EFFECT OF ENERGY LEVEL IN THE DIET OF INDIGENOUS VENDA HENS ON EGG PRODUCTION, HATCHABILITY AND SUBSEQUENT PRODUCTIVITY OF THE CHICKS

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BY

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DECLARATION

I declare that a dissertation hereby submitted by me for the degree of Master of Agricultural Management (Animal Production) at the University of Limpopo is my own independent work and has not previously been submitted by me to another University or Faculty. It is my own work in design and execution, and that all material contained therein has been duly acknowledged.

Signature………………………….. …….   Date......................................

Vincent Vonani Maphahla

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I dedicate this work to my late father, Mr Elmon Maphahla, late sister Vulani Maphahla, my mother Sarah, sister Happy, brother Tinyiko and grandmother, Kubani. Lastly, thanks to my wife Hlamalani and children Nyeleti, Risuna, Hlulani, Dangisa and Engetelo, and my entire family.

ABSTRACT

An experiment was conducted to determine the effect of energy level in the diets of indigenous Venda hens on egg production, hatchability and subsequent productivity of the chicks. The first part of the study determined the effect of energy level in the diets of indigenous Venda hens on egg production, hatchability and chick hatch-weight. A total of one hundred hens were randomly assigned to four dietary energy levels, replicated five times with 20 floor pens of 5 birds each. The treatments were CP_{15} E_{10} (10 MJ ME/kg DM feed), CP_{15} $E_{10.5}$ (10.5 MJ ME/kg DM feed), CP_{15} E_{11} (11 MJ ME/kg DM feed) and CP_{15} $E_{11.5}$ (11.5 MJ ME/kg DM feed). Energy level in the diets of Venda hens affected (P<0.05) feed intake, egg weight, egg production, egg hatchability and chick hatch-weight. Feed intake and egg weight of Venda hens were optimized at dietary energy levels of 10.70 (r^2 = 0.985) and 10.70 (r^2 = 0.246) MJ of ME/kg DM, respectively. Strong and positive relationships existed between energy level in the diets of Venda hens' egg production and egg hatchability. Energy level in the diets of Venda hens affected (P<0.05) egg albumen, yolk and shell weights. Egg albumen, yolk and shell weights were optimized at dietary energy levels of 10.55 (r^2 = 0.279), 10.85 (r^2 = 0.128) and 10.95 (r^2 = 0.863) MJ of ME/kg DM, respectively. Energy level in the diets of Venda hens had no (P>0.05) effect on egg contents.

The second part of the study determined the effect of energy levels in the diet of indigenous Venda hens on the performance of progeny chicks aged one to seven weeks. A total of 120 unsexed day-old chicks that hatched from the first part of the study were used according to the treatments and replicates from which they hatched. All the birds were offered the same grower feed and fresh water ad *libitum*. Energy level in the diet of indigenous Venda hens had no effect on (P>0.05) feed intake, dry matter digestibility, metabolisable energy intake, nitrogen retention and mortality of progenies aged one to seven weeks. However, positive effects (P<0.05) were observed on growth rate, live weight and feed conversion ratio. Live weight, growth rate and feed conversion ratio of Venda chickens were optimized at dietary energy levels of 10.73 (r^2 = 0.554),

11.2 (r^2 = 0.950) and 11.5 (r^2 = 1.000) MJ ME/kg DM, respectively. Male Venda progenies had higher (P<0.05) feed intake, growth rate and live weight, and better (P<0.05) feed conversion ratio than female progenies aged one to seven weeks.

The third part of the study determined the effect of energy level in the diets of indigenous Venda hens on the productivity and carcass characteristics of the progeny chickens aged eight to 13 weeks. A 2 (sexes) x 5 (dietary energy levels) factorial arrangement in a completely randomized design was used. Energy level in the diets of Venda hens had no effect (P>0.05) on feed intake, live weight, feed conversion ratio and mortality of their male progenies aged 50 to 91 days. However, male Venda chickens hatched from eggs produced by hens on a diet with 11.5 MJ/kg DM had higher (P<0.05) growth rates than those hatched from eggs produced by hens on a diet with 10.5 MJ/kg DM. Male progenies from hens fed diets having 11.5, 10 or 11 MJ ME/kg DM had the same (P>0.05) growth rates. Similarly, male progenies produced by hens fed diets containing 10, 10.5 or 11 MJ ME/kg had the same (P>0.05) growth rates. Dietary energy levels of the hens had no effect (P>0.05) on feed intake, live weight, feed conversion ratio and growth rate of female Venda chickens aged eight to 13 weeks. Energy level in the diets of Venda hens had no (P>0.05) effect on dry matter digestibility, apparent metabolisable energy and nitrogen retention of their male and female progenies. Venda male progenies were heavier (P<0.05) than female progenies. Male Venda progenies had improved (P<0.05) feed intake, growth rate and feed conversion ratio than female progenies aged eight to thirteen weeks. Energy level in the diets of Venda hens had no effect (P>0.05) on carcass, drumstick, thigh, liver and heart weights of the male progenies aged 91 days. However, energy level in the diets of Venda hens affected (P<0.05) breast, wing, gizzard and fat pad weights of male progenies ages 91 days. Energy level in the diets of Venda hens had no effect (P>0.05) on carcass and carcass weights of female progenies aged 91 days.

It is concluded that energy levels of the diets of Venda hens affected egg production, egg weight, egg hatchability and chick hatch-weight. The effects of maternal dietary energy level on intake, live weight and feed conversion ratio of Venda chicken progenies diminished with age.

TABLE OF CONTENTS

Contents **Page**

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

Indigenous chickens play an important role in the livelihoods of people in rural areas of Limpopo province. Almost 80 to 90 % of the rural populations keep small numbers of indigenous chickens under traditional free-range semi-scavenging systems (Gueye, 2003). The Venda chicken breed of South Africa is the most kept breed of chicken among rural communities of Limpopo province. Venda chickens contribute a lot to the income and nutrition of rural communities (ARC, 2006). The breed is used for dual purposes of meat and egg production. However, productivity of these chickens is low. Improving the productivity of indigenous chickens will offer a viable approach to improving nutritional and economic status of the rural households in South Africa.

The productivity of indigenous chickens depends on the management systems adopted (Gueye, 2003), thus improved nutritional management is very necessary to assist in achieving optimal productivity in terms of egg production, meat yield, feed conversion ratio and live weight. Bireck (2002) indicated that poor nutrition is among the important factors that contribute to the low growth rate and egg production of indigenous chickens. Bohnsack *et al*. (2005) reported that dietary energy supplementation to laying hens improved egg production.

1.2 Problem statement

Indigenous Venda chickens are economically, nutritionally and socially important to rural communities of Limpopo province (Norris & Ng´ambi, 2006). However, these chickens are characterized by fewer eggs produced and hatched, high chick mortality and poor growth rates (Swaston *et al*., 2001). This implies that their contribution to the household protein security may not be fully realized without appropriate chicken management, feeding and husbandry interventions. Often, the poor productivity of indigenous chickens has been attributed to their poor food resource base, limited foraging ranges and poor management practices (Alders *et al*., 2001). There is evidence that energy supplementation to the diets of broiler chicken breeders can improve egg production and hatchability, reduce mortality and increase productivity of the hatched chicks

(Swatson *et al*., 2001; Gueye, 2003). However, such evidence is limited and not conclusive. In fact, no such information on indigenous chickens was found.

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1.3 Motivation

Data on dietary energy requirements of the indigenous Venda chickens is limited, particularly on energy requirements for optimum productivity. Knowing the energy requirements will assist in the formulation of the diets that optimize productivity of the hens. Such information will also help to improve the economic, social and nutritional status of the indigenous chicken farmers.

1.4 Objectives

The objectives of this study were as follows:

i To determine the effect of energy level in the diets of indigenous Venda hens on egg production, hatchability and chick hatch-weight.

ii To determine the effect of energy level in the diets of indigenous Venda hens on subsequent productivity, mortality and carcass characteristics of the hatched chicks.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Energy is an important nutrient for laying hens (McDonald *et al*., 2010). It influences feed intake of chickens (Leeson & Summer, 2000; Peebles *et al.*, 2000; Mbajiorgu, 2010). Thus, diets deficient in energy-yielding nutrients will negatively affect productivity of the chickens in terms of number of eggs produced, fertility of the eggs and productivity of the hatched chicks (NRC, 1994). Dietary energy is limiting in most rural poultry production systems of South Africa (Nemavhola, 2001). Chickens meeting their dietary energy requirements are productive and have low mortality rates (Tadelle *et al*., 2003). However, low energy levels in poultry feeds result in low productivity and high mortality rates of broiler chickens (NRC, 1994). Similarly, high dietary energy levels result in poor productivity and high mortality rates in broiler and indigenous chickens (Mohammed & Sohail, 2008). There is, therefore, need for conclusive studies on the effects of dietary energy level on egg productivity and productivity of progenies of indigenous Venda hens.

2.2 Biochemical functions of Energy

Animals obtain energy from food (McDonald *et al.,* 2010). Energy is a property of energy-yielding nutrients. Nutrients which yield energy include carbohydrates, lipids and protein (Leeson *et al*., 1996; Leeson & Summer, 2000; Peebles *et al.*, 2000). The most efficient nutrient that the body of an animal uses for energy metabolism is carbohydrates. However, lipids yield higher energy values than carbohydrates (McDonald *et al.*, 2010). Proteins (amino acids) are also used as an alternative source of energy, when provided in the diet in excess and also when dietary carbohydrates and lipids are lacking (McDonald *et al.*, 2010; Leeson *et al.*, 1996).

Energy is transferable from one form to another in processes that involve synthesis of body tissues and poultry products, for example eggs. Chemical energy from food may be converted to mechanical or heat energy as nutrients are oxidized. Energy is required by the body for functions necessary for life – for mechanical work of muscular activity, movement of dissolved substances against concentration gradients and for synthesis of expended body constituents such as enzymes and hormones. The type of energy required for this is called maintenance energy (McDonald *et al.,* 2010). More energy is, therefore, required for production of poultry products, for example eggs, meat, etc. The energy used for production and maintenance is called metabolisable energy. Figure 2.1 shows how dietary energy is partitioned for its utilization within the body of poultry animals. When animals feed, they cannot convert all the energy of feed into the energy of products which are useful to humans. Hence, there is the calculation of feed conversion ratio. Part of ingested food energy is lost in the form of faeces, urine, gases and heat. The remaining energy is referred to as metabolizable energy which is used to maintain life and produce meat and eggs (Sugahara, 2003). In poultry, metabolizable energy is measured easily because the faeces and urine are voided together (McDonald *et al.*, 2010). Excess energy in the body is stored in the liver, muscle cells as glycogen and in adipose tissue as triacylglycerol. However, energy deficiencies in the body may result in lipolysis in adipose tissue (decreased lipogenesis) and, also, decreased muscle and liver glycogen. Additionally, energy can be derived from products of catabolism of amino acids (gluconeogenesis) in periods of fasting or when dietary energy is insufficient.

