ALP concentrations were recorded in birds fed 70 % of *ad li bitum*, compared with the rest of the water restriction levels ($P < 0.05$).

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Table 6.2: Effect of water restriction level on serum biochemical parameters of Naked Neck and Ovambo chickens

Parameter	Strain						SEM	Effects		
	Naked Neck			Ovambo				Strain	WRL	Strain × WRL
	W-40	W-70	W-100	W-40	W-70	W-100		P - value		
Uric acid (mg/dl)	7.8^{b}	6.1^{c}	4.8d^{e}	8.7^{a}	5.2^{d}	3.1^{e}	0.23	*	*	*
Creatinine(mg/dl)	0.3	0.2	0.05	0.6	0.8	0.1	0.06	*	ns	ns
Total protein (mg/dl)	4.3^{b}	4.2^{b}	3.4^{b}	5.3^{a}	4.1^{b}	3.8^{b}	0.30	ns	*	ns
Albumin (mg/dl)	2.3	2.3	2.0	2.1	2.0	2.0	0.17	ns	ns	ns
Globulin (mg/dl)	2.1^{b}	2.0^{b}	1.5^{b}	3.2^{a}	1.8^{b}	2.4^{b}	0.20	*	*	ns
Triglycerides (mg/dl)	72.0^{a}	55.9^{b}	48.5^{bc}	78.7^{a}	54.8^{b}	40.8^{c}	2.83	ns	*	ns
Total Cholesterol (mg/dl)	144.5^{ab}	149.5^{ab}	127.7^{b}	159.8^{a}	140.8^{b}	123.9^{b}	4.32	ns	*	*
HDLC (mg/dl)	55.2	56.7	52.3	48.9	47.6	46.2	6.23	ns	ns	ns
LDLC (mg/dl)	77.8^{bc}	85.4^{b}	67.1^{c}	91.7^{a}	87.3^{a}	70.2^{bc}	5.95	ns	*	ns
AST(U/l)	233.2^{b}	268.9^{ab}	228.1^{b}	247.2^{ab}	280.5^{a}	221.1^{b}	17.35	ns	ns	ns
ALT(U/l)	6.3^{b}	7.1^{a}	4.6^{b}	11.0^{ab}	19.0^{a}	7.2^{b}	3.34	ns	ns	ns
ALP(U/l)	752.5^{a}	393.9^{b}	676.0^{ab}	625.7^{ab}	473.0^{b}	590.1^{ab}	71.08	ns	ns	ns

WRL = water restriction level; HDLC = High density lipoprotein cholesterol; LDLC = Low density lipoprotein cholesterol; AST = aspartate transaminase; ALT = alanine transaminase; ALP = alkaline phosphatase.

Values of each parameter in a row with different superscript differ significantly ($P < 0.05$); W-40: 40% of *ad libitum* water consumption; W-70: 70% of *ad libitum* water consumption; W-100: *ad libitum* water consumption; SEM: standard error of mean; ns: not significant at $P < 0.05$;* $P < 0.05$;

6.4. Discussion

Analysis of normal haematocrit values of indigenous chickens is fundamental in diagnosing the various pathological and metabolic disorders. The observed increase in packed cell volume with severity of water restriction suggests a depletion of plasma water that, consequently, reduced plasma volume and possible haemoconcentration (Woerpel *et al*., 1984). The observation that the packed cell volume of birds exposed to 70% of *ad libitum* was similar to those of birds with free access to water suggests that normal plasma volume was maintained. Similar findings were reported for White Leghorn pullets which were shown to maintain a constant plasma volume during dehydration, probably by drawing water from extravascular spaces to buffer any losses of vascular water (Arad *et al*., 1989).

The observation that erythrocyte counts for NNK and OVB chickens increased with increasing severity of water restriction is likely a consequence of haemoconcentration and agrees with Maxwell *et al*. (1990), who reported increases in erythrocyte concentration in water-restricted broilers. In contrast, Pires *et al*. (2007) and Iheukwumere and Herbert, (2003) observed reduction in erythrocyte counts of water-restricted broilers, indicating that the intensity of the erythrocytic response elicited in a bird depends, to a large extent, on the breed and degree of water restriction to which a bird is subjected. The erythrocyte counts of NNK and OVB birds with free water access and those on restricted water intake were, however, lower than the 3.36 to 4.46 ($\times 10e^{12}$/l) range reported for Nigerian Naked Neck and 3.72 to 4.12($\times 10e^{12}$/l) for normal feathered ecotypes (Peters *et al*., 2002). Erythrocyte counts aid in the characterization of anaemia and serve as useful indices of bone marrow capacity to produce red blood cells (Awodi *et al*., 2005). Thus, the observed low erythrocyte counts recorded for birds in the different water restriction levels indicate a likely high susceptibility to anaemia-related disease conditions. This is corroborated by the fact that chickens in the current study had higher mean corpuscular volume than the range of 88-94fL reported for Nigerian native chickens, which could be attributed to release of immature red blood cells into the blood system (Peters *et al*., 2002).

The finding that leukocyte counts were elevated in severely restricted birds agrees with Maxwell *et al*. (1992), who showed that immune reactions of birds change with the intensity and type of stress to which they are exposed. Nutritional and environmental stresses induce leucocytosis and lymphopenia (Maxwell, 1993).The leucocyte counts of NNK and OVB chickens on *ad libitum* water intake were higher than the range of values of 5.56 and 5.66 ($\times 10e^9$/l) in normal feathered and Naked Neck chickens in Nigeria, respectively (Peters *et al*., 2002). High leucocyte counts might be an adaptation of NNK and OVB chickens to chronic stress and diseases (Campbell and Coles, 1986). Shaniko (2003) reported that leucocytes in avian species serve a phagocytic role and are responsible for defense of the body against infections, and, as such, are routinely used as indicators of stress responses and sensitive bio-makers of immune functions.

Differences in uric acid concentration between OVB and NNK chickens at the most severe water restriction level may be attributed to possible variation in the rate of glomerular filtration rate (GFR) between the two breeds. According to Ahmed and Alamer (2011), the increase in blood uric acid in water-restricted birds is largely a result of greater water uptake to the kidneys and decreased blood flow towards the urinary apparatus that causes a reduction of urine and increase of blood urea concentration. Water restriction to 40% of *ad libitum* in OVB may have elicited more water conservation mechanisms, which resulted in reduced excretory moisture in relation to NNK chickens. In this context, higher uric acid levels in OVB than NNK chickens at the most severe water restriction imply that the former are more adapted to water-scarce environments. The higher uric acid concentration in OVB than NNK chickens can also be explained by changes in urea excretion and reabsorption as suggested by Skadhauge (1981) who reported a substantial reabsorption of filtered urea, facilitated by low urine flow, leading to a rise in the serum level of this metabolite.

The elevated creatinine concentrations in water-restricted birds relative to birds on *ad libitum* water in both strains could be attributed to muscle wasting and increased creatinine phosphate catabolism during periods of water insufficiency (Bell *et al*., 1972). The observation that OVB chickens had higher creatinine concentration than NNK at the most severe water restriction level can be attributed to greater protein catabolism for metabolic water production as an adaptive attribute during periods of water insufficiency. Creatinine content in blood has been reported to vary with the quantity and quality of protein supplied in the diet (Iyayi *et al*., 1998). This reason, however, cannot be advanced for the observed variation, where all birds were exposed to the same diet and common environmental conditions. Therefore, the observed variation could only be due to strain differences and water restriction level.

Total protein, albumin and globulin concentrations are often used to assess the hydration status of birds, with high levels indicating dehydration, due to concentration in a reduced volume of plasma (Cork and Halliwell, 2002). Serum total protein and globulin concentrations were significantly elevated in water-restricted birds. The increase in serum total protein values may also have been caused by an increased protein breakdown to maintain physiological functions during periods of water insufficiency (Katanbaf *et al*., 1988). The lack of increase in albumin concentrations in water restricted birds could be attributed to albumin depletion due to reduced feed intake (Iheukwumere and Herbert, 2003).

Similarly, Arad *et al*. (1985) found that there were no alterations in albumin in Sinai and White Leghorn hens with 48 h of water deprivation under severe hot conditions.

Increase in triglycerides and total cholesterol levels with increasing water restriction can be attributed to increased fat mobilization for metabolic water production (Ahmed and Alamer, 2011). The observation that OVB had higher total cholesterol levels at the most severe water restriction than NNK reflects a greater capacity of the former to mobilize body fat reserves to obtain metabolic water. The lower total cholesterol levels of NNK relative to OVB chickens under severe water restriction could be a reflection of a more frugal use of body water and hence superior adaption to water scarcity than the latter. The observed increase in low density lipoprotein cholesterol with increased severity of water restriction, irrespective of strain, is undesirable and puts birds at greater risk of heart attack due to arteries narrowed by atherosclerosis (Peebles *et al*., 2004). Excess low density lipoprotein cholesterol forms plaques on the inner walls of arteries which slow down blood flow to the heart leading to anthrosclerosis or hardening of arteries.

The observation that water restriction levels of 40% of *ad libitum* and *ad libitum* resulted in equal concentrations of aspartate transaminase is difficult to explain. A similar trend was observed for ALP activity. Aspartate transaminase concentrations have been shown to increase with increasing severity of water restriction in broilers indicating possible liver, heart or skeletal muscle damage (Fasina *et al*., 1999). The observation that water restriction did not alter ALT and alkaline phosphatase concentrations shows that the integrity of the liver was preserved, since elevated values for these parameters are associated with cellular necrosis of this organ. Similar findings were reported by Iheukwumere and Herbert (2003) who found no effect of water restriction on the activities of these enzymes in severely water-restricted Anak broilers.

6.5. Conclusions

The elevation of PCV, erythrocyte and leucocyte counts in NNK chickens only occurred at 40% of *ad libitum* intake, indicating a greater capacity of the breed to withstandmoderate water restriction than OVB. The high UA concentration in OVB than NNK at the most severe water restriction might suggest a decline in excretion rate of urea. Lower serum CREAT levels in NNK than OVB at the most severe water restriction indicates a reduced mobilization of muscle CREAT phosphate for metabolic water production, which suggests an enhanced capacity to withstand severe water restriction than the latter. Irrespective of strain, water restriction led to haemoconcentration. The high TC concentration in OVB suggests a greater capacity to mobilize body fat reserves to obtain metabolic water than NNK chickens, however, the low TC levels of NNK chickens at the most severe water restriction level could be a reflection of a more frugal use of body water, and hence superior adaption to water scarcity compared with OVB chickens. The high low-density lipoprotein levels at the most severe water restriction level, in both strains is undesirable and puts birds at greater risk of atherosclerosis. ALT activity indicated that liver function was not affected in both breeds. It is likely that NNK chickens could be more reliant on metabolic water to maintain homeostasis than OVB birds.The study showed that water restriction evokes haematological and serum biochemical responses consistent with hydric stress. The effects of these changes on the ultimate physicochemical properties and fatty acid composition of meat from water restricted indigenous chickens requires further investigation.