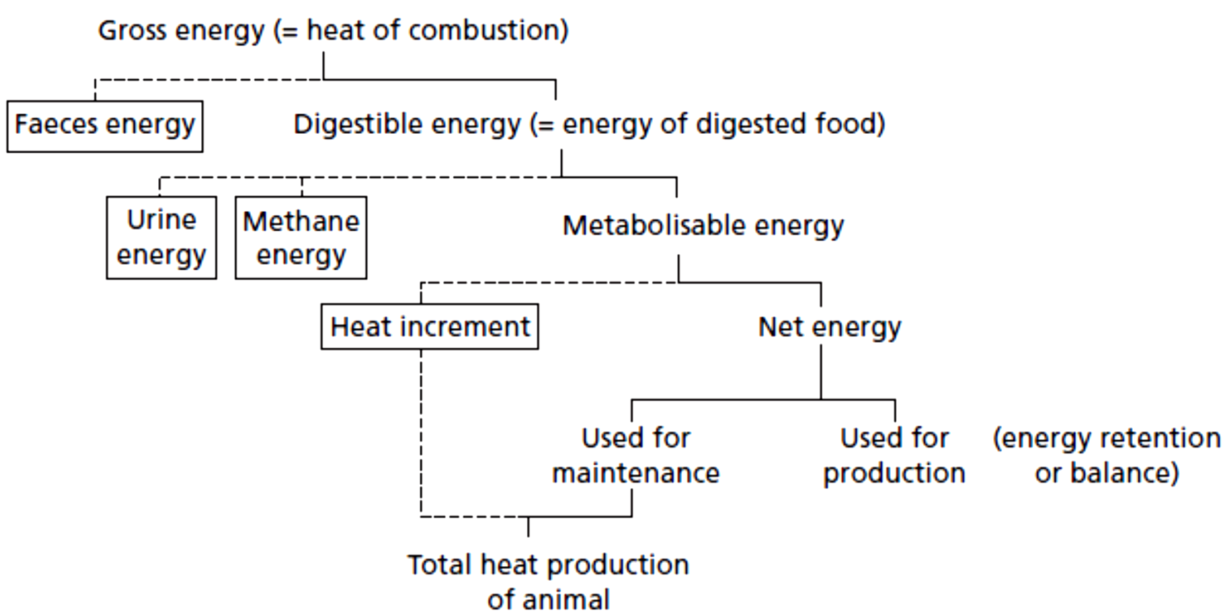

Figure 2.1 Partition of dietary energy in the animal (Source: McDonald *et al.*, 2010)

It is of interest in this study, to determine the effect of increasing dietary metabolisable energy in the diet of Venda chicken hens on egg production variables, growth performance and carcass characteristics of progenies produced by these hens. There is very limited research information on this subject in Venda chicken hens.

2.3 Effect of dietary energy level on egg production and egg composition

Dessie & Ogle (1997) found that feed resources of indigenous chickens lack dietary energy, hence supplementation is important. Studies on indigenous chickens show that dietary energy supplementation has a positive effect on egg production and growth performance (Nemavhola, 2001). Tadelle (1996) reported that supplementing dietary energy of indigenous chicken diets resulted in considerable increases in egg production. Rhashid (2003) reported that indigenous hens kept under extensive systems require 11.6 MJ of ME/kg DM. Thus, meeting the nutrient requirements may result in improved egg production. In broiler breeders, McDonald *et al.* (2010) indicated that a metabolisable energy level of 11.1 MJ/kg DM optimizes egg production. Grobas *et al.* (1999) found that increases in dietary energy level from 11.2 to 11.8 MJ of ME/kg DM significantly improve egg production in ISA brown hens. However, Peebles *et al.* (2000) found that increased dietary energy level from 11.3 to 12.3 MJ of ME/kg DM, in broiler breeder hens, did not improve egg production. Similarly, Wu *et al.* (2007) found that increasing dietary energy level from 11.55 to 12.60 MJ of ME/kg DM did not increase egg production in broiler breeder hens. These authors (Wu *et al.,* 2007; Peebles *et al.,* 2000) suggested that excess metabolizable energy is not channeled towards egg production but accretion of adipose tissues which results in increased body weight. Therefore, in practice, the effect of restricting feed (energy) intake to control body weight is critical to maximize egg production in broiler breeders and there is scope for increasing dietary energy intake (NRC, 1994; Leeson & Summers, 2000). However, no information was found on dietary energy level for optimal egg production in indigenous Venda hens.

The yolk and albumen in the egg supply the developing embryo with nutrients for normal growth. The albumen is an important reservoir for water, essential ions and protein. It, also, has anti-microbial properties (Deeming, 2002). The egg yolk contains lipids and sugars, which are sources of energy for the developing embryo (Noble *et al*., 1996). The egg yolk, also, provides proteins, minerals, vitamin A and thiamine in particular. These important nutrients, found in the egg, must be provided to the hens' diets. Bohnsack *et al*. (2000) suggested that laying hens are highly capable of adjusting their energy intake, such that the same amount of energy used for egg production is relatively constant. Thus, increasing the dietary energy level may not result in increased egg albumen and egg yolk weights. Grobas *et al*. (1999) reported that egg albumen and yolk weights were not affected when maternal dietary energy was increased from 10.6 to 11.7 MJ of ME/kg DM in ISA brown breeder hens. Similarly, Spratt & Leeson (1987) found that egg albumen and yolk weights of broiler breeders increased as maternal dietary energy increased. No literature was found on the effects of dietary energy level on egg productivity in Venda hens.

2.4 Effect of dietary energy level on egg hatchability and chick hatch-weight

Embryonic development is completely dependent on nutrients deposited in the egg for its growth and development, consequently, the physiological status of the chick at hatching is greatly influenced by the nutrition of the breeder hen (Kemp & Kenny, 2007). Nahm (2001) and Wilson (1997) indicated that hatchability is affected by numerous factors, including nutrition of the breeder hens. Nasr *et al.* (2011) observed that dietary energy level had an effect on hatchability of broiler breeder chickens.

Peebles *et al.* (2000) found that increasing dietary energy to 12.3 MJ of ME/kg DM did not affect hatchability in broiler breeder hens. NRC (1994) nutrient requirements indicate that broiler breeder hens should be fed diets containing 12 MJ of ME/kg DM in order to optimize hatchability. Whitehead *et al*. (1989) reported a reduction in egg production and hatchability when broiler breeders were fed on a limited quantity of a diet containing 10.5 MJ of ME/kg DM compared to those containing 11.5 MJ of ME/kg DM.

Faroog *et al*. (2000) reported that egg weight influenced the weight of day old chicks. Too large and too small eggs were reported to cause problems in incubation and adversely affected hatchability. However, Dessie & Olge (1997) reported that energy rather than protein is the major limiting nutrient in the diets of indigenous hens.

2.5 Effect of dietary energy level on egg weight

The weight of the shell, albumen and yolk contribute significantly to egg weight and are influenced by the nutrition of the hen. Some researchers have reported that increasing dietary energy level in hens increases egg weight (Harms *et al*., 2000; Perez-Bonilla *et al.*, 2012). In a study by Dessie (1996), it was observed that increasing dietary energy level to 12.6 MJ/kg improved egg weights of indigenous hens. The positive effect of supplementing the diet of indigenous chickens with energy has also been supported by King'ori *et al*. (2004) and Okitoi *et al*. (2006). Rashid *et al*. (1995) had similar findings in ducks, where increasing dietary energy levels resulted in higher egg weights. However, other researchers observed that an increase in energy level in the diets of hens did not have a significant impact on the weight of egg components (Peebles *et al.*, 2000; Zou & Wu, 2005). Adeyemo & Longe (1996) reported that there were no significant differences in egg weight when hens were fed varying dietary energy levels ranging from 10.0 to 11.3 MJ of ME/kg DM. Similarly, Ciftci *et al*. (2003) reported that dietary energy levels have no effect on egg weight. There is no information available on the subject of energy level in the diets of Venda hens.

2.6 Effect of dietary energy level on productivity of the progenies

Improving growth productivity of chickens starts in ensuring proper nutrition of the breeder hen, thus it is important to determine precise nutrient requirements of the breeder hens. Several studies have been conducted to determine the effects of maternal nutrition on growth performance of the progeny of commercial broiler breeder hens (Enting *et al.,* 2007; Peebles *et al.,* 2002). Enting *et al.* (2007) reported that maternal dietary energy level did not affect body weight, daily weight gain and feed conversion ratio of broiler chickens aged one to 21 days. Similarly, Proudfoot & Hulan

(1987) reported that energy level of maternal diets did not affect live weight nor feed conversion ratio of broiler chickens aged one to 21 days. Spratt & Leeson (1987), also, did not find effects of maternal energy level on feed conversion ratio of the progeny chickens aged 21 to 42 days. However, Zhu *et al.* (2012) reported that maternal dietary energy level interacted with maternal dietary crude protein. Thus, increases in both nutrients resulted in improvements in growth performance of the progeny aged one to 21 days.

Zhu *et al.* (2012) found that carcass characteristics of the broiler breeder progenies aged 66 days were not affected by maternal dietary energy level. These authors further reported that the shear force, intramuscular fat and diameter of breast muscle fibres were, also, not affected by maternal dietary energy level. Information on effect of maternal dietary energy level growth performance of Venda chickens is not available.

2.7 Conclusion

Information on the effect of energy level in the diets of hens on egg production and hatchability and subsequent productivity of the chicks is limited and not conclusive. No studies on the effect of energy level in the diets of Venda hens on egg production and hatchability and subsequent productivity of the chicks was found. Thus, there was need to do more studies on the effects of energy level in the diets of Venda hens on egg production and hatchability and subsequent productivity of the chicks.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study site

The study was conducted at the University of Limpopo Experimental Farm (Syferkuil), Limpopo Province, South Africa. The farm is located 10 km northwest of the Turfloop Campus. Ambient temperatures around the study area were between 20 and 37 ^{0}C during the summer and around 25 ^{0}C or lower during winter seasons. The average annual rainfall was between 446.8 and 468.4 mm.

3.2 Preparation of the house

The hatchery and experimental houses were thoroughly cleaned with water and disinfected with chemicals (Jeyes fluid) and then left to dry for seven days. The houses were left empty for one week after cleaning to break the life cycle of any disease causing organisms that were not killed by the disinfectant. The incubator and all the equipment such as drinkers, feeders and wire separators were cleaned thoroughly and disinfected before the start of the experiment. The footbath was thoroughly cleaned and a new disinfectant added daily.

3.3 Acquisition of the materials and birds

All the required materials (medicines, vaccines and chemicals) for the experiment were purchased in advance prior to the commencement of the study. A total of 100 laying indigenous Venda hens produced at the University of Limpopo Experimental Farm (Syferkuil) were used in this study.

3.4 Experimental design, treatments and procedures

The first part of the study determined the effect of energy level in the diets of indigenous Venda hens on egg production, hatchability and chick hatch-weight. One hundred laying Venda hens aged 33 weeks, were randomly assigned to four dietary treatments in a completely randomized design. The experiment had four treatments replicated five times, resulting in a total of 20 floor pens of 5 birds each. Experimental diets were formulated using WinFEED 3 Feed formulator (EFG software); Table 3.01 shows ingredients used. The birds were offered *ad libitum* feed and fresh water. The daily lighting program was 17 hours. The treatments were as follows:

$CP_{15}E_{10}$: Diet containing 15 % CP and 10 MJ of ME/kg DM

$CP_{15}E_{10.5}$: Diet containing 15 % CP and 10.5 MJ of ME/kg DM

$CP_{15}E_{11}$: Diet containing 15 % CP and 11 MJ of ME/kg DM

$CP_{15}E_{11.5}$: Diet containing 15 % CP and 11.5 MJ of ME/kg DM

The second part of the study determined the effect of energy level in the diets of indigenous Venda hens on productivity of the progeny chickens aged one to seven weeks. A total of 120 chicks were assigned to four treatments in a completely randomized design. Treatments were replicated 5 times, each replicate having 6 chicks. These were the chicks hatched from eggs obtained during the first part of the study and had an average weight of 38 ± 1.3 g. All the unsexed chicks were fed the same grower diet having 20 % crude protein and 11 MJ of ME/kg DM which met NRC requirements for indigenous chickens (NRC, 1994). The chickens were raised up to seven weeks of age. Thus, the treatments were as follows:

$CP_{15}E_{10}$: Unsexed chickens hatched from eggs produced by Venda hens fed a diet containing 15 % CP and 10 MJ of ME/kg DM

$CP_{15}E_{10.5}$: Unsexed chickens hatched from eggs produced by Venda hens fed a diet containing 15 % CP and 10.5 MJ of ME/kg DM

$CP_{15}E_{11}$: Unsexed chickens hatched from eggs produced by Venda hens fed a diet containing 15 % CP and 11 MJ of ME/kg DM

$CP_{15}E_{11.5}$: Unsexed chickens hatched from eggs produced by Venda hens fed a diet containing 15 % CP and 11.5 MJ of ME/kg DM

The third part of the study determined the effect of energy level of the diets of indigenous Venda hens on the productivity and carcass characteristics of the progeny chickens aged eight to 13 weeks. A total of 120 chickens were used in the study, 65 males and 55 females. The chickens had an average weight of 591.3 ± 63.73 g. A 2 (sexes) x 4 (dietary energy levels of the hens) factorial arrangement in a completely randomized design was used to determine the effect of sex and dietary energy level on feed intake, growth, mortality and carcass characteristics of indigenous Venda chickens aged between eight and thirteen weeks. The treatments were as follows:

$MCP_{15}E_{10}$: Male chickens hatched from eggs produced by Venda hens fed a diet containing 15% CP and 10 MJ of ME/kg DM

$MCP_{15}E_{10.5}$: Male chickens hatched from eggs produced by Venda hens fed a diet containing 15% CP and 10.5 MJ of ME/kg DM

$MCP_{15}E_{11}$: Male chickens hatched from eggs produced by Venda hens fed a diet containing 15% CP and 11 MJ of ME/kg DM

$MCP_{15}E_{11.5}$: Male chickens hatched from eggs produced by Venda hens fed a diet containing 15% CP and 11.5 MJ of ME/kg DM

$FCP_{15}E_{10}$: Female chickens hatched from eggs produced by Venda hens fed a diet containing 15 % CP and 10 MJ of ME/kg DM

$FCP_{15}E_{10.5}$: Female chickens hatched from eggs produced by Venda hens fed a diet containing 15 % CP and 10.5 MJ of ME/kg DM

$FCP_{15}E_{11}$: Female chickens hatched from eggs produced by Venda hens fed a diet containing 15 % CP and 11 MJ of ME/kg DM.

$FCP_{15}E_{11.5}$: Female chickens hatched from eggs produced by Venda hens fed a diet containing 15 % CP and 11.5 MJ of ME/kg DM.

3.5 Data collection and chemical analysis

All eggs were weighed during the collection period. An average weight was determined for each replication. Two eggs from each replicate were used to determine egg contents. Egg albumen and yolk weights were determined and analysed for nitrogen and calcium. Egg hatchability was determined after 21 days of egg incubation. The hatchability percentage was determined in each replicate by dividing the number of hatched eggs by the total number of eggs set and then multiplying by one hundred. An electronic weighing scale was used to weigh the chicks in each replicate within 24 hours after hatching. Voluntary feed intake was measured by subtracting the weight of the leftovers from that of feed offered per week, and the difference was divided by the number of the birds per pen. Thus, daily feed intake per bird was calculated from these values. Mortality of the chickens was recorded daily. Feed conversion ratio was calculated by dividing the average feed intake by the average weight gain in each pen. Digestibility was carried out when chickens were between 42 and 49 days and between 84 and 91 days old for the second and third parts of the study, respectively. Digestibility was conducted in specially designed metabolic cages having separated watering and feeding troughs. Two birds were randomly selected from each replicate and transferred to metabolic cages for measurement of apparent digestibility. A three day acclimation period was allowed prior to a three-day collection period. Droppings voided by each bird were collected on a daily basis at 10.00 hours. Care was taken to avoid contamination from feathers, scales, debris and feeds

At 13 weeks of age all the remaining Venda chickens per pen were weighed on an electronic scale to obtain the live weight and then slaughtered, thereafter, carcass weights of the chickens were measured. Dressing percentage was calculated by dividing carcass weight by the live weight times a hundred. Breast, thigh, drumstick, wings, liver, gizzard, carcass weight, fat pad and heart weights were measured.

Dry matter contents of feeds, feed refusals, faeces and meat samples were determined by drying the samples at a temperature of 105 ^{0}C for 48 hours. Nitrogen contents of feed, feed refusals, egg and meat samples were determined using the Kjedahl method (AOAC, 2000). Gross energy values of feeds and faeces were measured using a bomb calorimeter (AOAC, 2000). Thus, apparent metabolisable energy determined by subtracting the energy excreted in the faeces from the energy in the feed consumed (AOAC, 2002). Calcium and phosphorus were analysed using the method described by Schroeder (1994).

Table 3.01 Ingredients used in diet formulation

Ingredients (%)	Diet			
	$CP_{15}E_{10}$	$CP_{15}E_{10.5}$	$CP_{15}E_{11}$	$CP_{15}E_{11.5}$
Maize	64.00	64.20	63.60	63.00
Maize gluten meal	10.85	11.67	11.83	11.23
Fish meal	5.01	5.12	4.89	4.99
Soya Hi Pro	4.35	4.28	4.25	4.17
Full fat soya	4.87	4.92	4.71	4.80
Sunflower oil	0.21	0.31	0.38	0.52
Di-Sodium phosphate	1.30	1.35	1.27	1.30
DL-Methionine	0.20	0.20	0.20	0.20
L-Lysine HCL	0.20	0.20	0.20	0.20
Vitamin/Mineral premix	0.15	0.15	0.15	0.15
Crude protein	15.0	15.0	15.0	15.0
Energy (MJ of ME/kg DM)	10.0	10.5	11.0	11.5

3.6 Data analysis

The effects of energy level in the diet of Venda hens on egg production, hatchability and subsequent productivity of the chickens were analyzed using the General Linear Model procedure of the Statistical Analysis System (SAS, 2008). The Least Significant Differences (LSD) test for multiple comparison was used to test the significance of differences between treatment means ($P<0.05$) (SAS, 2008). The responses in intake, feed conversion ratio, growth rate, live weight and carcass characteristics to energy level of the diet were modelled using the following quadratic equation:

$$Y = a + b_{1X} + b_{2X}^2$$

Where Y = optimum feed intake, feed conversion ratio, egg production, hatchability, chick hatch-weight, growth rate, live weight, mortality rate and carcass characteristics;

a = intercept; b = coefficients of quadratic equation; x = dietary energy level and $-b_1/2b_2$ = x value for optimum response. The quadratic model was fitted to the experimental data by means of NLIN procedure of SAS (2008). The quadratic model was used because it gave the best fit.

The relationships between egg production, hatchability and chick hatch-weight of Venda chickens and energy level of the diet were modelled using a linear regression equation (SAS, 2008) of the form:

$$Y = a + bx$$

Where y = egg production, hatchability or chick hatch-weight; a = intercept; b = coefficient of the linear equation; x = dietary energy level.

CHAPTER 4

RESULTS

Results of the effect of energy level in the diets of Venda hens on feed intake, egg weight, egg production, egg hatchability and chick hatch-weight are presented in Table 4.01. Indigenous Venda hens on a diet having 11 MJ of ME/kg DM ate more ($P<0.05$) feed than those on diets having 10, 10.5 or 11.5 MJ of ME/kg DM. Similarly, hens on a diet containing 10.5 MJ of ME/kg DM had higher ($P<0.05$) feed intakes than those on diets containing 10.0 or 11.5 MJ of ME/kg DM. However, Venda hens on diets containing 10 or 11.5 MJ of ME/kg DM had similar ($P>0.05$) feed intakes. Indigenous Venda hens on a diet having 10.5 MJ of ME/kg DM produced heavier ($P<0.05$) eggs than those on diets having 10, 11 or 11.5 MJ of ME/kg DM. Hens on a diet containing 11.5 MJ of ME/kg DM produced heavier ($P<0.05$) eggs compared to those from hens on diets containing 10 or 11 MJ of ME/kg DM. However, Venda hens on diets having 10 or 11 MJ of ME/kg DM produced eggs with similar ($P>0.05$) weights. Venda hens on diets containing 11 or 11.5 MJ of ME/kg DM produced more ($P<0.05$) eggs than those on diets containing 10 or 10.5 MJ of ME/kg DM. Similarly, Venda hens on a diet containing 10 MJ of ME/kg DM produced more ($P < 0.05$) eggs than those on a diet containing 10.5 MJ of ME/kg DM.

Hens on a diet of 11.5 MJ of ME/kg produced eggs with higher ($P<0.05$) hatchability values than those produced by hens on diets containing 10, 10.5 or 11 MJ of ME/kg DM. Venda hens on diets containing 10.5 or 11 MJ of ME/kg DM produced eggs with higher ($P<0.05$) hatchability values than those on a diet having 10 MJ of ME/kg DM. However, hens on diets having 10.5 or 11 MJ of ME/kg DM produced eggs with similar ($P>0.05$) hatchability values.

Venda hens on a diet containing 10 MJ ME/kg DM produced eggs with higher ($P<0.05$) chick hatch-weights than those on diets having 10.5, 11 or 11.5 MJ of ME/kg DM. However, hens on diets having 10.5 or 11 MJ of ME/kg DM produced eggs with similar ($P>0.05$) chick hatch–weights, their hatch-weights were, however, higher ($P<0.05$) than those on a diet containing 1.5 MJ ME/kg DM. Feed intake and egg weight of Venda hens were optimized at dietary energy levels of 10.70 ($r^2 = 0.985$) and 10.70 ($r^2 = 0.246$) MJ of ME/kg DM, respectively (Figures 4.01 and 4.02, respectively and Table 4.02).