CHAPTER 7: Physicochemical properties of breast meat from water-restricted Naked-Neck and Ovambo chickens

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Abstract

An experiment was conducted to determine the effect of water restriction on the physical and chemical properties of breast meat of Naked Neck (NNK) and Ovambo (OVB) unsexed pullets. A total of 54 16-week old birds of each strain were randomly distributed into 18 floor pens (3 replicate pens/strain; 6 birds/pen) and were given either *ad libitum*, 70 % of *ad libitum* and 40 % of *ad libitum* water intake in a 2 × 3 factorial arrangement of treatments.Water intake levels of 40 % of *ad libitum* produced meat with significantly lower cooking loss, and higher ($P < 0.05$) redness (a*) values in NNK chickens compared with OVB chickens ($P < 0.05$). Water intake level had no effect on lightness (L*) and yellowness (b*) values, shear force, moisture and protein contents in both strains ($P > 0.05$). The fat content of NNK meat was 41 % lower ($P < 0.05$) than that of OVB meat at 70 % of *ad libitum*, but 31 % higher at 40 % of *ad libitum* water intake. The ash content was significantly elevated in birds on 70 % of *ad libitum* ($P < 0.05$) compared to those on *ad libitum* and 40 % of *ad libitum* water intake, which had similar ($P > 0.05$) ash contents. Birds on 40% of *ad libitum* water intake had significantly higher ($P < 0.05$) proportions of octadecanoic acid (C18:0), *cis, cis*-9,12-octadecadienoic acid (C18:2*n*-6), *cis*-8,11,14,17-eicosatetraenoic acid (C20:4*n*-6), *cis*-7,10,13,16-docosatetraenoic acid (C22:4*n*-6), *cis*-4,7,10,13,16,19-docosahexaenoic acid (C22:6*n*-3), total polyunsaturated fatty acid (PUFA), total ῳ-3 PUFA and total ῳ-6 PUFA proportions, but lower ($P < 0.05$) *cis*-7-hexadecenoic (C16:1*c*7), *cis*-9-octadecenoic (C18:1c9), *cis*-11-octadecenoic acid (C18:1*c*11), *cis*-13-docosenoic acid (C22:1*c*13), total monounsaturated fatty acids than those on the 70 % of *ad libitum* and *ad libitum* water intake, respectively. The proportion of *trans*-9-octadenoic acid (C18:1*t*9) was higher in NNK chickens on 40 % of *ad libitum* water intake than OVB chickens ($P < 0.05$). It was concluded that water restriction at 40 % of *ad libitum* water intake resulted in favourable cooking loss values and meat redness (a*) values, ῳ-3 and 6 PUFA proportions and a high ῳ-*6*/ῳ-*3* ratio. The high fat content of NNK chickens at 40 % of *ad libitum* water intake compared to OVB chickens suggests a superior adaptation to hydric stress.

Keywords: chickens, fatty acids, hydric-stress, meat quality, welfare

7.1. Introduction

In recent years, consumer preference for natural or organic meat produced with no or minimal use of chemicals and livestock supply chains with a low water footprint is growing rapidly in many parts of world (Fanatico *et al*., 2005; Hoekstra, 2012). The water footprint concept, an indicator used to assess how water-intensive an animal product is and to what extent it relates to water depletion, water pollution, or both, is rapidly gaining popularity in some societies and will likely influence consumers' purchasing patterns in future (Hoekstra, 2012; Doreau *et al*., 2012). This shift in consumer preference has increased the relevance of local unimproved chickens because of their superior meat flavour and texture, perceived health benefits and relatively low water foot print compared to exotic chickens (Dyubele *et al*., 2010; Hoekstra, 2012).

In South Africa, breeds, including the Naked Neck, Ovambo and Venda dominate the gene pool (Mtileni *et al*., 2009). Almost 80% of rural households own these chickens, which serve as an immediate source of meat and income when money is needed for urgent family needs (Mtileni *et al*., 2013). The chickens also play important social, cultural and symbolic roles that transcend their practical use as food or commodities. Birds are often given away as gifts, sacrificed to ancestors and divinities, or consumed as part of ritual and secular celebrations, thereby strengthening important social bonds (Aklilu *et al.*, 2007; Mapiye *et al*., 2008). Despite their importance, the chickens are exposed to various sub-optimal husbandry conditions and stress-provoking situations that can adversely affect their productivity and the quality of products. Dry-season water and feed shortages are major problems in the production of free-range chickens in most rural areas and as such the chickens are prone to dehydration (Mata *et al*., 2012). The problem of dehydration is aggravated by the erratic supply of unpalatable water, adulterated by naturally occurring anti-quality factors or anthropogenic pollutants (Beede, 2012). Preliminary investigations have suggested that the bulk of the chickens in communal production systems receive between 20 and 70% of their *ad libitum*water requirements (Rwanedzi, 2010; Chapter 3). It is, therefore, likely that access to adequate, fresh, clean drinking water could be one of the major causes of the low productivity of these chickens.

Water restriction reduces feed intake and growth, impairs conversion of dietary nutrients into muscle and alters the metabolism of carbohydrates and fats in broilers (Chapter 5; Warriss *et al.*, 1988; Viola *et al*., 2009).Water restriction also had a significant negative effect on several haematological and serum biochemical indicators of hydric stress (Chapter 6). These changes, in turn, are responsible for differences in the ultimate physicochemical and sensory properties of meat such as pH, water holding capacity, colour, tenderness, fat content and composition, juiciness, flavour and palatability (Debut *et al*., 2003, Barbut *et al*., 2008; Dadgar *et al*., 2012).However, the impact of water restriction on the physical and chemical properties of meat from local unimproved strains of chickens in South Africa has not been evaluated. Understanding the effects of water restriction on meat quality characteristics of these chickens is not only crucial in identifying consumer preferences of strains that can be used in drought-prone areas, but also in promoting this organic chicken meat in future. Drought-resilient birds are likely to have a low water footprint (higher water efficiency) which may have a positive impact on marketing and trade of this meat.

The objective of this trial was to study the effect of water restriction on the physical and chemical properties of breast meat from NNK and OVB chickens. The hypothesis tested was that water restriction negatively influences the physicochemical properties of meat from NNK and OVB chickens.

7.2. Materials and Methods

7.2.1. Study site

The detailed description of the study site, average ambient temperatures and relative humidity during the experimental period are given in section 5.2.1.

7.2.2. Ethical aspects of the study

Details on the care and use of chicks were compliant with internationally accepted standards for welfare and ethics in animals as described in section 5.2.1.

7.2.3. Birds, water restriction levels and management

The details on the number of birds used per strain, water restriction levels and management of the birds are provided in section 5.2.2.

7.2.4. Slaughtering of birds

Samples of 12 birds from each treatment were randomly selected for physicochemical evaluation. The birds were slaughtered in the early morning (0800 h). After bleeding, the carcasses were scalded in water at temperatures ranging between 70 and 90 °C. Feathers were plucked manually. The carcasses were then eviscerated and weighed using a digital electronic scale (Jadever JPS-1050, Micro Precision Calibration Inc, USA). The breasts were cut off the carcasses, deboned and stored in food-grade high density polyethylene bags at 4 °C for 24 h.

7.2.5. Meat quality measurements

7.2.5.1. Determination of meat colour

The muscle colour of fresh breast meat was measured using a Hunterlab Color Flex® EZ spectrophotometer (Model 45/0°, Hunter Associates Laboratory, USA). The spectrophotometer was standardised against a white calibration tile. A portion of the breast muscle measuring 5.5 cm in diameter and with a thickness of 1 cm from each sample was used. The following Hunter colour scales (CIE, 1976) were measured: lightness (L*), redness (a*) and yellowness (b*) from three locations on the cut surface of individual breast samples.

7.2.5.2 Water-holding capacity and shear force determination

After chilling the carcass for 24 h at 4^0C, breast muscles were collected to measure meat quality characteristics. Water-holding capacity (WHC) was determined by placing meat samples in thin-walled plastic bags and cooking in a continuously boiling water-bath for 50 minutes, with the bag opening extending above the water surface (Petracci and Baéza, 2009).

The force (N), energy (N/mm) and extension (mm) of boiled breast muscle was determined in five rectangular strips ($1cm^2$ × 3cm long) per sample using a Warner-Bratzler shear device attached to an Instron universal testing machine (Model 5565, Instron Ltd., Buckinghamshire, UK). A cross-head speed of 200 mm/min and a 5 kN load cell calibrated to read over a range of 0-100 N were applied.

7.2.5.3. Chemical composition and fatty acid profile

Breast meat samples were freeze-dried for a week and then ground through a 2 mm screen. The dry matter, and crude protein (N × 6.25), mineral and fat contents of the breasts were determined according to the standard methods of the Association of Official Analytical Chemists (AOAC, 1990). The moisture content was determined as the difference between weight of fresh sample and the freeze-dried sample. All analyses were done in triplicate.

Lipids were extracted from the breast muscle using a mixture of chloroform–methanol (2:1, v/v) according to Folch *et al*. (1957). Chloroform extracts were dried, dissolved in toluene and the lipids were methylated with 5% methanolic HCl at 80°C for 1 h (Kramer *et al*., 1998). Samples were cooled, hexane was added and then 0.88% KCl was added to expel hexane containing the fatty acid methyl esters (FAME). Hexane extracts were dried over anhydrous sodium sulphate and stored at -20 °C until analysed. Internal standard, 19:0 methyl ester/ml toluene was added prior to addition of methylating reagents. Fatty acid methyl esters were purified by thin layer chromatography using hexane/diethyl ether/acetic acid (90:10:1, by vol) before analysis using CP-3800 gas chromatography (Varian Inc., Walnut Creek, CA, USA) equipped with a flame ionization detector and SP-2340 fused-silica capillary column (30m × 0.25mm ×0.2 µm film thickness; Supelco, Bellefonte, PA,USA). The system was operated under constant pressure (15 psi) using hydrogen as the carrier gas and a 20:1 split-ratio. The injector and detector were held at 250 °C and the FAME were quantified using a flame ionization detector. Samples were injected (1 µl, 0.5 µg/µl) and the column temperature was held initially at 50°C for 30 s, increased to 170°C at 25°C /min, held for 3 min, increased to 180°C at 2°C/min, then increased to 230°C at 10°C /min (Dugan *et al* 2007). Chromatograms were integrated using Varian Star Chromatography Workstation software. Peaks were verified and response factors calculated for internal standard based calculations using GLC603 reference standard from NUCHEK-PREP Inc. (Elysian, MN, USA). Fatty acid concentrations were reported as a percentage of total FAME identified.

7.2.6. Statistical analyses

The effect of strain and water intake level and their interaction on meat quality attributes and fatty acid profiles were analysed using GLM procedure of SAS (2003). The following model was used:

$$Y_{ijk} = \mu + B_i + T_j + (B \times T)_{ij} + \varepsilon_{ijk}$$

where Y_{ij}= meat colour, WHC, shear force, proximate composition, fatty acid profile;

μ = overall mean

B_i = bird strain effect of the i^{th} strain, with i = Naked Neck and Ovambo;

T_j = water restriction effect of j^{th}water intake level, with j = *ad libitum*, 70 and 40% of *ad libitum*;

$(B\times T)_{ij}$ = interaction of the i^{th} strain of bird and the j^{th} level of water intake;

ε_{ijk} = random error term assumed to be normally and independently distributed with mean 0 and variance equal to δ^2.

Least square means were generated and separated using the LSMEANS and PDIFF options, respectively SAS (2003).

7.3. Results

7.3.1. Physical properties

There was a significant interaction between strain and water intake level on the cooking loss. Cooking losses of OVB chickens fed water *ad libitum* were 3% higher than the rest of the strains and water intake level treatment combinations (P<0.05), which had similar cooking losses (Table 7.1). No significant differences in the L* and b* values were observed between strains and between the water intake levels (P > 0.05). However, there was a significant interaction between strain and water intake level for redness (a*) values (P < 0.05). Breast meat of NNK chickens had higher redness values at 40% of *ad libitum* water intake but lower lightness (L*) and yellowness (b*) values at 70% of *ad libitum* water intake than OVB chickens. No significant differences in the shear force parameters (force, extension and energy) were observed between the strains and water intake levels (P > 0.05; Table 7.1).

7.3.2. Proximate composition

The moisture and protein contents of the breast muscles did not differ between strains and between water intake levels (P > 0.05; Table 7.1). There was a significant interaction between strain and water intake level on fat content (P < 0.05). The fat content of NNK meat was similar to OVB meat in birds on *ad libitum* water intake but 41% lower and 31% higher than those of OVB meat at 70 and 40% of *ad libitum* water consumption, respectively (P<0.05). Ash content was significantly higher in OVB (5.3 ± 0.11 g/100g DM) than in NNK (4.8 ± 0.13 g/100g DM) meat (P < 0.05). The ash content was also significantly elevated in birds given water at 70% of *ad libitum* (5.5 ± 0.16 g/100g DM) compared to those on *ad libitum* (5.0 ± 0.16 g/100g DM) and 40% of *ad libitum* (4.6 ± 0.16 g/100g DM) water intake, which had similar ash contents.

7.3.3. Fatty acid composition

There was no interaction between strain and water intake level on most fatty acids (P > 0.05), except for *trans*-9-octadenoic acid (C18: 1*t*9).The proportion of *trans*-9-octadenoic acid in meat showed little variation between the strain and water intake treatment combinations, except at the 40% of *ad libitum* water intake when it was significantly higher in NNK chickens than OVB chickens ($P < 0.05$; Table 7.2). Strain had no effect on all the fatty acids analysed ($P > 0.05$) but water intake level had a significant effect on several of fatty acids (Table 7.3). Meat from birds on 40% of *ad libitum* water intake had higher ($P < 0.05$) octadecanoic acid (C18:0), *cis*-9,12-octadecadienoic acid (C18:2ω-6), *cis*-7,10,13,16-docosatetraeonic acid (C20:4ω-6), *cis*-7,10,13,16-docosatetraenoic acid (C22:4*ω*-6) and *cis*-4,7,10,13,16,19-docosahexaenoic acid (C22:6*ω*-3) but lower *cis*-7-hexadecenoic acid (C16:1*c*7), *cis*-9-octadecenoic acid (C18:1*c*9), *cis*-11-octadecenoic acid (C18:1*c*11), *cis*-13-docosenoic acid (C22:1*c*13) than those on the 70% of *ad libitum* and *ad libitum* water intakes, respectively (Table 7.3).

Birds on the 70% of *ad libitum* and *ad libitum* water intakes had higher proportions of total monounsaturated fatty acids (MUFA) than birds on the 40% of *ad libitum* water intake ($P<0.05$) In contrast, the total polyunsaturated fatty acid (PUFA), ω-3 PUFA and omega-6 PUFA proportions were significantly higher in meat from birds on the 40% of *ad libitum* water intake than those of birds on 70% of *ad libitum* and *ad libitum* water intakes. Water intake level had no effect ($P > 0.05$) on the total saturated fatty acids (SFA) content and ω-6/ω-3 ratio.

Table 7.1: Effects of graded levels of water intake on physical and chemical properties of Naked Neck and Ovambo breast meat

Meat quality characteristic	Naked Neck			Ovambo			SEM	P- value		
	40% of *ad libitum*	70% of *ad libitum*	*Ad libitum*	40% of *ad libitum*	70% of *ad libitum*	*Ad libitum*		Strain	Water intake	S × WI
Cooking loss (% of total)	32.1[ab]	31.8[ab]	30.1[b]	30.6[b]	30.4[b]	34.8[a]	1.21	0.56	0.52	0.03
Physical properties										
Meat colour										
L*	53.6	62.7	61.2	59.1	55.9	57.2	3.22	0.51	0.59	0.18
a*	9.60[a]	5.40[b]	6.30[b]	6.70[b]	8.60[a]	8.10[ab]	0.59	0.17	0.16	0.01
b*	13.1	12.0	12.7	15.6	13.1	13.7	0.86	0.06	0.16	0.70
Shear force value										
Force (N)	77.1	56.7	64.0	75.9	99.1	73.5	13.7	0.16	0.77	0.29
Extension (mm)	12.9	10.8	13.4	13.8	13.6	13.0	0.76	0.10	0.29	0.15
Energy (N/mm)	991	693	850	1055	1370	975	202	0.11	0.81	0.29
Chemical composition										
Moisture (g/100g Fresh material)	70.9	71.2	73.7	71.9	71.8	72.1	0.60	0.85	0.11	0.13
Crude protein (g/100g DM)	34.6	32.1	34.9	31.9	32.4	32.9	2.40	0.37	0.10	0.19
Crude fat (g/100g DM)	3.50[c]	4.50[c]	10.4[a]	2.40[d]	7.60[b]	10.6[a]	0.30	0.02	0.001	0.01
Ash (g/100g DM)	4.50	5.50	4.50	5.50	5.50	4.70	0.20	0.03	0.009	0.09

[a,b,c]Values in the same row with different superscripts are different at $P < 0.05$; SEM = standard error of the mean; S × WI = Strain × Water intake level interaction

Table 7.2: Interaction between strain and water restriction level on the fatty acid composition (% of total fatty acids) of breast meat from Naked Neck and Ovambo chickens

Fatty acid	Naked Neck			Ovambo			SEM	P-value		
	40% of *ad libitum*	70% of *ad libitum*	*Ad libitum*	40% of *ad libitum*	70% of *ad libitum*	*Ad libitum*		Strain	Water intake	S×WI
C14:0	0.60	0.56	0.77	0.55	0.67	0.64	0.13	0.84	0.59	0.71
C15:0	0.31	0.33	0.26	0.33	0.37	0.31	0.04	0.35	0.46	0.90
C16:0	27.1	28.3	28.6	24.5	29.6	28.0	1.23	0.55	0.07	0.37
C17:0	0.47	0.42	0.48	0.55	0.44	0.37	0.05	0.95	0.25	0.27
C18:0	25.4	21.6	18.9	23.3	22.0	19.4	1.75	0.79	0.03	0.72
C19:0	6.85	11.5	12.0	7.66	10.2	7.70	1.54	0.25	0.11	0.29
C20:0	0.52	0.35	0.39	0.38	0.45	0.38	0.06	0.76	0.53	0.22
C15:1*c*9	0.45	0.28	0.13	0.42	0.22	0.25	0.08	0.88	0.24	0.53
C16:1*c*7	0.47	0.60	0.87	0.45	0.47	0.51	0.08	0.35	0.02	0.18
C16:1*c*9	3.07	4.99	6.30	2.79	4.83	5.65	0.83	0.62	0.05	0.96
C18:1*c*9	24.4	21.4	22.3	25.7	20.3	23.4	2.15	0.90	0.01	0.99
C20:1*c*11	0.60	0.61	0.66	0.65	0.72	0.63	0.07	0.48	0.01	0.60
C22:1*c*13	1.08	0.61	0.38	1.12	0.52	0.64	0.18	0.65	0.89	0.66
C18:1*t*9	0.59^{a}	0.55^{ab}	0.51^{ab}	0.46^{b}	0.61^{a}	0.51^{ab}	0.03	0.42	0.01	0.04
C18:3*ω*-3	0.78	0.81	0.87	0.89	0.75	0.80	0.01	0.94	0.75	0.48
C22:5*ω*-3	0.67	0.37	0.19	0.84	0.28	0.39	0.14	0.37	0.02	0.48
C22:6 *ω*-3	1.17	0.49	0.33	1.14	0.22	0.51	0.30	0.84	0.01	0.69
C18:2*ω*-6	2.12	3.32	3.15	3.24	3.88	3.86	1.41	0.10	0.01	0.49
C20:2*ω*-6	0.42	0.33	0.25	0.63	0.33	0.42	0.11	0.11	0.09	0.55
C20:3*ω*-6	0.46	0.23	0.24	0.38	0.28	0.23	0.10	0.87	0.08	0.77
C20:4*ω*-6	2.99	2.32	2.46	8.66	2.87	4.75	1.62	0.66	0.01	0.44
SFA	61.3	63.1	61.4	57.3	63.7	56.8	1.85	0.51	0.24	0.25
Total MUFA	30.7	29.0	31.1	31.6	27.7	31.6	3.29	0.54	0.01	0.75
Total PUFA	8.61	7.87	7.49	16.8	8.61	11.0	2.44	0.20	0.02	0.37
Total ω-3	2.62	1.67	1.39	2.87	1.25	1.70	0.44	0.88	0.01	0.60
Total ω-6	5.99	6.20	6.10	12.9	7.36	9.26	2.71	0.17	0.01	0.38
ω-6/*ω*-3	2.29	3.71	4.39	4.49	5.88	5.44	2.93	0.58	0.12	0.42

[a,b,c]Values in the same row with different superscripts are different at $P < 0.05$.*c*= *cis*; *t* = *trans*; SFA = total saturated fatty acids; MUFA = mono unsaturated fatty acids; PUFA = poly unsaturated fatty acids; *ω*-3 = Omega- 3 fatty acids; *ω*-6 = Omega- 6 fatty acids; SEM = standard error of the mean; S × WI = Strain × Water intake level interaction

Table 7.3: Effect of graded levels of water intake on the fatty acid composition (% of total identified fatty acids) of breast meat from Naked Neck and Ovambo chickens