A strong (r^2 = 0.728) and positive relationship existed between energy level in the diets of Venda hens and egg production (Figure 4.03 and Table 4.03). Similarly, there was a strong (r^2 = 0.995) and positive relationship between energy level in the diets of Venda hens and egg hatchability (Figure 4.04 and Table 4.03). However, there was a strong (r^2 = 0.884) but negative relationship between energy level in the diets of Venda hens and chick hatch-weight (Figure 4.05 and Table 4.04).

Results of the effect of dietary energy level in the diets of Venda hens on egg albumen, yolk and shell weights are presented in Table 4.04. Venda hens on a diet containing 10.5 MJ of ME/kg DM produced eggs that had higher ($P<0.05$) albumen weights than those on diets having 10, 11 or 11.5 MJ of ME/kg DM. However, hens on diets having 10, 11 or 11.5 MJ of ME/kg DM produced eggs which had similar ($P>0.05$) albumen weights. Venda hens on a diet having 10.5 MJ ME/kg DM produced eggs with higher ($P<0.05$) yolk weights than those on diets containing 10 or 11 MJ ME/kg DM. However, hens on diets having 10.5 or 11.5 MJ ME/kg DM produced eggs which had the same egg yolk weights. Similarly, hens that were on diets having 10, 11 or 11.5 MJ ME/kg DM produced eggs with the same ($P>0.05$) yolk weights. Venda hens that were fed a diet containing 10.5 MJ ME/kg DM produced eggs which had higher ($P<0.05$) shell weights than eggs from hens that were fed a diet containing 10 MJ ME/kg DM. However, eggs produced by hens fed diets containing 10.5, 11 or 11.5 MJ ME/kg DM had similar ($P>0.05$) egg shell weights. Similarly, hens on diets having 10, 11 or 11.5 MJ ME/kg DM produced eggs that had the same ($P>0.05$) shell weights.

Egg albumen, yolk and shell weights were optimized at dietary energy levels of 10.55 (r^2 = 0.279), 10.85 (r^2 = 0.128) and 10.95 (r^2 = 0.863) MJ of ME/kg DM, respectively (Figures 4.06, 4.07 and 4.08, respectively and Table 4.05).

Energy level in the diet of Venda hens had no effect ($P<0.05$) on egg albumen nitrogen, yolk nitrogen, shell calcium and shell phosphorus contents (Table 4.06).

Table 4.01 Effect of energy level in the diet of indigenous Venda hens on feed intake (g/bird/day), egg weight (g/egg), egg production (eggs/hen/14 days), egg hatchability (%) and chick hatch- weight (g/bird) of Venda chickens

Diet code	Variable				
	Feed intake	Egg weight	Egg production	Hatchability	Chick hatch-weight
$CP_{15} E_{10}$	100^c	54.3^c	5.75^b	46.92^c	20.65^a
$CP_{15} E_{10.5}$	115^b	60.88^a	4.75^c	56.25^b	18.44^b
$CP_{15} E_{11}$	117^a	54.46^c	9.25^a	62.70^b	18.38^b
$CP_{15} E_{11.5}$	101^c	55.75^b	9.75^a	72.35^a	17.05^c
SE	4.498	0.399	0.250	2.680	0.177

a, b, c : Means in the same column not sharing a common superscript are significantly different (P<0.05).

SE : Standard error

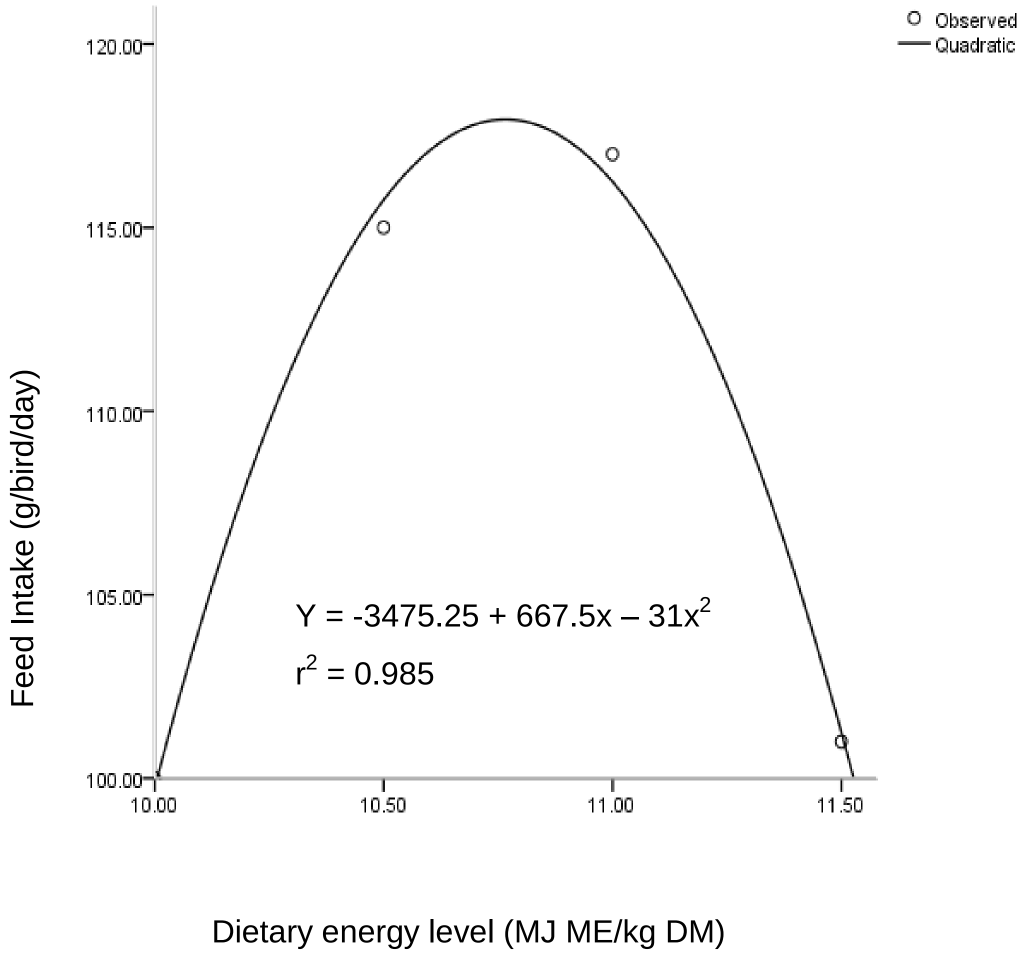

Figure 4.01 Effect of energy level in the diet on feed intake of Venda hens

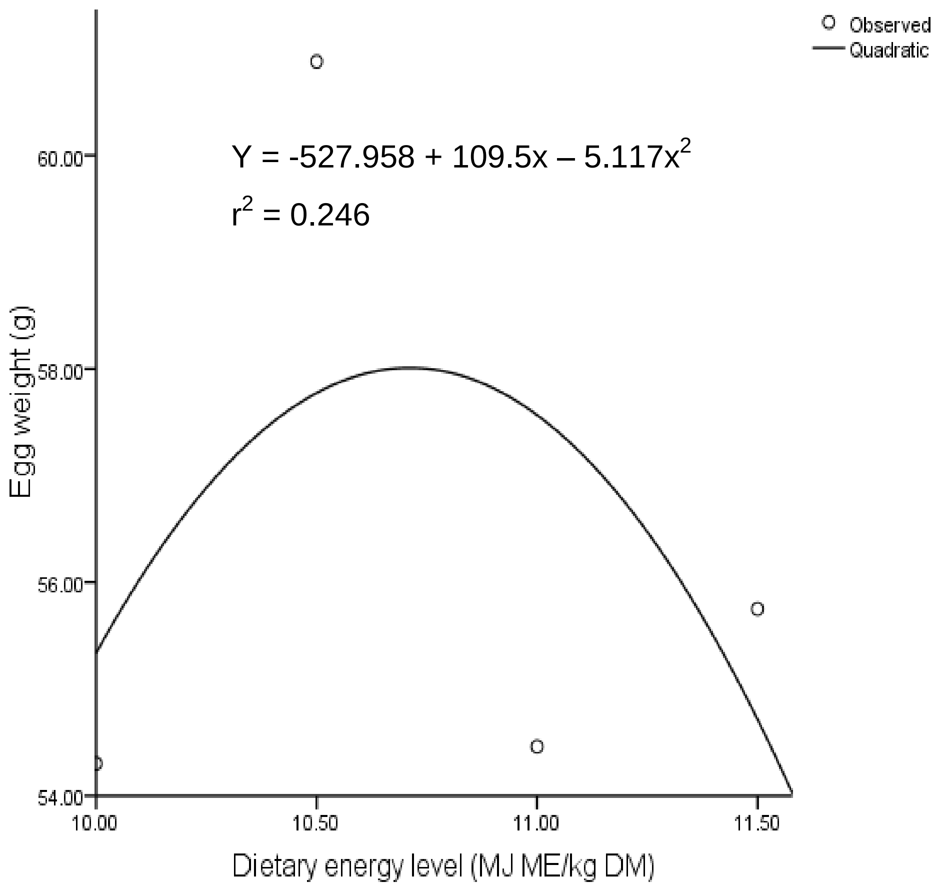

Figure 4.02 Effect of energy level in the diet of Venda hens on egg weight

Table 4.02 Dietary energy levels (MJ ME/kg DM) for optimal feed intake and egg weight (g/egg) of Venda hens