Fatty acid	Water restriction level			SEM	P-value
	40% of *ad libitum*	70% of *ad libitum*	*Ad libitum*		
C14:0	0.56	0.61	0.71	0.10	0.59
C15:0	0.32	0.35	0.29	0.03	0.46
C16:0	24.5	29.0	28.3	0.97	0.07
C17:0	0.51	0.43	0.42	0.04	0.25
C18:0	24.4[a]	21.8[ab]	19.2[b]	1.24	0.03
C19:0	7.26	8.84	9.85	1.22	0.11
C20:0	0.45	0.40	0.38	0.05	0.53
C15:1c9	0.44[a]	0.25[ab]	0.19[b]	0.06	0.24
C16:1*c*7	0.46[b]	0.54[ab]	0.69[a]	0.06	0.02
C16:1*c*9	2.93[b]	4.91[ab]	5.97[a]	0.66	0.05
C18:1*c*9	22.6[b]	24.9[a]	24.6[a]	1.70	0.01
C20:1*c*11	0.63	0.66	0.65	0.06	0.01
C22:1*c*13	1.10[b]	0.57[a]	0.51[a]	0.13	0.89
C18:1*t* 9	0.52	0.58	0.51	0.02	0.01
C18:3*ῳ*-3	0.84	0.78	0.83	0.06	0.75
C22:5*ῳ*-3	0.76[a]	0.32[b]	0.29[b]	0.08	0.02
C22:6 *ῳ*-3	1.16[a]	0.36[b]	0.42[b]	0.19	0.01
C18:2*ῳ*-6	7.38[a]	3.60[b]	5.09[b]	0.10	0.01
C20:2*ῳ*-6	0.52	0.33	0.34	0.07	0.09
C20:3*ῳ*-6	0.42	0.25	0.23	0.07	0.08
C20:4*ῳ*-6	2.33[a]	0.60[b]	0.61[b]	0.94	0.01
SFA	57.9	61.4	59.1	1.46	0.24
Total MUFA	28.7[b]	32.4[a]	33.1[a]	2.33	0.01
Total PUFA	9.21[a]	6.24[b]	7.81[b]	1.73	0.02
Total ῳ-3	2.76[a]	1.46[b]	1.54[b]	0.25	0.01
Total ῳ-6	10.7[a]	4.78[b]	6.27[b]	1.75	0.01
ῳ-6/*ῳ*-3	3.86	3.27	2.73	1.12	0.12

[a,b,c]Values in the same row with different superscripts are different at $P < 0.05$.

c = cis

t = trans

SFA = Total saturated fatty acids

MUFA = Monounsaturated fatty acids

PUFA = Polyunsaturated fatty acids

ῳ-3 = Omega- 3 fatty acids

ῳ-6 = Omega- 6 fatty acids

SEM = standard error of the mean

7.4. Discussion

The high WHC as measured by cooking loss in OVB chickens subjected to *ad libitum* water intake compared to NNK chickens can be attributed to the high fat content of the former. McKee (2002) reported that a part of the intramuscular fat is lost during cooking, and fat loss due to high temperature (85^0C) caused increasing fluid loss in meat (Joseph *et al*., 1997). However, Jaturasitha *et al.* (2008) found no significant difference in cooking loss among indigenous Thai chickens. In the present study, the lower cooking loss of water-restricted birds compared to birds on *ad libitum* water intake could be associated with a depleted fat content used for metabolic water production (Ahmed and Alamer,2011). Exposure to severe water restriction has been reported to deplete glycogen stores and causes a shift from anabolism to catabolism of carbohydrate and fat (Warriss *et al.*, 1988), which in turn reduces fat content and cooking losses, respectively. More research is however required to understand the exact mechanisms that affect the water-holding capacity of indigenous chicken meat under water stress conditions.

One of the most important aspects in terms of meat appearance is colour, which the consumer uses as an indicator of freshness and/or spoilage (Faustman and Cassens, 1990). The observation that NNK had a redder breast meat than OVB chickens at the most severe water restriction level could be attributed to slower growth rates occasioned by water restriction which could have resulted in higher contents of type I muscle fibres and lower contents of type II muscle fibres (Mlynek and Gulinski, 2007).

Warner–Bratzler shear force (WBSF) is widely used to evaluate the toughness of both myofibrillar and connective tissue (Sañudo *et al.*, 2004). Shear force values reported for slow-growing chickens vary considerably, depending on factors such as genotype, rearing and feeding system, age and handling prior to and at slaughter (Wattanachant, 2008). The lack of influence of graded levels of water intake on WBSF of NNK and OVB meat concurs with Fanatico *et al.* (2005) who reported no differences among slow growing broiler chicken genotypes. On the contrary, Jaturasitha *et al.* (2008) reported significantly higher WBSF values for normal feathered Thai chickens than NNK chickens raised under extensive indoor conditions. The observed WBSF values for birds on *ad libitum* water intake reported were within the range of values of 60 to 90 Newtons reported for South African indigenous chickens (Hanyani, 2012) but higher than the range of values of 41 to 51 Newtons reported for normal feathered and NNK chickens in Thailand (Wattanachant and Wattanachant, 2007; Chuaynukool *et al.*, 2007).

In this study, moisture and protein contents of breast meat from NNK and OVB chickens were not affected by water intake levels probably because the birds in the three water intake levels had similar characteristics i.e., the same strain, sex, and age and were fed the same diet. These results agree with Van Marle-Koster and Webb (2000), in which no strain differences were observed.

The low ash content in breast meat of birds fed water at 40% of *ad libitum* could be attributed to a decline in feed intake prompted by a need to preserve body water by reducing faecal water loss together with reducing body heat increment (Ahmed and Alamer, 2011). However, Castellini *et al*. (2002) reported an increase in meat ash content of free-ranging birds and attributed the increase to selected ingestion of soil particles from the ground.

The fat content of birds on *ad libitum* water intake contradict findings in earlier studies by Van Marle-Koster and Webb (2000) who found higher fat content in OVB than NNK breast meat of birds reared under extensive indoor conditions. The differences in the fat content could be attributed to differences in the age of the birds at slaughter, since the birds were fed similar diets and breasts without skin were used in both studies. Birds used in this study were eight weeks older than those used by Van Marle-Koster and Webb (2000). The fat contents of NNK and OVB breast meat were within the range of values of 0.37 to 7.20% reported for extensive outdoor conditions (Abeni and Bergoglio, 2001), but lower than the range of values reported for 16 week old indigenous chickens in Thailand (Jaturasita *et al*., 2008). The fat contents were, however, higher than the Thai Kai Dang indigenous chicken strain raised under extensive indoor conditions (Wattanachant *et al*, 2004; Chuaynukool *et al*., 2007). Further studies to determine the interaction between age and fat content of local strains are justified.

The finding that NNK birds on 40% of *ad libitum* water intake had a higher fat content than OVB could be due to differences in body weight at slaughter or strain-related differences in enzymes responsible for lipid synthesis or catabolism (Smith *et al*., 2009). The results could also be an indication that the former is less reliant on intramuscular fat for metabolic water production (Ahmed and Alamer, 2011). The results are consistent with studies by Decuypere *et al*. (1993) who found that the superior heat tolerance of NNK chickens was related to lower proportions of subcutaneous and intramuscular fat compared to their normal feathered counterparts. Supporting these results, Macleod and Hocking (1993) found that body fat content measured by intramuscular fat content, abdominal fat thickness, or plasma cholesterol and triglycerides level was negatively correlated with heat tolerance.

The fatty acid composition of meat is strongly related to the flavour (Miller, 1994) and the health of consumers (Hunton, 1995). The finding that hexadecanoic (C16:0), octadecanoic (C18:0) and *cis*-11-octadecenoic acids (C18:1*c*9) were amongst the most abundant fatty acids agree with Van Marle-Koster and Webb (2000).The observation that the meat from our study contained more saturated fatty acids than PUFA concurs with Wattanachant *et al.* (2004) who reported that Thai indigenous chicken muscle contained a higher percentage of SFA and a lower percentage of PUFA as compared with broiler chicken muscle. In contrast, Van Marle-Koster and Webb (2000) showed that NNK and OVB chickens had higher proportions of PUFA than SFA, and thus likely to be more preferable by humans from a health point of view. The difference between our results and those obtained by these authors could be attributed to a number of factors such as differences in fatty acid profiles and the content of the diet. The high proportions of saturated compared to unsaturated fatty acids obtained in this study are not desirable. Wood *et al.* (2003) reported that C14:0 and C16:0 fatty acids raise low-density (LDL) serum cholesterol, which is positively related to the occurrence of various cancers and heart diseases. The proportions of SFA obtained in this study were similar to the value of 62% reported for Southern Thai native chicken but higher than the values of 42% and 40% reported for NNK and OVB chickens in South Africa, respectively (Van Marle-Koster and Webb 2000).

The finding that the proportions of individual (C16:1 and C18:1) and total MUFA increased with water intake could be related to the levels of intramuscular fat content observed in the current study. In general, the proportions of MUFA increase in parallel with fat content due to the reduced activity of Δ9 desaturase, responsible for the synthesis of *c*-MUFA from SFA (Smith *et al*, 2009).

The higher proportion of omega-3 PUFA in birds on 40% of *ad libitum* intake compared to those on 70% of *ad libitum* and *ad libitum* water intakes, respectively could be attributed to high levels of docosapentaenoic acid (C22:5ω-3) and docosahexaenoic acid (C22:6*ω*-3).The proportions of PUFA in meat have been shown to increase with decreasing fat content due to less dilution by endogenously synthesised fatty acids (Raes *et al*., 2004; De Smet *et al*., 2004).The long chain omega-3 PUFA play an important role in the development of cerebral and retinal tissues and in the prevention of heart diseases and some cancers (Simopoulos, 2004; Alfaia *et al.*, 2009). As a result, nutritionists now recommend not only limiting fat intake but also consumption of large amounts of polyunsaturated fatty acids, especially those of the *ω*-3 rather than the *ω*-6 polyunsaturated fatty acids (Simopoulos, 2004). The omega-3 PUFA levels obtained in this study were within the range of values of 1.87 to 2.55% reported for Black boned and Thai indigenous chickens (Jaturasitha *et al*., 2008).

The finding that omega-6 PUFA levels were significantly elevated in birds on 40% of *ad libitum* water intake than those on 70% of *ad libitum* and *ad libitum* water intake, could also be related to intramuscular fat levels. The fat levels also possibly influenced the ω-6/*ω*-3 PUFA ratio, due to the difference of this ratio in polar, mainly phospholipids located in the cell membranes, and neutral lipids consisting mainly of triacylglycerols in the adipocytes that are located along the muscle fibres and in the interfascicular area (De Smet *et al*., 2004).Our findings suggest that water restriction may alter subcutaneous fatty acid composition by decreasing fat content or altering the associated neutral to polar lipids ratio

7.5. Conclusions

Water restriction up to 40% of *ad libitum* water intake resulted in favourable cooking loss values and meat redness (a*) values, and WBSF values that were comparable to those of birds on *ad libitum* water intake. In NNK chickens texture values were higher in the 40% treatment corresponding to the lower fat content. However, water intake levels of 40% of *ad libitum* adversely affected the fat content but resulted in meat with favourable proportions of omega-3 PUFA and a high ῳ-*6*/ῳ-*3* ratio. The high fat content of Naked Neck chickens at 40% of *ad libitum* water intake compared to Ovambo chickens suggests that they are less reliant on intramuscular fat for metabolic water production and thus a superior adaptation to hydric stress and lower water footprint. Future studies should explore the relationship between water restriction and the sensory quality attributes of the meat as perceived by consumers.

CHAPTER 8: Effects of pre-slaughter water restriction on the sensory characteristics of breast meat from Naked-Neck and Ovambo chickens

(Submitted to *Journal of Poultry Science Japan***)**

Abstract

The objective of the trial was to determine proximate composition and sensory attributes of breast meat from Naked Neck (NNK) and Ovambo (OVB) chickens subjected to pre-slaughter water restriction for 8 weeks. Twelve left breast fillets from 16-week old birds of each strain subjected to *ad libitum* (W-100), 70 % of *ad libitum* (W-70) and 40 % of *ad libitum* (W-40) water restriction levels were used. A consumer panel of 44 judges evaluated the sensory quality characteristics of the breasts on a 9-point hedonic scale. No significant differences were observed in dry matter and protein contents between the two strains and between the water restriction levels ($P > 0.05$) but fat and ash contents were significantly depressed in birds on the W-40 treatment ($P < 0.05$). Naked Neck had higher initial impression of juiciness scores than OVB chickens but only in birds on W-100 and W-70 treatment. Sensory scores for first bite, connective tissue and tenderness decreased with increasing severity of water restriction ($P < 0.05$). Aroma, flavour and atypical flavour were not affected by strain or water restriction level ($P > 0.05$). There were significant strain differences for sustained impression of juiciness and tenderness, with the highest scores occurring in NNK chickens. Stepwise regression analysis showed that aroma influenced the flavour of breast meat ($P < 0.05$). Fat content was significantly correlated with initial impression of juiciness, first bite and sustained impression of juiciness of breast meat. It was concluded that water restriction up to W-40 had a significant and adverse impact on juiciness and first bite scores of meat.

Keywords: Breast, hydric stress, local chickens, sensory evaluation

8.1. Introduction

The Ovambo and Naked Neck chickens are important chicken genotypes produced for consumption in rural areas of Southern Africa. Almost 80% of rural households own these chickens and their meat is valued for its unique game type taste, texture and perceived health benefits (Mtileni *et al*., 2009). The chickens also play important social, cultural and symbolic roles in rural communities that transcend their practical use as food or commodities. For example, birds are given away as gifts, sacrificed to ancestors and divinities, or consumed as part of ritual and secular celebrations, thereby strengthening important social bonds (Aklilu *et al.*, 2007). In some societies, chickens may be used to foretell the future through divination rites. Tadelle *et al.* (2001) described how chickens of different colour, sex and age may be used for purposes such as assuring good harvest returns and for honouring ancestors or spirits.

Recently, consumers' preference for natural or organic meat produced with minimal use of additives and chemicals is growing in many parts of the world (Rizzi *et al*., 2007). The shift in consumer preferences has increased the relevance of local slow-growing chickens because of their superior meat flavour and texture, which are the main attributes that attract consumers to purchase the chicken meat (Muchenje *et al*., 2008a). However, these chickens are exposed to various sub-optimal husbandry conditions and stress-provoking situations that adversely affect their productivity and the quality of products. Dry-season water and feed shortages are major problems in the production of free ranging chickens in most rural areas and as such the chickens are prone to dehydration (Gondwe and Wollny, 2007). The problem of dehydration is aggravated by erratic supply of unpalatable and dirty "grey water" from bathrooms, kitchens and stagnant water pools. Preliminary investigations have suggested that the bulk of the chickens in communal production systems receive between 20 and 70% of their water requirements (Rwanedzi, 2010). It is, therefore, likely that access to fresh clean drinking water could be one of the major causes for the low productivity of these chickens.

The deleterious effects of limited supply or access to water on the growth performance (Chapter 5), haematological and biochemical properties (Chapter 6) and physicochemical properties of breast meat (Chapter 7) from indigenous chickens were demonstrated. Exposure to severe water restriction has been reported to deplete glycogen stores and causes a shift from anabolism to catabolism, from lipogenesis to lipolysis, and a reduced metabolic rate (Warriss *et al.*, 1988). These changes, in turn, are responsible for differences in the sensory properties of meat (Debut *et al*., 2003).No reported work has, however, evaluated the sensory characteristics of meat from slow growing local strains of chickens subjected to pre-slaughter water restriction. Understanding the effects of water restriction on meat quality characteristics of these chickens is crucial in identifying consumer preferences of strains that can be used in drought prone areas and promoting this chicken meat in future.

The objective of the study was to determine the effect of pre- slaughter water restriction on the sensory characteristics of meat from Naked Neck and Ovambo chickens. The hypothesis tested was that birds subjected to pre-slaughter water restriction have better sensory qualities than birds on *ad libitum* water consumption.

8.2. Materials and Methods

8.2.1. Study site

The detailed description of the study site and ethical aspects of the study are given in section 5.2.1.

8.2.2. Birds, treatments and management

The details on the number of birds used per strain, water restriction levels and management of the birds are provided in section 6.2.2.

8.2.3. Slaughtering of birds

The birds were slaughtered as described in section 7.2.4.

8.2.4. Chemical composition of meat samples

Breast meat samples were freeze-dried for a week and ground through a 2mm screen. The dry matter, and crude protein (N × 6.25), mineral and fat contents of the breasts were determined according to the standard methods of the Association of Official Analytical Chemists (AOAC, 1990). The moisture content was determined as the difference between weight of fresh sample and the freeze dried sample. All analyses were repeated twice.

8.2.5. Meat sample preparation

Breast meat samples (without skin) sorted by strain and water restriction level were prepared separately, 24 h post-mortem, by grilling at 180°C for 50 minutes in a preheated oven.

8.2.6. Sensory evaluation

A consumer panel of 44 panelists was used for sensory evaluation of the chicken breast meat. The panel demographics are shown in Table 8.1.

The sensory evaluation panelists were students and academic staff from Cedara College of Agriculture and the University of KwaZulu-Natal. Written consent to participate in the study was obtained from all panelists. Prior to each session, it was explained to the panelists how to evaluate and record scores for each sensory quality attribute.The panellists were provided with meat quality attributes and their definitions, and an attribute intensity rating scale (Appendix 4). As shown in Table 8.2, attribute intensity rating was on a 9-point hedonic scale. The attributes and their definitions, and the attribute rating scale were explained to the panelists. The panelists served as both analytical sensory judges and consumer representatives. The reliability of the panelists was tested through a trial sensory evaluation and they were found to be reliable. The explanations given to the panelists were sufficient for them to reliably do the analytical sensory evaluation because of their high academic level.

Table 8.1: Consumer panel demographics for consumer sensory evaluation of Naked Neck and Ovambo chicken breast meat

Variable	Gender	
	Male	Female
Total number of subjects (n)	23	21
Percent of total number of subjects (%)	52	48
Mean age (years)	25	25.1
Age range (years) (sd)	20 – 35 (4.1)	20 – 39 (5.8)

sd = standard deviation

Table 8.2: Definitions of attributes for sensory analysis of breast meat from Naked Neck and Ovambo chickens subjected to graded levels of water restriction

Attribute	Definition
Aroma 1 = Extremely bland; 9= Extremely intense	Typical chicken aroma
Initial juiciness 1 = Extremely dry; 9 = Extremely juicy	The amount of fluid exuded on the cut surface when pressed between the thumb and forefinger
First bite 1 = Extremely tough; 9 = Extremely tender	The impression formed on the first bite
Sustained impression of juiciness 1 = extremely dry; 9 = extremely juicy	The impression of juiciness formed as you start chewing
Muscle fibre and overall tenderness 1 = extremely tough; 9 = extremely tender	Impression of tenderness after mastication (2–3 chews)
Amount of connective tissue 1= extremely abundant; 9 = none	The amount of residual tissue after most of the sample has been masticated (15 chews)
Overall flavour intensity 1= extremely bland; 9 = extremely intense	A combination of taste while chewing and swallowing referring to the typical chicken flavour
A-typical flavour intensity 1= none to 9 = extremely intense	Any off-flavour not consistent with chicken flavour

Whole breast samples were warmed in small batches for 1 minute in a microwave oven just before serving. Samples (approximately 15g) were served in white 125 ml polystyrene cups. Each sample cup was blind-coded with a 3-digit random number. The samples were served in a random order, which was predetermined using a table of random permutations of six. After tasting each sample, the panellists would rinse their mouth with water before tasting the next sample to reduce crossover effects. Fifteen panellists completed the sensory evaluation every 30 minutes in individual testing booths under white lighting. The sensory evaluation was done twice (two replicates) using the same panellists.

8.2.7. Statistical analyses

The effect of strain and water restriction level and their interaction on dry matter, crude protein, ash and fat content and arc-sine transformed sensory attributes' scores were analysed using the GLM procedure of SAS (2003). The following model was used:

$Y_{ijk} = \mu + B_i + T_j + (G \times T)_{ij} + \varepsilon_{ijk}$

where Y_{ijk}= dry matter, crude protein, ash and fat content and sensory attributes;

μ = overall mean

B_i = bird strain effect of the i^{th} breed, with i = NNK and OVB;

T_j = water restriction effect of j^{th} restriction level, with j = *ad libitum*, 70 and 40% of *ad libitum*;

$(B \times T)_{ij}$ = interaction of the i^{th} strain of bird and the j^{th} level of water restriction;

ε_{ijkl} = random error term assumed to be normally and independently distributed with mean 0 and variance equal to δ^2.

Least square means were compared using the PDIFF procedure of SAS (2003). Stepwise regression analysis was performed to determine the sensory attributes that had a significant influence on the overall flavour intensity, and hence acceptability of a sample. Statistical significance was considered at the 5 % level of probability. Pearson's correlation coefficients between fat content and sensory characteristics of breast meat samples were determined using the PROC CORR procedure SAS (2003).

8.3. Results

8.3.1. Chemical composition

The proximate composition of breast meat from Naked Neck and Ovambo chickens subjected to graded levels of water restriction are presented in Table 8.3. Dry matter and protein contents of the breast muscles did not differ between strains and water restriction levels ($P > 0.05$). There was a significant interaction between strain and water restriction level on fat content ($P < 0.05$). The fat content of Naked Neck meat was similar to Ovambo meat in birds fed water ad libitum but 41% lower and 31% higher than Ovambo meat at 70 and 40% of *ad libitum* water consumption, respectively. Ash content was significantly higher in Ovambo (5.3±0.11) than Naked Neck (4.8±0.13) meat ($P < 0.05$). The ash content was also significantly elevated in birds given water at 70% of ad libitum compared to the *ad libitum* and 40 % of *ad libitum* groups, which had similar ash contents (Table 8.3).