Trait	Formula	r^2	X	Optimal Y-level
Feed intake	$Y= -3475.25 + 667.5x – 31x^2$	0.985	10.70	118
Egg weight	$Y= -527.958 + 109.5x - 5.117x^2$	0.246	10.70	57.9

r^2 : Coefficient of determination

X : Dietary energy level for optimal production

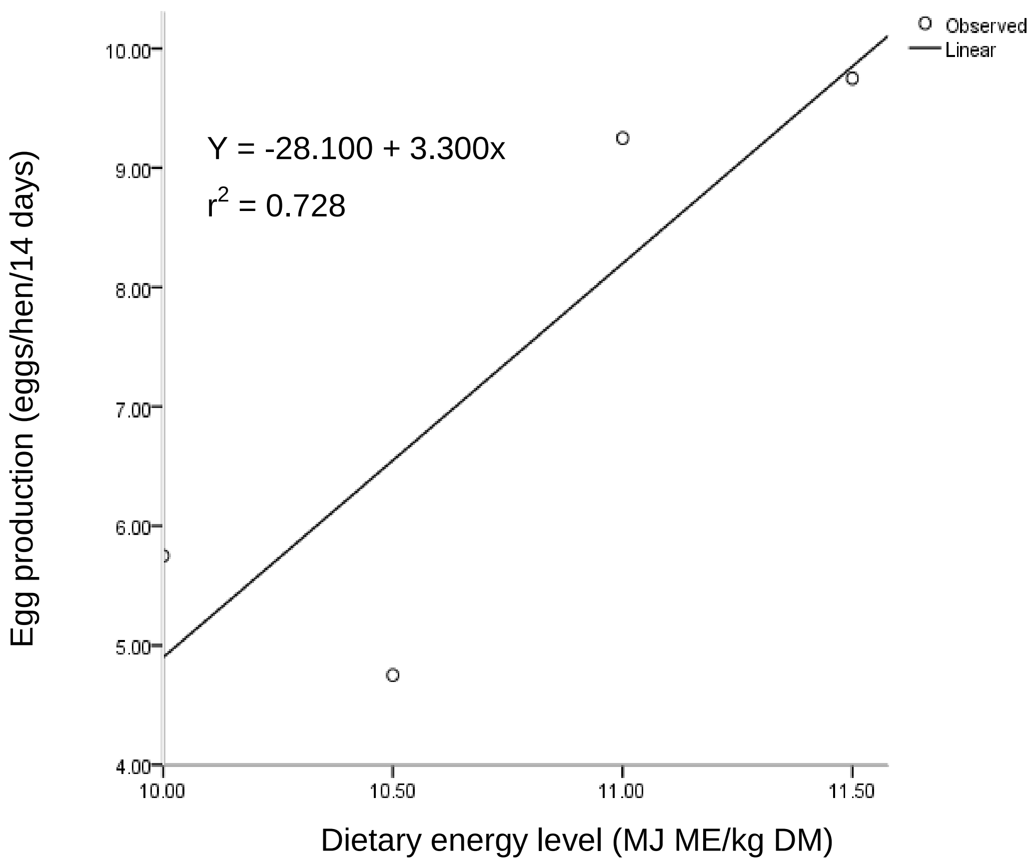

Figure 4.03 Relationship between energy level in the diet of Venda hens and egg production

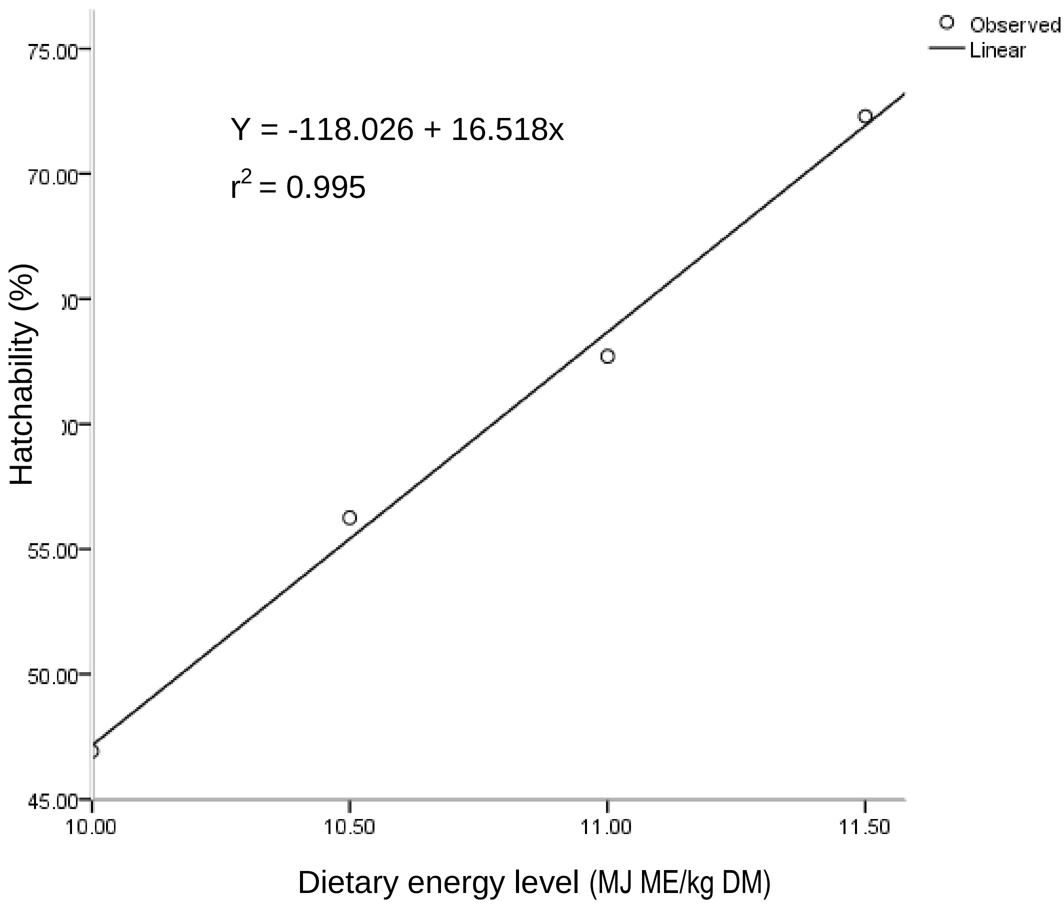

Figure 4.04 Relationship between dietary energy level and hatchability of Venda hen eggs

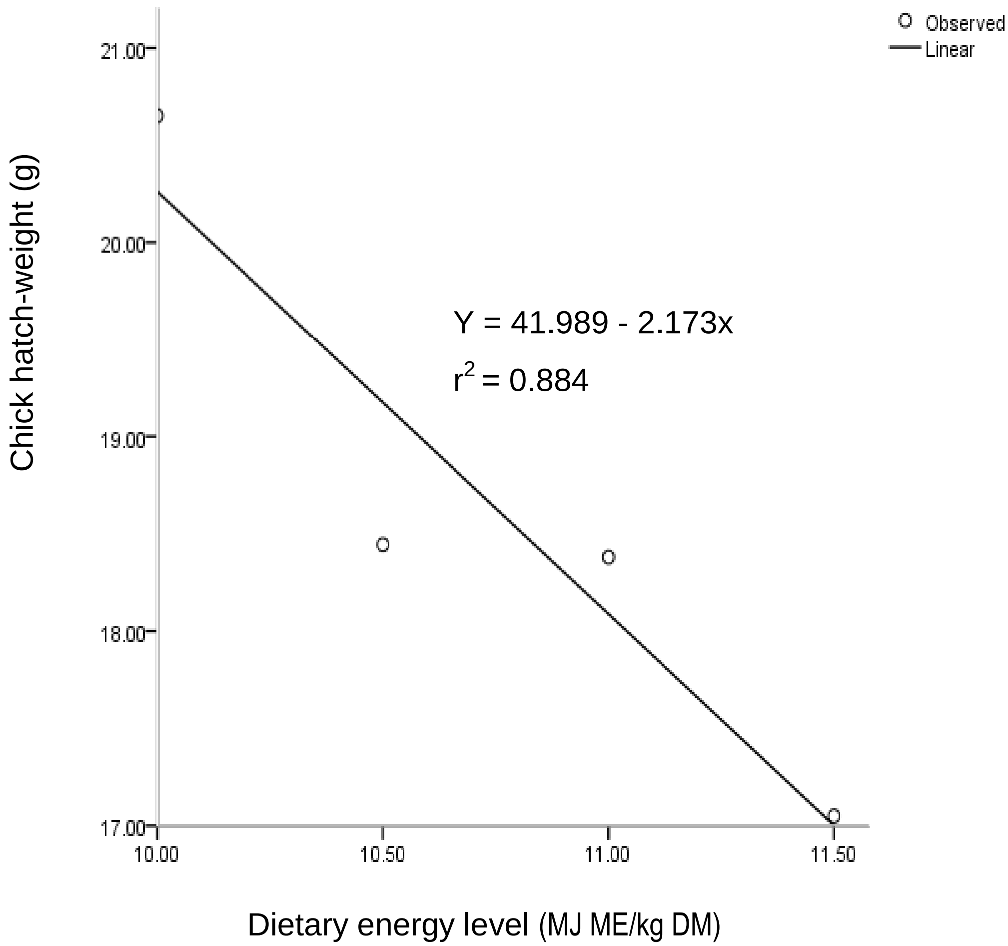

Figure 4.05 Relationship between energy level in the diet of Venda hens and chick hatch-weight

Table 4.03 Relationship between energy level (MJ ME/kg DM) in the diet of Venda hens and egg production (eggs/hen/14 days), egg hatchability (%) and chick hatch-weight (g/bird)

Trait	Formula	r^2	Significance
Egg production	Y = -28.100 + 3.300x	0.728	0.147
Egg hatchability	Y = -118.026 + 16.518x	0.995	0.003
Chick hatch-weight	Y = 41.989 - 2.173x	0.884	0.60

r^2: Coefficient of determination

Table 4.04 Effect of energy level in the diet of indigenous Venda hens on egg albumen, yolk and shell weights (g)

Diet code		Variable	
	Albumen	Yolk	Shell
$CP_{15}E_{10}$	27.9^b	20.4^b	6.3^b
$CP_{15}\ E_{10.5}$	31.6^a	22.2^a	6.9^a
$CP_{15}\ E_{11}$	26.8^b	20.5^b	6.8^{ab}
$CP_{15}\ E_{11.5}$	27.6^b	21.3^{ab}	6.8^{ab}
SE	0.620	0.416	0.166

$^{a,\ b}$: Means in the same column not sharing a common superscript are significantly different (P<0.05).

SE : Standard error

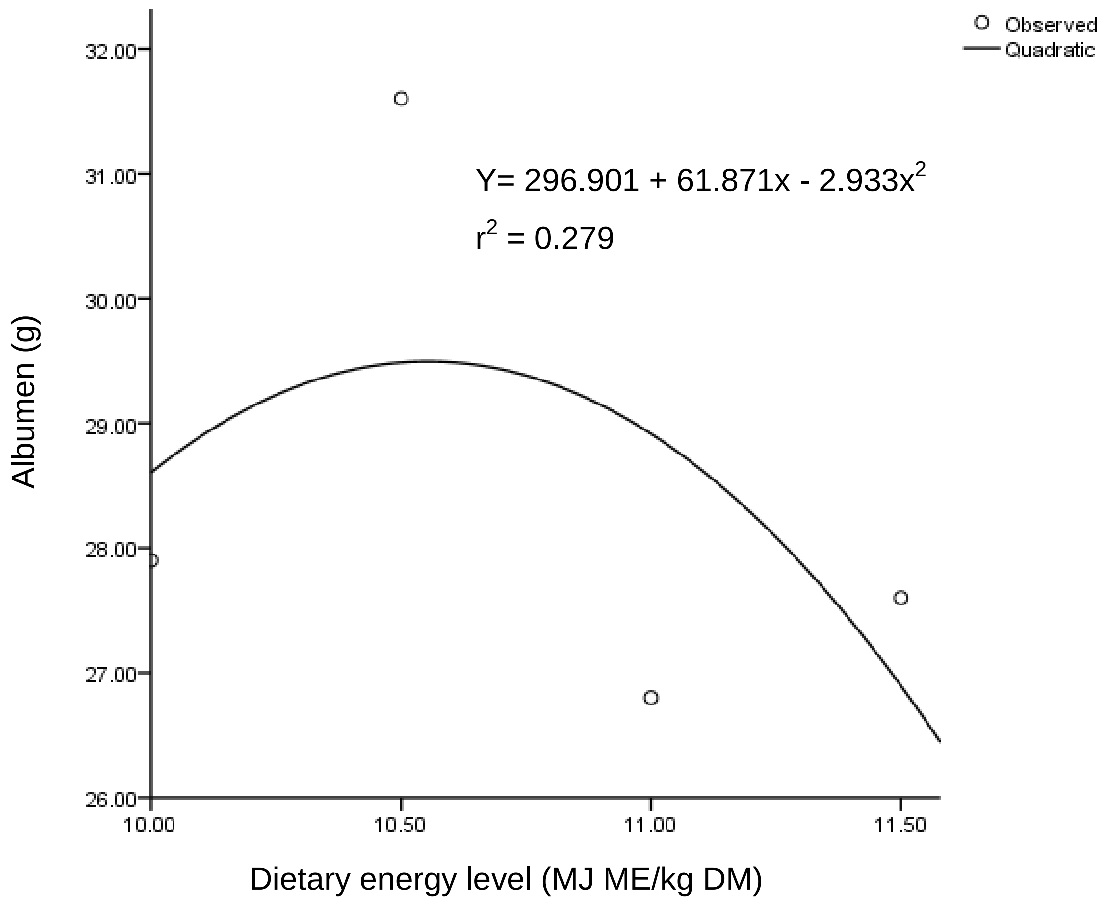

Figure 4.06 Effect of energy level in the diet of Venda hens on egg albumen weight

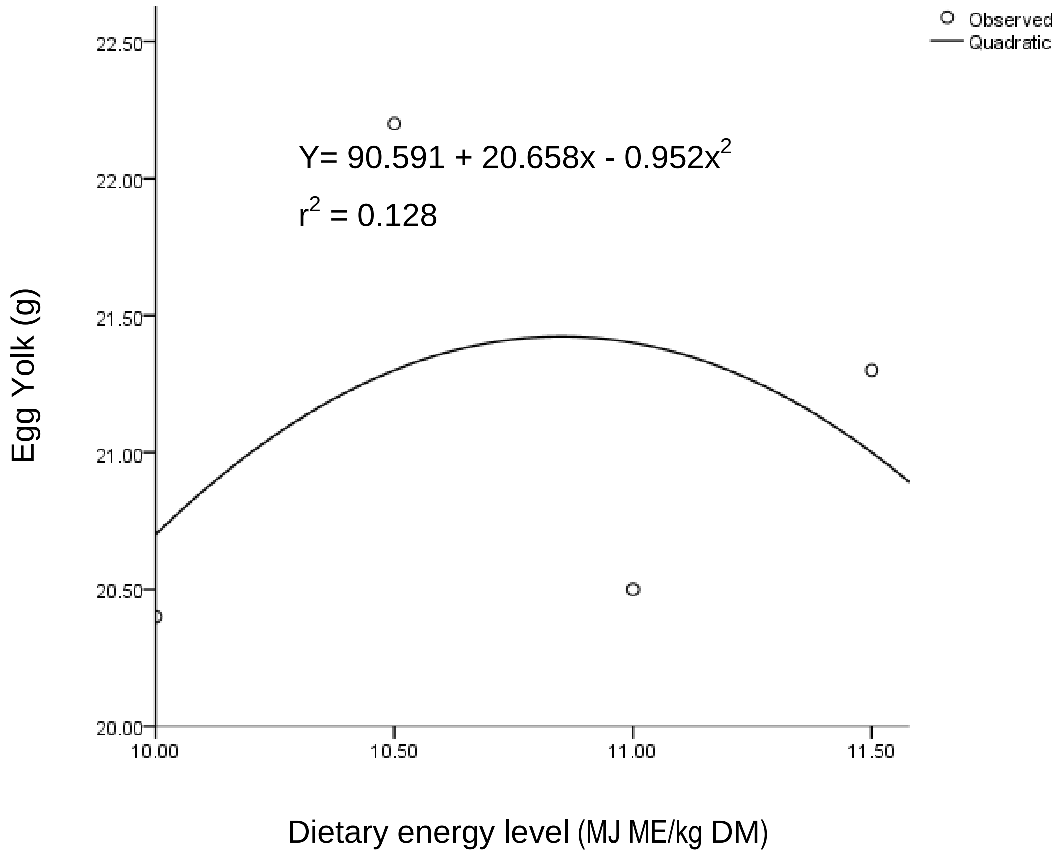

Figure 4.07 Effect of energy level in the diet of Venda hens on egg yolk weight

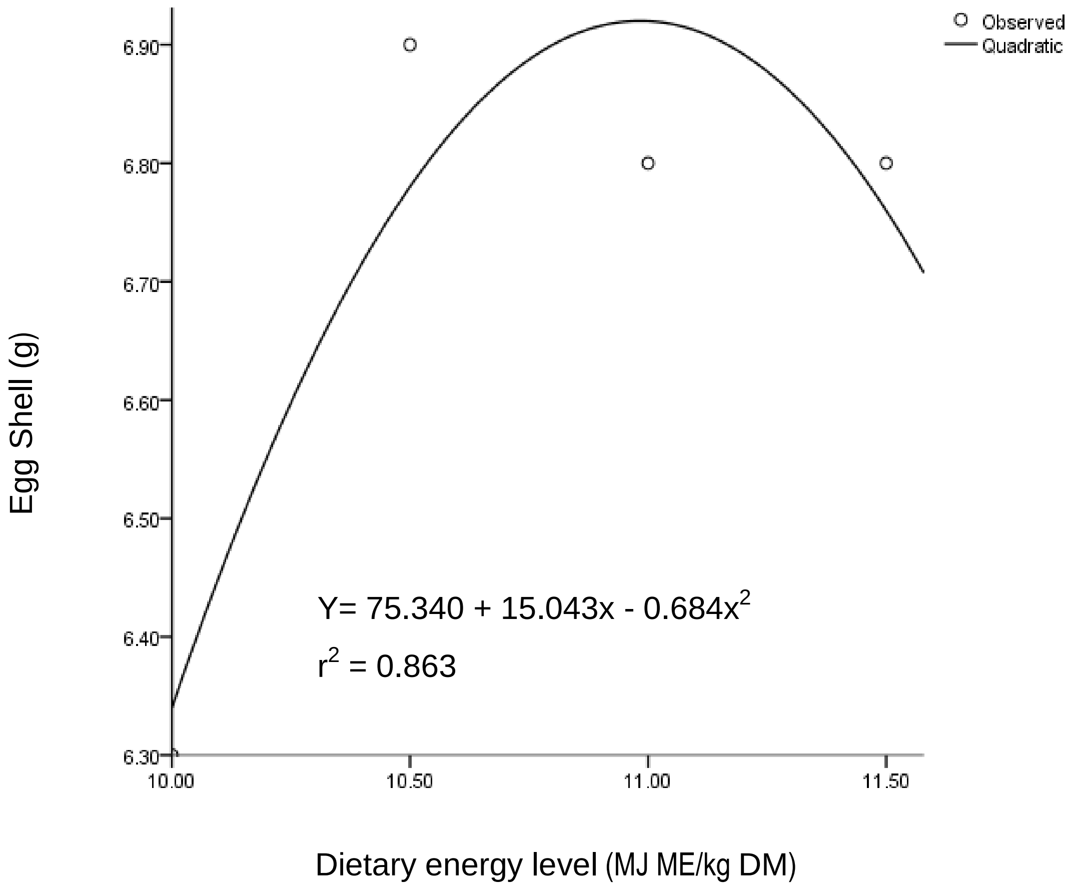

Figure 4.08 Effect of energy level in the diet of Venda hens on egg shell weight

Table 4.05 Dietary energy levels (MJ ME/kg DM) for optimal egg albumen, yolk and shell weights of Venda hens

Trait	Formula	r^2	X	Optimal Y-level
Albumen	$Y = 296.901 + 61.871x - 2.933x^2$	0.279	10.548	29.452
Yolk	$Y = 90.591 + 20.658x - 0.952x^2$	0.128	10.849	21.484
Shell	$Y = 75.340 + 15.043x - 0.684x^2$	0.863	10.948	6.999

r^2: Coefficient of determination

X: Dietary energy level for optimal production

Table 4.06 Effect of energy level in the diet of Venda hens on egg albumen nitrogen, yolk nitrogen, shell calcium (Ca) and shell phosphorus (P) contents (% on dry basis)

Diet code	Variable			
	Albumen N	Yolk N	Shell Ca	Shell P
$CP_{15} E_{10}$	12.56	6.25	46.88	0.07
$CP_{15} E_{10.5}$	12.43	5.62	48.54	0.06
$CP_{15} E_{11}$	13.48	4.29	46.77	0.07
$CP_{15} E_{11.5}$	13.5	5.55	50.41	0.07
SE	0.18	0.10	1.32	0.00

SE : Standard error

Results of the effect of energy level in the diets of indigenous Venda hens on feed intake, growth rate, live weight and feed conversion ratio of their progenies aged one to seven weeks are presented in Table 4.07. Energy level in the diets of indigenous Venda hens had no effect (P>0.05) on feed intake of the progenies aged one to 7 weeks. Venda chickens hatched from eggs produced by hens on diets with 10.5, 11 or 11.5 MJ/kg DM had higher (P<0.05) growth rates than those hatched from eggs produced by hens on a diet with 10 MJ/kg DM. However, Venda chickens hatched from eggs produced by hens on diets with 10.5, 11 or 11.5 MJ/kg DM had similar (P>0.05) growth rates.

Venda chickens hatched from eggs produced by hens on a diet with 10.5 MJ/kg DM were heavier (P<0.05) than those from eggs produced by hens on diets with 10, 11 or 11.5 MJ/kg DM. However, Venda chickens hatched from eggs produced by hens on diets with 10, 11 or 11.5 MJ/kg DM feed had similar (P>0.05) live weights at 49 days of age. Venda chickens hatched from eggs produced by hens on diets with 11 or 11.5 MJ/kg DM had better (P<0.05) feed conversion ratios than those from eggs produced by hens on diets with 10 or 10.5 MJ/kg DM. Similarly, chickens hatched from eggs produced by hens on a diet with 10.5 MJ of ME/kg DM had a better (P<0.05) feed conversion ratio than those from eggs produced by hens on a diet with 10 MJ of ME/kg DM. Live weight, growth rate and feed conversion ratio of Venda chickens were optimized at energy levels of the diets of hens of 10.73 (r^2 = 0.554), 11.2 (r^2 = 0.950) and 11.5 (r^2 = 1.000) MJ ME/kg DM, respectively (Figures 4.09, 4.10 and 4.11, respectively and Table 4.08)

Energy level in the diets of Venda hens had no effect (P>0.05) on diet digestibility, metabolisable energy and nitrogen retention of their progenies aged seven weeks (Table 4.09).