Table 8.3: Proximate composition of Naked Neck and Ovambo breast meat of birds subjected to graded levels of water restriction

Meat quality attribute	Genotype						SEM	ANOVA		
	Naked Neck			Ovambo				Strain	WRL	Strain × WRL
	W-100	W-70	W-40	W-100	W-70	W-40		P -value		
Dry matter (%)	29.1	28.8	26.3	28.1	28.2	27.9	0.61	0.9389	0.0706	0.1344
Crude protein (%)	34.6	32.1	34.9	31.9	32.4	32.9	2.38	0.3690	0.1043	0.1898
Crude fat (%)	10.4^{a}	4.5^{c}	3.5^{c}	10.6^{a}	7.6^{b}	2.4^{d}	0.30	0.0151	0.0001	0.0003
Ash (%)	4.5^{b}	5.5^{a}	4.5^{b}	5.5^{a}	5.5^{a}	4.7^{b}	0.20	0.0285	0.0090	0.0902

Means within a row with differing superscripts are significantly different (P< 0.05); W-40: 40% of *ad libitum* water consumption; W-70: 70% of *ad libitum* water consumption; W-100: *ad libitum* water consumption; SEM: standard error of mean; WRL: water restriction level

8.3.2. Sensory characteristics

Sensory characteristics of breast muscle meat of Naked Neck and Ovambo chickens subjected to water restriction are shown in Table 8.4. A significant interaction between bird strain and water restriction level was also observed on initial impression of juiciness ($P < 0.05$). Naked Neck chickens had higher sensory scores for initial impression of juiciness than Ovambo chickens, but only in birds offered water *ad libitum* and 70 % of *ad libitum* consumption (Table 8.4). Strain had no effect on aroma intensity, first bite and amount of connective tissue, overall flavour intensity and atypical flavours ($P > 0.05$). Sustained impression of juiciness was, however, affected by strain ($P < 0.05$). Breast meat of Naked Neck chickens had higher scores for sustained juiciness (4.7 ± 0.14) than Ovambo chickens (4.3 ± 0.14).

Water restriction level had a significant effect on first bite, sustained impression of juiciness, amount of connective tissue and tenderness ($P < 0.05$). Combining genotypes, breast meat of birds on 70 and 40 % of *ad libitum* water restriction had lower scores for first bite, sustained impression of juiciness, amount of connective tissue and tenderness than birds with free water access ($P < 0.05$). Aroma intensity did not differ between strains and among water restriction levels ($P > 0.05$).

Stepwise regression analysis (Table 8.5) showed that, in Naked Neck chickens, aroma, first bite and sustained impression of juiciness all had a significant influence on the overall flavour of breast meat from all water restriction levels while in Ovambo chickens, only aroma influenced the overall flavour of breast meat, irrespective of water restriction level ($P < 0.05$).

Table 8.4: Effect of water restriction on sensory characteristics of breast meatfrom Naked Neck and Ovambo chickens

Meat quality attribute	Genotype						SEM	ANOVA		
	Naked Neck			Ovambo				Strain	WRL	Strain × WRL
	W-100	W-70	W-40	W-100	W-70	W-40		P –value		
Aroma intensity	5.0	4.5	4.7	4.4	4.9	4.8	0.27	0.6201	0.6456	0.1624
Initial impression of juiciness	5.1[a]	4.0[b]	3.2[c]	4.3[b]	3.0[c]	4.0[b]	0.23	0.4893	0.0001	0.0013
First bite	5.3[a]	4.6[ab]	4.4[ab]	5.1[a]	4.4[b]	4.1[b]	0.28	0.2551	0.0116	0.7061
Sustained impression of juiciness	5.5[a]	4.6[b]	4.2[b]	4.8[ab]	3.8[c]	4.1[bc]	0.24	0.0270	0.0010	0.4116
Overall tenderness	5.2[a]	4.9[a]	4.5[ab]	4.9[ab]	4.4[ab]	4.0[b]	0.27	0.0785	0.0202	0.9714
Amount of connective tissue	4.6[a]	4.4[a]	4.2[a]	4.4[a]	4.2[ab]	3.6[b]	0.25	0.1194	0.0491	0.5692
Overall flavour intensity	4.9	4.7	4.7	4.6	4.8	4.7	0.25	0.8565	0.9583	0.6684
Atypical flavour intensity	3.5	3.6	4.1	3.5	3.7	3.9	0.30	0.9746	0.4546	0.8395

Values of each parameter in a row with different superscript differ significantly ($P < 0.05$); W-40: 40 % of *ad libitum* water consumption; W-70: 70% of *ad libitum* water consumption; W-100: *ad libitum* water consumption; SEM: standard error of mean; WRL: water restriction level

Table 8.5: Stepwise linear regression coefficients showing the influence of sensory attributes on the overall flavour of Naked Neck and Ovambo breast meat

Meat quality attribute	Strain					
	Naked Neck			Ovambo		
	W-100	W-70	W-40	W-100	W-70	W-40
Aroma intensity	0.424[a]	0.515[a]	0.310[a]	0.058	0.253[a]	0.225[a]
Initial impression of juiciness	-0.198	0.175	-0.179	-0.046	0.140	-0.054
First bite	0.111	0.380[a]	0.375[a]	-0.170	0.288	-0.058
Sustained impression of juiciness	0.614[a]	-0.322	0.314	-0.128	0.090	0.195
Overall tenderness	-0.185	-0.038	0.011	0.160	-0.108	0.164
Amount of connective tissue	-0.033	-0.086	-0.291	-0.267	0.087	0.083
Atypical flavour intensity	-0.005	0.031	0.068	-0.047	0.116	0.070

a = stepwise linear regression analysis, significant at P- value < 0.05

8.3.3. Correlations between fat content and sensory attributes of breast meat from Naked Neck and Ovambo chickens

Correlation coefficients between fat content and sensory attributes of chicken breast meat subjected to graded levels of water restriction are presented in Table 8.6. Fat content was positively correlated to initial impression of juiciness, first bite and sustained impression of juiciness in birds fed water ad libitum and 70 % of ad libitum, respectively but negatively correlated to these traits in birds given water at 40 % of *ad libitum* ($P < 0.05$). No significant correlations were observed between fat content and aroma, tenderness, amount of connective tissue, flavour and atypical flavours between strains and water restriction levels ($P > 0.05$).

Table 8.6:Correlation between fat content and sensory scores of Naked Neck and Ovambo chickens subjected to graded levels of water restriction

Meat quality attribute	Genotype						Overall
	Naked Neck			Ovambo			
	W-100	W-70	W-40	W-100	W-70	W-40	
Aroma intensity	0.56	0.47	0.38	0.61	0.63	0.39	0.65
Initial impression of juiciness	0.37*	0.28*	-0.22*	0.31*	0.23*	-0.26*	0.33*
First bite	0.34*	0.33*	-0.31*	0.31*	0.30*	-0.38*	0.32*
Sustained impression of juiciness	0.34*	0.36*	-0.33*	0.31*	0.35*	-0.32*	0.31*
Overall tenderness	0.47	0.42	0.41	0.51	0.49	0.47	0.46
Amount of connective tissue	0.17	0.34	0.13	0.61	0.79	0.69	0.47
Overall flavour intensity	0.37	0.43	0.38	0.31	0.33	0.39	0.13
Atypical flavour intensity	0.49	0.35	0.38	0.31	0.36	0.59	0.28

Significantly correlated at $*P < 0.05$.

8.4. Discussion

It is well known that dry matter and protein content are among the main determinants of chicken meat quality (Castellini *et al*., 2002b). The results of our chemical analysis showed that dry matter and protein contents of the Naked Neck and Ovambo breast muscles were not influenced by water restriction levels probably because the birds in the three water restriction levels had similar characteristics; i.e., the same strain, sex, and age and were fed the same diet. These results are in agreement with those reported by Van Marle Koster *et al.* (2000) in which there were no differences between the two strains, respectively. However, the dry matter and protein contents of breast meat obtained in this study were 19 and 24%, and 27 and 29% lower than those reported by these authors for Naked Neck and Ovambo chickens, respectively.

The low ash content in breast meat of birds fed water at 40% of ad libitum could be attributed to decline in feed intake and selected ingestion of small stones from the bedding triggered by a need to preserve body water by reducing faecal water loss together with reducing body heat increment (Ahmed and Alamer, 2011). Castellini *et al*. (2002a) reported an increase in meat ash content of free ranging birds and attributed the increase to selected ingestion of soil particles from the ground. Some studies, however discounted these findings, indicating that meat ash content was not affected by rearing system (Fanatico *et al*., 2007).

The fat content of birds on *ad libitum* intake obtained in this study contradict findings in earlier studies by Van Marle Koster and Webb, (2000) who found higher fat content in Ovambo than Naked Neck breast meat of birds reared under extensive indoor conditions. The considerable variation in the content of fat might be the result of differences in the age of slaughter since the birds were fed similar diets and breasts without skin were sampled. Birds used in this study were 8 weeks older than those used by Van Marle Koster *et al.* (2000). The fat content of Naked Neck and Ovambo breast meat reported in this study are within the limits reported by Abeni and Bergoglio (2001). The authors reported that fat content varied from 0.37 to 7.20% under extensive outdoor conditions. However, the fat contents were significantly lower than the range of values reported for Naked Neck and normal feathered strains fed until 16 weeks of age in Thailand (Jaturasita *et al*., 2008), but higher than the Thai Kai Dang indigenous chicken strain raised under extensive indoor conditions (Wattanachant *et al.*, 2004; Chuaynukool *et al*., 2007). Further studies to determine the interaction between age and fat content of local strains are warranted.

The finding that Naked Neck breast meat of birds in the 40% had a higher fat content than Ovambo chicken meat is probably an indication that the former is less reliant on intramuscular fat for metabolic water production than the latter. The results are consistent with studies by Decuypere *et al*. (1993) who found that the superior heat tolerance of Naked Neck chickens was related to lower proportions of subcutaneous and intramuscular fat compared to their normal feathered counterparts. Supporting these results, Macleod *et al*. (1993) found that body fat content measured by intramuscular fat content, abdominal fat thickness, or plasma cholesterol and triglycerides level was negatively correlated with heat tolerance.