Table 4.07 Effect of energy level in the diet of Venda hens on live weight aged seven weeks (g/bird), feed intake (g/bird/day), growth rate (g/bird/day) and feed conversion ratio (FCR) (g feed/g live weight gain) of the unsexed progenies aged one to seven weeks

Diet code	Variable				
	Intake	Mortality	Growth rate	Live weight	FCR
CP_{15} E_{10}	38.9	0.45	6.1^{b}	509^{b}	6.4^{a}
CP_{15} $E_{10.5}$	41.2	0.44	6.9^{a}	733^{a}	5.9^{b}
CP_{15} E_{11}	40.0	0.42	7.1^{a}	576^{b}	5.6^{c}
CP_{15} $E_{11.5}$	39.9	0.45	7.2^{a}	547^{b}	5.5^{c}
SE	0.47	0.003	0.25	43.16	0.20

$^{a, b, c}$: Means in the same column not sharing a common superscript are significantly different (P<0.05).

SE : Standard error

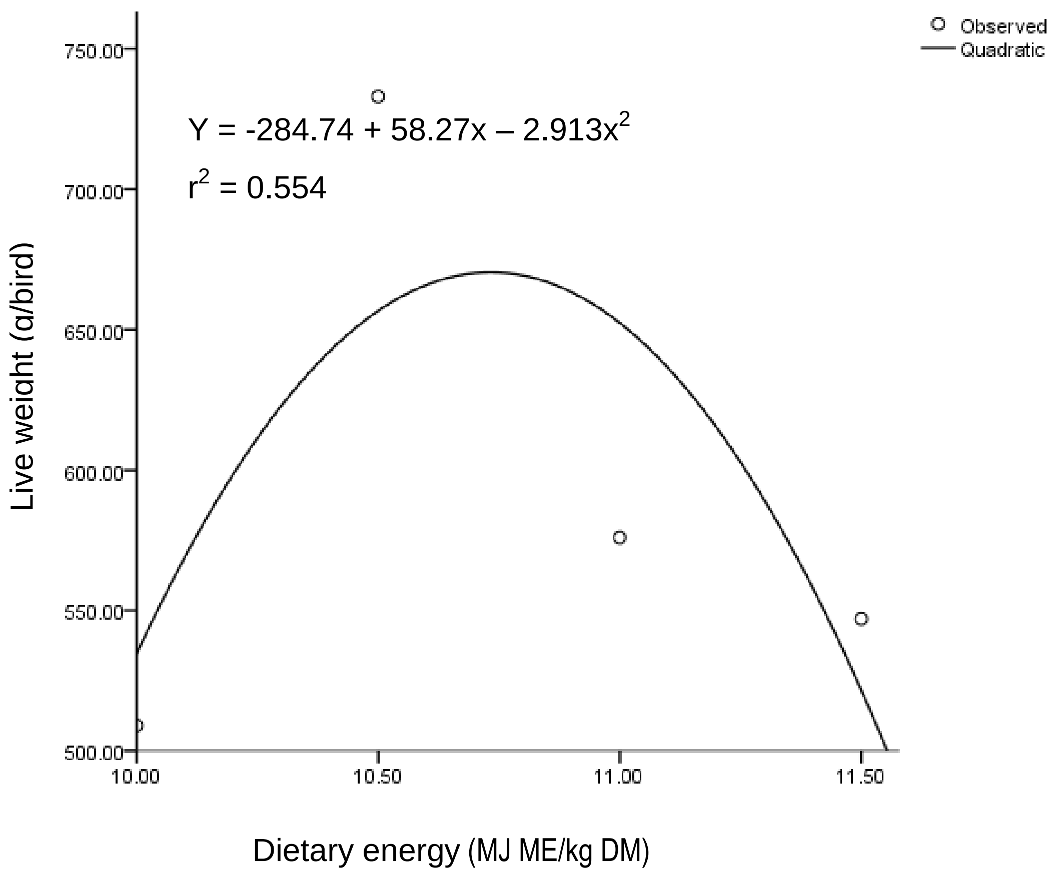

Figure 4.09 Effect of energy level in the diet of Venda hens on live weight of unsexed progenies aged one to seven weeks

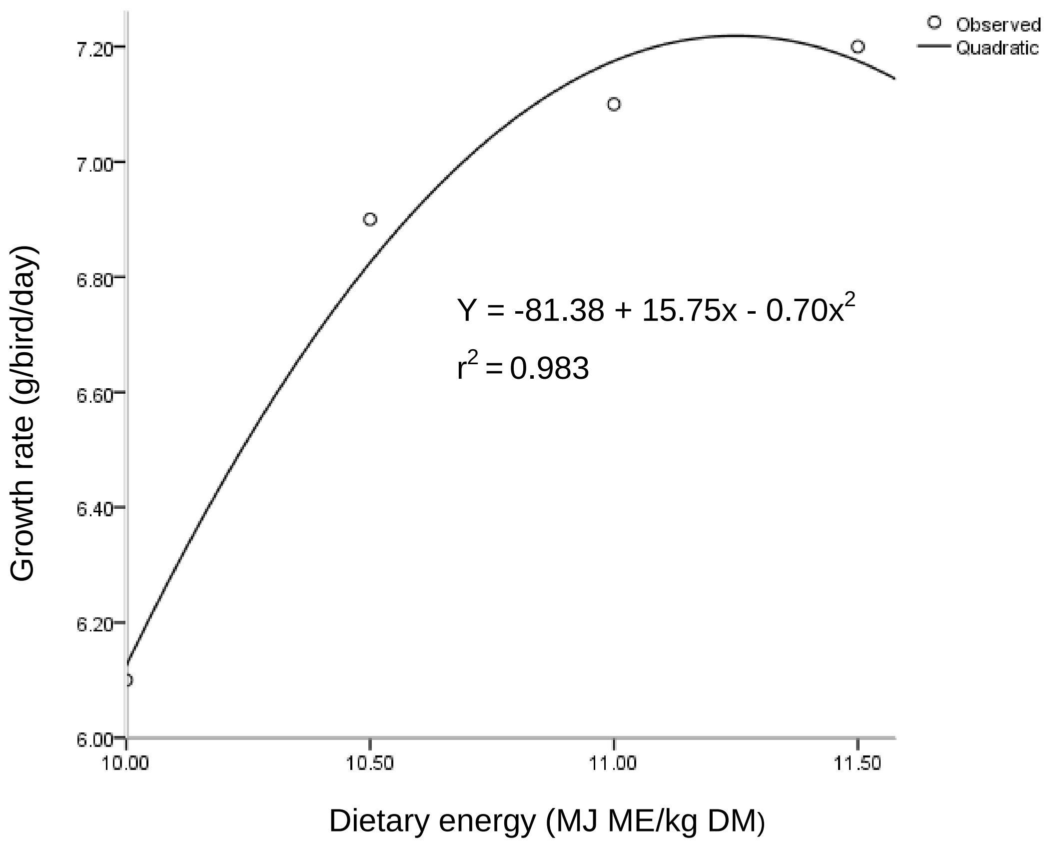

Figure 4.10 Effect of energy level in the diet of Venda hens on growth rate of the unsexed progenies aged one to seven weeks

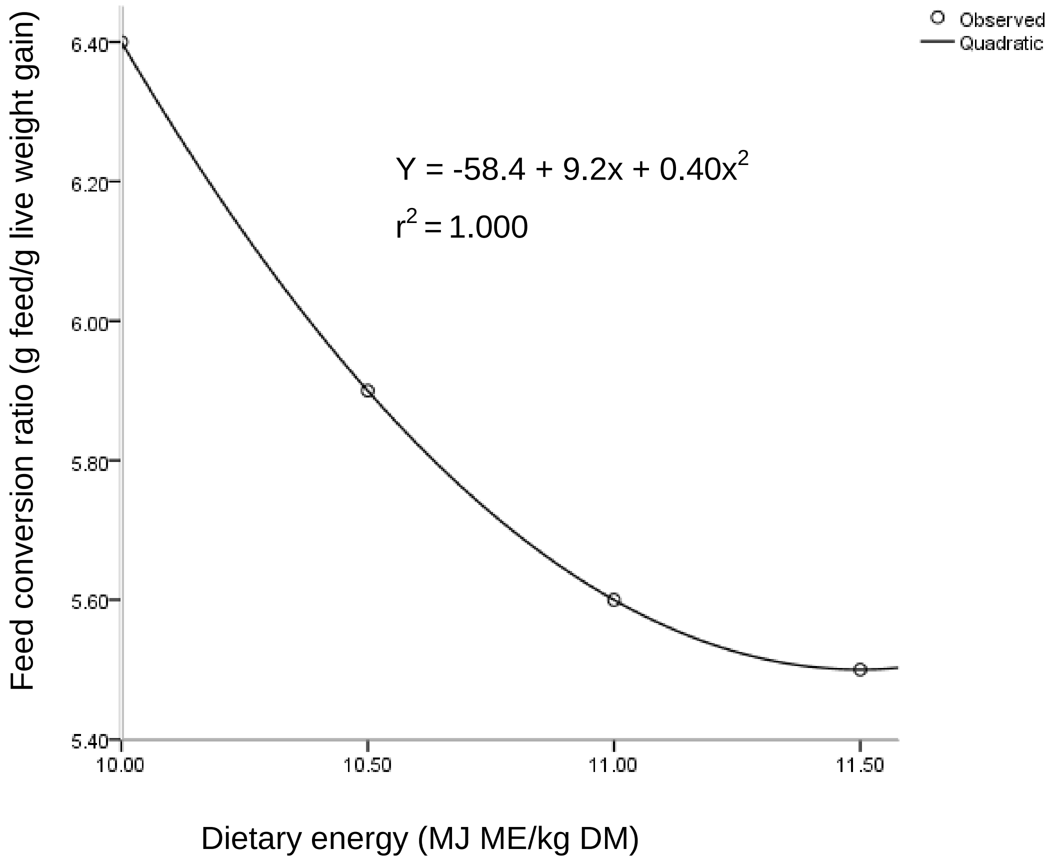

Figure 4.11 Effect of energy level in the diet of Venda hens on feed conversion ratio of unsexed progenies aged one to seven weeks

Table 4.08 Energy levels (MJ ME/kg DM) in the diets of Venda hens for optimal feed intake (g/bird/day), growth rate (g/bird/day) and feed conversion ratio (FCR) (g feed/g live weight gain) of the unsexed progenies aged one to seven weeks