Intramuscular fat (IMF) is involved in determining meat quality, particularly nutritional and sensory characteristics, and conservation ability (Ruiz *et al*., 2001). The difference in fat content profiles of Naked Neck and Ovambo breast meat contributed to significantly lower sensory scores on initial impression of juiciness, first bite and sustained impression of juiciness of Ovambo compared to Naked Neck meat. Juiciness of meat is largely due to the stimulatory effect of lipids on salivation, such that meat with low lipid content produces a dry sensation to the palate (Warris *et al*., 1988). Strain differences in juiciness of breast meat were noted between Italian dual-purpose and hybrid genotypes with different lipid content and composition (Castellini *et al*., 2006). Similarly, the low first bite scores observed in water-restricted birds could be attributed to the fact that water restriction reduced feed consumption and shifted energy metabolism from carbohydrates to lipids for metabolic water production, which invariably exhausted lipids stored in adipose tissue and muscle, leading to dry and firm meat (Warriss *et al*., 1988). The significant negative correlations between fat content and initial impression of juiciness, first bite and sustained impression of juiciness of breast meat from birds receiving 40% of *ad libitum* corroborate this explanation.

The reason for low tenderness scores of meat from water-restricted birds is not clear. However, shear force values for chicken meat have been reported to be inversely correlated with the amount of intramuscular fat (Rizzi *et al*., 2007). It is therefore possible that water restriction depleted intramuscular fat for metabolic water production, which resulted in tougher and stringier meat. The specific influence of intramuscular connective tissue on tenderness depends on their thickness, which is the amount of collagen present, as well as the density and type of cross linkages between collagen fibrils (Xiong *et al.*, 1999). Alternatively, the low ratings for tenderness and connective tissue of breast meat from water-restricted birds may be due to a relatively higher proportion of connective tissue and muscle fibers.

When chicken meat is cooked, the ensuing chemical reactions release many substances, such as volatile compounds, that give aroma and flavour to the meat (Aliani and Farmer, 2005). The extent to which volatile compounds and other substances are released depends on the cooking method (Muchenje *et al.*, 2008a). For example, Xazela *et al.* (2011) found differences in sensory scores for aroma intensity and flavour between roasted and boiled chevon. Since breast meat samples used in this study were cooked using the same method, it is reasonable to assume that the reactions following cooking produced the same aroma and flavour agents, hence the absence of differences in aroma and flavour.

The observation that aroma had a significant influence on the overall flavour agrees with Chulayo *et al.* (2011) who found a positive correlation between aroma and flavour scores in indigenous chicken meat. Flavour is a complex attribute of meat palatability embracing both the four primary taste sensations (bitter, sweet, sour and salty) and aroma (Calkins and Hodgen, 2007). Aroma and taste in poultry meat are important both aesthetically and physiologically for, if pleasant, they stimulate the secretion of digestive juices.

8.5. Conclusions

The study showed that the fat and ash contents and sensory quality of Naked Neck and Ovambo breast meat were affected by water restriction level. The fat and ash contents of Naked Neck and Ovambo breast meat subjected to 40 % of ad libitum was significantly lower than the rest of the water restriction levels. Meat from Naked Neck chickens was rated juicier and more tender than that of Ovambo chickens only in birds offered water *ad libitum* and 70 % of *ad libitum*, probably because of the negative correlation between fat content and juiciness scores at the most severe water restriction level. Findings from this study could, however, have been improved if relationships between fatty acid composition and sensory characteristics of meat from indigenous chickens had been evaluated.

CHAPTER 9: General Discussion and Conclusions

9.1 General Discussion

Livestock production will be adversely affected by the expected rise in temperature and inadequacy of water resources in Southern Africa. Indigenous chickens are an integral component of smallholder agriculture and are found in almost all households for the purposes of protein supply in the diet and a source of income. Identification and genetic selection of chicken breeds that will cope with the expected water scarcity, variable feed supply and high ambient temperatures becomes a viable and sustainable option for smallholder farmers who cannot afford expensive mitigation strategies. Indigenous chickens offer a good starting point in the search for better adapting breeds in Sub Saharan Africa. Genetic diversity among indigenous chicken suggests that the Naked Neck and Ovambo breeds dominate the gene pool in Southern Africa. Meanwhile, published literature on their adaptability to harsh environments, flock dynamics and utilization patterns and socio-economic characteristics is scarce. In addition, few publications exist on the effect of water restriction on the performance, haematological and biochemical responses and meat quality of indigenous chickens.

The current study identified that the contribution of indigenous chickens to household nutrition and income in communal and resettlement production systems of South Africa was low. This was shown by the low numbers for chickens slaughtered for home consumption and sold on the markets. However, a significant portion of adult chickens were exchanged as gifts between family members and relatives, and other members of the community, confirming the findings of Naidoo (2003), Swatson (2003) and Mtileni *et al*. (2009) that indigenous chickens play an important role in strengthening social bonds. It was also discovered that a significant proportion of adult chickens were lost to predation. Apposite protective measures such as limiting the scavenging area and use low-cost mobile cages made from locally available materials need to be put in place to minimise these losses. Although most households had high numbers of hatched chicks, a large number incurred huge production losses due to high chick mortality, irrespective of production system. A number of factors drove the high mortality among chicks and included aerial predators, poor nutrition, inclement, hot-dry, weather conditions, and of particular interest, poor watering practices. As with adult chickens, protection of chicks during vulnerable periods is of paramount importance. The action taken by the farmer to protect his/her chicks will depend on socioeconomic circumstances of the farmer, season and geographical region. It is important to note that isolated efforts to solve the challenges plaguing the indigenous chicken enterprise are likely to have limited impact, and an integrated approach embracing good nutrition, housing and health care management to minimise the impact of underlying factors is advocated.

The study also demonstrated that Naked Neck chickens on *ad libitum* water intake had lower water requirements and high feed efficiency than Ovambo under thermoneutral conditions and up to 16 wk of age. The low water requirements coupled with a high feed conversion efficiency exhibited by Naked Neck chickens under extreme water stress is of practical significance to indigenous chicken producers in drought prone areas where access to feed and water are major challenges. From a breeding point of view, such traits can be infused into flocks through careful cross-mating between Naked Neck and their normal feathered counterparts which easily succumb to extreme water stress.

Changes in blood composition are useful predictors of potential resistance of livestock to environmental, nutritional and pathological stresses. Drought-resilient chickens are expected to manifest the least changes in haematological parameters and serum metabolites when subjected to stressful situations relative to those under optimal production conditions. The haematological and biochemical responses of chickens to water restriction of up to 40 % of *ad libitum* intake were consistent with the incidence of stress as evidenced by the high packed cell volumes, erythrocyte counts and leucocyte counts compared to those on the 70 % of *ad libitum* and *ad libitum* water intake levels where normal plasma volumes were maintained. A similar response was observed on some serum biochemical indicators of hydric stress (uric acid, creatinine, triglycerides, total cholesterol, low density lipid cholesterol, total protein and globulin). However, the haematological parameters and blood serum metabolites levels of water-restricted NNK chickens deviated marginally from those of birds on *ad libitum* water intake compared to those of OVB chickens, suggesting that the former were better able to cope with hydric stress than the latter.

Mobilization of nutrient reserves during periods of water-stress was expected to influence the physiochemical properties of meat (Debut *et al*., 2003; Barbut *et al*., 2008; Dadgar *et al*., 2012). The physical and chemical properties of chicken meat in the current study were influenced by water-stress levels. Water restriction levels up to 40% of *ad libitum* water intake adversely affected the fat content, but resulted in favourable cooking loss values and meat redness (a*) values compared to the other restriction levels, irrespective of strain. From a health point of view, SFAs, ῳ-6 and ῳ-6/ῳ-3 must decrease, while MUFAs, PUFA and n-3 have to increase (Muchenje *et al*., 2009). The observation that increased water restriction caused an increase in ῳ-

6 can be considered a negative from a health point of view. This negative health effect was however counteracted by the increase in ω-3 and PUFA which have positive health implications. The fact that water restriction had no effect on the PUFA/SFA ratio of the fatty acid composition of breast meat from Naked Neck and Ovambo chickens implied that the health properties of intramuscular fat did not deteriorate. The high fat content observed for Naked Neck chickens at 40 % of *ad libitum* water intake compared to Ovambo chickens at the same water-stress level suggested a lesser dependence on body fat reserves for metabolic water production and superior adaptation to hydric stress. While the descriptive laboratory analyses yielded technically precise and reliable information about the physical and chemical properties of the meat from water restricted birds, the results did not tell whether or not the meat would be acceptable to consumers.

In Chapter 8, a study was conducted to determine the effect of water restriction on the sensory characteristics of meat from NNK and OVB chickens. The hypothesis tested was that sensory characteristics of breast meat from NNK and OVB chickens subjected to water restriction are similar to those of birds on *ad libitum* water consumption. There were significant strain differences in the sustained perception of juiciness and tenderness, with NNK meat being rated juicier and tenderer than OVB. The occurrence of dry, firm, tougher and stringier meat increased as severity of water restriction increased. The study therefore demonstrated that differences in sensory characteristics exist between strains subjected to water restriction. This finding is of special importance in identifying consumer preferences of strains that can be used in drought-prone areas as well as promoting indigenous chicken meat in future.

9.2. Conclusions

Indigenous chicken productivity was being offset by sub-optimal protection from predators, nutrition and water provision during the dry seasons. The challenge of inadequate water supply to chickens was being exarcerbated by ignorance on the part of the producers about the water requirements of chickens. A significant proportion of producers were observed not to offer water to their chickens trusting the ability of the birds to find their own water. Although water restriction had a negative impact on the growth performance, physiological well being, physical, chemical and sensory properties of indigenous chicken meat, NNK chickens were more resilient and performed better than OVB chickens under conditions of water restriction. It was concluded that NNK chickens were more adapted to the prevailing water shortage conditions found in communal production systems than OVB chickens.

9.3 Recommendations

Efforts to increase productivity of indigenous chickens focus on sound feeding and health management practices. Watering practices have only received cursory attention from research and developmental programmes. The impact of inadequate water supply on the productivity and welfare of indigenous chickens cannot be overemphasized. Fresh clean water should be available at all times to indigenous chickens. Farmers should desist from using dirty or ‘grey’ waste water from washing dishes and laundry to water their chickens as this has significant implications on the welfare of the birds and the health consumers of indigenous chicken meat and products. The importance of provision of adequate safe clean water to indigenous chickens should be constantly impressed upon the farmers, lest the gains from improved nutrition and health get diminished.To prevent the spread of diseases and parasites, farmers should also stop the current ‘free for all’ watering practice, where water meant for chickens is accessible to all livestock and wild animals. Effective management and utilization of the limited water resource in drought-prone communal production systems is recommended. This can be achieved through harvesting water from roof tops and storage during periods of plenty for use at predetermined times during the dry periods. Indigenous chicken producers are also encouraged to plant succulent forage species to compliment drinking requirements.

Chapter 10: References

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CHAPTER 11. Appendices

Appendix 1: Recording sheet for flock dynamics

Name of community……………………… Name of household…………………… Date…………………

Flock composition	Chicks (0-6 wks)	Pullets	Cockerels	Hens	Cocks
Number					

Entries	Hatchings (* for chicks only)	Purchases	Gifts in	Exchanged in	Entrusted in
Chicks					
Pullets					
Cockerels					
Hens					
Cocks					

Exits	Sold	Consumption	Deaths		Theft/ straying away	Gifts out	Exchanged out	Entrusted out
			Disease	Predated				
Chicks								
Pullets								
Cockerels								
Hens								
Cocks								

Productioncharacteristicsand egg use

Parameter	**Number**
Hens looking after chicks	
Idle hens	
Hens in lay	
Hens sitting on eggs	
Eggs being incubated	
Eggs hatched	
Eggs wasted	
Eggs in nest	
Eggs consumed	
Eggs sold	
Number of chicks weaned	

Do you provide water to the chicken? Yes/No; If yes, fill in the following table.

Source of water for chickens(kitchen, bath or laundry waste water, tap, river, bore hole, well,)	**What is the quality of the water** (Clear, Soapy, Muddy, Salty, Smelly, Don't know)	**Who is responsible for providing water to chickens? (**Men, Wife, Boys, Girls, Hired labour)	**What is the walking distance to the water source?** (< I km, 1 to 5 km, 6 to 10 km, > 10 km)	**How frequently do you provide water?**(Once a day, Once in 2 days, More than 2 days)
How much water do you provide to	**Where is the water normally put? (**Placed	**How often do you clean the containers?**	**Which class of birds did you give the**	

your chickens (Litres)?	in drinkers, plastic container, metal container, Used tyre)	**(**Daily, weekly, monthly)	**highest priority for water? (**Chicks, Pullets, Cockerels, Hens, Cocks)	

SUPPLEMENTARY FEEDING (OTHER THAN SCAVENGED FEED)
Describe the supplement in the following chart.

Type of supplement	Source (household harvest, purchase, donation)	If purchased, unit price	Quantity and time of feeding per day	Person who feeds the chickens

ANIMAL HEALTH

1. Have you experienced any disease problems in your flock this month? Yes/No If yes, indicate the symptoms/disease and control measures taken using the chart below. Rank the problems in order of importance.

Type of disease/ symptoms	**Control measure**	**Cost incurred to control**	**Last occurrence in the flock**	**Age group affected**	**Rank according to importance**
Swollen head					
Swollen joints					
Coughing					
Diarrhoea (bloody/greenish)					
Twisted neck					
Paralysed legs/wings					
Fowl pox/warts					
Newcastle disease					
Mites/ticks					
Fleas					

2. Do you have access to veterinary services? Yes/No

   If yes, please fill in the chart below.

Source/name of centre	**Type of service (advice, diagnosis, drugs)**	**Cost incurred, if any**	**Frequency of visits by veterinary assistants**

Problems encountered in chicken rearing during the month

1 ……………………………………………………………………………………………………….

2 ……………………………………………………………………………………………………….

3 ……

Appendix 2:Structured questionnaire and chick mortality monitoring instrument administered to smallholder indigenous chicken production systems of Msinga district in KwaZulu Natal Province, South Africa

A. HOUSEHOLD DEMOGRAPHIC INFORMATION

1. Head of household

a. Sex M☐ F☐

b. Marital status Married☐ Single ☐ Divorced☐ Widowed☐

c. Age < 30☐ 31-45☐ 30-50☐ 46-60☐ >60☐

d. Highest level of education No formal education ☐ Grade 7☐ Grade 12☐ Tertiary☐

2. What is your principal occupation? ....

3. What is your religion? Christianity ☐ Traditional☐ Moslem☐ other (specify)…………

4. What is the size of your household? Adults: M……. F……….. Children: M…… F……

5. How much land do you own (ha)? …………

6. How much land is arable (ha)? ………………

7. What crops did you grow last season? (Rank 1 as the most commonly grown used crop)

Crop	**Rank**	**Area (ha)**	**Purpose of production**	
			Consumption	**Sale**

8. What type of livestock species do you keep? (Rank 1 as the most important specie)

Class	Cattle	Goats	Sheep	Chickens	Other (specify)
Number					
Rank					

9. What are your sources of income? (Tick first column as appropriate and rank 1 as the most important source of income)

Source	**Amount raised**	**Rank**
Crops		
Livestock		
Salary/wages		
Pension		
Other (specify)		

HOUSING

10. Where do the chickens rest at night? 1. Do not know 2. Kitchen/store 3.In the main house 4. Perch on trees 5. Other (specify)…………………………………..

11. Do you clean the chicken house? Yes/No

12. If yes, how frequently do you clean the chicken house?1. Daily 2. Weekly 3. Monthly 4. Less than once per month.

13. Who cleans the house? 1. Adult male (>18 years) 2. Adult female (>18 years) 3. Boys (<18 years) 4. Girls (<18 years) 5. Hired labour

FEEDING SYSTEMS

14. What type of feed is given to birds during;

Season	**Type of feed**				
	Kitchen waste	**Bought concentrate**	**Home made ration**	**Crushed grain**	**Whole grain**
Hot- wet					
Cold-Dry					

15. How do you feed your chickens?

Season	**Supplementary feed**	**Scavenging feed**	**Both**
Hot –Wet			
Cold –Dry			

WATERING SYSTEMS

16. How do your chickens access water?

Season	**Scavenge**	**Water is provided**	**Do not know**
Hot-Wet			
Cold-Dry			

17. What are the sources of water for chickens? (Tick one or more)

Season	**Source**				
	Tap	**Municipality Tankers**	**Waste water (kitchen, laundry, sewage)**	**Borehole**	**Don't know**
Hot-wet					
Cold-dry					

18. What is the quality of water that your chickens drink during the dry season? (Tick one or more)

Season	**Water Quality**				
	Good/Clear	**Muddy**	**Salty**	**Smelly**	**Don't know**
Hot-wet					
Cold-dry					

19. What is the frequency of water supply to chickens during the cold-dry season? 1. Freely available☐ 2. once a day ☐ 3. Twice a day☐ 4. Every other day ☐ 5. Once in 2 days ☐ 6. More than 2 days 7.Others (specify)……………

20. What is the frequency of water supply to chickens during the Hot-wet season? 1. Freely available☐ 2. once a day ☐ 3. Twice a day☐ 4. Every other day ☐ 5. Once in 2 days ☐ 6. More than 2 days 7.Others (specify)……………

Hen no.	Date of hatching	No. of Chicks hatched	Number dead and cause of death												No. at end of 12 weeks
			Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10	Wk11	Wk12	
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
Source of water for chicks															
What is the quality of the water															
Walking distance to the water source?															
Frequency of watering															
Litres of water provided															
How often do you clean the containers?															
Medication (Present/Absent)															
Supplementary feed (Present/Absent)															
Housing (Present/Absent)															
Other birds (Present/Absent)															

Appendix 3: Ethics approval document

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

Research Office
Animal Ethics Research Committee

Govan Mbeki Centre, Westville Campus,
University Road, Chiltern Hills, Westville, 3629, South Africa
Telephone 27 (031) 260-2273/35 Fax (031) 260-2384
Email: animalethics@ukzn.ac.za

17 February 2012

Reference: 048/12/Animal

Mr N Chikumba
School of Agricultural, Earth and
Environmental Sciences
Rabie Saunders Building
University of KwaZulu-Natal
Pietermaritzburg Campus

Dear Mr Chikumba

Ethical Approval of Research Project on Animals

I have pleasure in informing you that on recommendation of the review panel, the Animal Ethics Sub-committee of the University Research and Ethics Committee has granted ethical approval for 2012 on the following project:

"Indigenous chicken responses to hydric gradients."

Yours sincerely

Prof. Theresa HT Coetzer (Chair)
ANIMAL RESEARCH ETHICS COMMITTEE

Cc Registrar, Prof. J Meyerowitz
Research Office, Mr N Moodley
Head of School, Prof. AT Modi
Supervisor, Prof. M Chimonyo

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Founding Campuses:
- Edgewood
- Howard College
- Medical School
- Pietermaritzburg
- Westville

Appendix 4:Recording sheet for sensory evaluation of chicken meat

Name ……………… Gender:........................... Age:.........................

Please evaluate the following samples of chicken meat for the designated characteristics.

	Characteristics	Rating scale	Sample codes					
1	**Aroma intensity** Take a few short sniffs as soon as you remove the foil. Typical chicken aroma. (Bland= non irritating or stimulating)	1= Extremely bland 2= Very bland 3= Fairly bland 4= Slightly bland 5=Slightly intense 6= Fairly intense 7= Very intense 8=Extremely intense						
2	**Initial impression of juiciness** The amount of fluid exuded on the cut surface when pressed between the thumb and forefinger	1= Extremely dry 2= Very dry 3= Fairly dry 4= Slightly dry 5=Slightly juicy 6= Fairly juicy 7= Very juicy 8=Extremely juicy						
3	**First bite** The impression that you form on the first bite	1= Extremely tough 2= Very tough 3= Fairly tough 4= Slightly tough 5=Slightly tender 6= Fairly tender 7= Very tender 8=Extremely tender						
4	**Sustained impression of juiciness** The impression of juiciness that you form as you start chewing	1= Extremely dry 2= Very dry 3= Fairly dry 4= Slightly dry 5=Slightly juicy 6= Fairly juicy 7= Very juicy 8=Extremely juicy						
5	**Muscle fibre & overall tenderness** Chew sample with a light chewing action	1= Extremely tough 2= Very tough 3= Fairly tough 4= Slightly tough						

		5=Slightly tender 6= Fairly tender 7= Very tender 8=Extremely tender						
6	**Amount of connective tissue (Residue)** The chewiness of the meat	1=Extremely abundant 2= Very abundant 3= Excessive amount 4= Moderate 5= Slight 6= Traces 7= Practically none 8= None						
7	**Overall flavour intensity** This is the combination of taste while chewing and swallowing referring to the typical chicken flavour	1= Extremely bland 2= Very bland 3= Fairly bland 4= Slightly bland 5=Slightly intense 6= Fairly intense 7= Very intense 8=Extremely intense						
8	**A- Typical flavour intensity**	**1**= None 2= Practically none 3= Traces 4= Moderate 5= Slightly intense 6= Fairly intense 7= Very intense 8= Extremely intense						

TICK RELEVANT A-TYPICAL FLAVOR/S						
1	Livery/bloody			**5**	Metallic	
2	Cooked vegetable			**6**	Sour	
3	Pasture /grassy			**7**	Unpleasant	
4	Animal like/kraal (manure			**8**	Other	

Appendix 5: Published papers

Chikumba, N., Swatson, H and Chimonyo, M. 2013. Haematological and serum biochemical responses of chickens to hydric stress. Animal 7 (9): 1517-1522.

Chikumba N. and Chimonyo, M. 2013. Effects of water restriction on the growth performance, carcass characteristics and organ weights of Naked Neck and Ovambo chickens of Southern Africa. Asian-Australasian Journal of Animal Science (http//dx.doi/10.5713/ajas.2013.13383).

Physicochemical properties of breast meat from water-restricted Naked-Neck and Ovambo chickens. British Poultry Science (In press).