Trait	Formula	r^2	X	Optimal Y-level
Live weight	$Y= 284.74+ 58.27x- 2.913x^2$	0.554	10.73	6.71
Growth rate	$Y= -81.38+ 15.75x - 0.70x^2$	0.950	11.2	7.2
FCR	$Y= -58.4 + 9.2x - 0.40x^2$	1.000	11.5	5.5

r^2: Coefficient of determination

X: Energy level in the diets of Venda hens for optimal production of unsexed progenies aged one to seven weeks

Table 4.09 Effect of energy level in the diet of Venda hens on diet dry matter digestibility (%) metabolisable energy (ME) (MJ/kg DM) and nitrogen retention (g/bird/day) of unsexed chicks aged 7 weeks

Diet code	Variable		
	Dry matter digestibility	Metabolisable energy	Nitrogen retention
$CP_{15}E_{10}$	0.56	11.9	1.49
$CP_{15}E_{10.5}$	0.55	12.6	1.53
$CP_{15}E_{11}$	0.54	11.2	1.64
$CP_{15}E_{11.5}$	0.57	13.7	1.57
SE	0.52	0.39	0.03

$^{a, b, c}$: Means in the same column not sharing a common superscript are significantly different (P<0.05)

SE : Standard error

Results of the effects of energy level in the diets of hens on feed intake, growth rate, live weight and feed conversion ratio of male and female progenies aged 50 to 91 days are presented in Table 4.10. Energy level in the diets of indigenous hens had no effect (P>0.05) on feed intake, live weight, feed conversion ratio and mortality of their male progenies aged 50 to 91 days. However, male Venda chickens hatched from eggs produced by hens on a diet with 11.5 MJ/kg DM had higher (P<0.05) growth rates than those hatched from eggs produced by hens on a diet with 10.5 MJ/kg DM. Male progenies from hens fed diets having 11.5, 10 or 11 MJ ME/kg DM had the same (P>0.05) growth rates. Similarly, male progenies produced by hens fed diets containing 10, 10.5 or 11 MJ ME/kg had the same (P>0.05) growth rates.

Energy level in the diets of Venda hens had no effect (P>0.05) on feed intake, growth rate, live weight, feed conversion ratio and mortality of their female progenies aged eight to 13 weeks. Indigenous Venda male progenies were heavier (P<0.05) than female progenies. Male Venda progenies had improved (P<0.05) feed intake, growth rate and feed conversion ratio than female progenies aged eight to thirteen weeks.

Results of the effect of energy level in the diets of Venda hens on diet dry matter digestibility, metabolisable energy and nitrogen retention of their male and female progenies aged thirteen weeks are presented in Table 4.11. Energy level in the diets of Venda hens had no (P>0.05) effect on dry matter digestibility, apparent metabolisable energy and nitrogen retention of their male and female progenies.

Results of the effect of energy level in the diets of Venda hens on carcass characteristics of male and female progenies aged 91 days are presented in Table 4.12. Energy level in the diets of Venda hens had no (P>0.05) effect on carcass, drumstick, thigh, liver and heart weights of male and female progenies. However, level of energy in the diets of Venda hens had effect (P<0.05) on breast meat, wing, gizzard and fat pad weight of male progeny chickens. All carcass characteristics of female progenies were not affected (P>0.05) by energy level in the diets of Venda hens. Gizzard weights of male chickens produced by Venda hens fed diets containing 10, 11 or 11.5 MJ ME/kg DM were higher (P<0.05) than gizzard weights of chickens produced by Venda hens fed a diet containing 10.5 MJ ME/kg DM. However, gizzard weights of chickens produced by Venda hens fed diets having 10, 11 or 11.5 MJ ME/kg were similar (P>0.05). Male Venda chickens had higher (P>0.05) carcass, breast meat, drumstick, thigh, wing, gizzard and fat pad weights than female chicken progenies aged 91 days. However, liver and heart weights of male and female Venda progenies were similar (P>0.05). Hens on a diet with 10.5 MJ ME/kg DM produced male progenies with lower (P>0.05) breast meat and gizzard weights than male progenies of Venda hens fed diets containing 10, 11 or 11.5 MJ ME/kg DM. However, breast meat and gizzard weights of male progenies from Venda hens fed diets containing 10, 11 or 11.5 MJ ME/kg DM were similar (P>0.05).

Results of the present study show that wing weights of male progenies from Venda hens fed diets containing 10 or 11.5 MJ ME/kg DM were higher (P<0.05) than those of male progenies from Venda hens fed diets having 10.5 or 11 MJ ME/kg DM. However, male progenies produced by Venda hens fed diets containing 10 or 11.5 MJ ME/kg DM had similar (P>0.05) wing weights. Similarly, male progenies of Venda hens fed diets having 10.5 or 11 MJ ME/kg DM had the same (P>0.05) wing weights. Male progenies from Venda hens fed 11 MJ ME/kg DM had higher (P>0.05) fat pad weights than those from Venda hens fed a diet having 10.5 MJ ME/kg DM aged 91 days. However, male progenies hatched from eggs produced by Venda hens fed diets containing 10, 11 or 11.5 had similar (P>0.05) fat pad weights. Similarly, male progenies from Venda hens fed diets containing 10, 10.5 or 11.5 MJ ME/kg DM had the same (P>0.05) fat pad weights.

Table 4.10 Effect of energy level in the diet of Venda hens on live weight at thirteen weeks (g/bird) feed intake (g/bird/day) growth rate (g/bird/day) and feed conversion ratio (FCR) (g feed/g live weight gain) of male and female progenies aged eight to 13 weeks

Diet code	Variable				
	Intake	Mortality	Growth	Live weight	FCR
$CP_{15}E_{10}$	82	0.0	17^{ab}	1600	4.8
$CP_{15}E_{10.5}$	86	0.0	13^{b}	1435	6.6
$CP_{15}E_{11}$	85	0.0	18^{ab}	1660	4.7
$CP_{15}E_{11.5}$	87	0.0	23^{a}	1767	3.7
SE	1.79	0.0	2.58	334.1	0.63
Female					
$CP_{15}E_{10}$	68	0.0	6.7	1122	10.2
$CP_{15}E_{10.5}$	74	0.0	10	1275	7.4
$CP_{15}E_{11}$	72	0.0	6.7	1230	10.7
$CP_{15}E_{11.5}$	70	0.0	9.5	1165	7.4
SE	3.29	0.0	0.95	154.2	0.88
Sex					
Male	85^{a}	0.0	18^{a}	1615^{a}	5^{b}
Female	71^{b}	0.0	8^{b}	1198^{b}	10^{a}
SE	1.32	0.0	1.14	47.3	0.91

$^{a, b, c}$: Means in the same column not sharing a common superscript are significantly different (P<0.05)

SE : Standard error

Table 4.11 Effect of energy level in the diet of Venda hens on apparent diet dry matter digestibility (%) metabolisable energy (MJ/kg DM) and nitrogen retention (g/bird/day) of male and female progenies aged 13 weeks

Diet code	Variable		
	Dry matter digestibility	Metabolisable energy	Nitrogen retention
Male			
CP_{15} E_{10}	0.67	11.3	1.8
CP_{15} $E_{10.5}$	0.73	11.5	2.3
CP_{15} E_{11}	0.68	10.5	1.8
CP_{15} $E_{11.5}$	0.65	10.7	1.7
SE	0.547	1.25	0.61
Female			
CP_{15} E_{10}	0.56	10.73	1.99
CP_{15} $E_{10.5}$	0.71	11.38	2.32
CP_{15} E_{11}	0.69	11.27	2.14
CP_{15} $E_{11.5}$	0.64	10.45	1.95
SE	0.498	0.94	0.38
Sex			
Male	0.68	11.3	2.4
Female	0.68	11.0	2.1
SE	0.230	0.320	0.150

SE : Standard error

Table 4.12 Effect of energy level in the diet of Venda hens on carcass characteristics (g) of male and female Venda chickens aged 91 days

Diet code	Variable								
	Carcass	Breast	Drumstick	Thigh	Wing	Gizzard	Liver	Heart	Fat
Male									
$CP_{15}\,E_{10}$	1180	141^{a}	78	88	84^{a}	20^{a}	15	3.7	7.5^{ab}
$CP_{15}\,E_{10.5}$	1190	103^{b}	71	57	59^{b}	14^{b}	10	3.2	3.0^{b}
$CP_{15}\,E_{11}$	1357	125^{a}	79	82	65^{b}	13^{a}	13	4.6	10.0^{a}
$CP_{15}\,E_{11.5}$	1424	138^{a}	78	88	84^{a}	20^{a}	15	3.7	7.5^{ab}
SE	72.41	5.45	4.2	10.08	3.82	1.73	1.21	0.63	1.90
Female									
$CP_{15}\,E_{10}$	892	88	53	74	56	13	13	2.9	3.1
$CP_{15}\,E_{10.5}$	801	81	52	61	42	13	10	3.0	3.1
$CP_{15}\,E_{11}$	925	83	56	35	45	14	11	2.8	3.1
$CP_{15}\,E_{11.5}$	949	82	53	74	56	13	13	2.8	3.1
SE	82.7	8.14	7.78	3.28	4.5	0.74	1.04	0.29	0.53
Sex									
Male	1288^{a}	127^{a}	77^{a}	79^{a}	73^{a}	17^{a}	13	4	7^{a}
Female	961^{b}	90^{b}	53^{b}	61^{b}	50^{b}	12^{b}	12	3	3^{b}
SE	38.8	3.4	3.1	3.7	2.1	0.6	0.5	0.2	0.7

$^{a,\,b}$: Means in the same column not sharing a common superscript are significantly different ($P<0.05$).

SE : Standard error

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 Discussion

The results of the present study show that energy level in the diet of Venda hens affected feed intake. Increases in dietary energy level resulted in increased feed intake of Venda hens. Mbajiorgu (2010) reported similar results to those of the current study in growing Venda chickens. However, Pesti (1991) and Wu *et al*. (2005) reported that increasing dietary energy level decreased feed intake of laying hens. Thus, breed differences may, possibly, contribute to differing responses of dietary energy levels. A dietary energy level of 10.70 MJ of ME optimized feed intake of Venda hens. However, Mbajiorgu (2010) reported a higher dietary energy level of 14 MJ ME/kg DM that optimized feed intake of growing Venda chickens aged eight to 13 weeks.

Increased dietary energy level resulted in improvement of egg weight of Venda hens. Wu *et al.* (2005) observed increases in egg weight with increased dietary energy level in Bovans White and Delkb White hens. However, Fanimo (1996) reported that increasing dietary energy level decreased the egg weight in Black Harco hens. Gunawardana *et al.* (2009) and Perez-Bonilla *et al.* (2012) observed that dietary energy level did not affect egg weight in Hy-line hens. Similarly, King'ori *et al.* (2004) reported that egg weight was not affected by dietary energy level in indigenous hens. Adeyemo & Longe (1996), also, reported that the egg weight was not influenced by changing dietary energy level. Egg weight of Venda hens, in the present study, was optimized at a dietary energy level of 10.70 MJ of ME/kg DM. This dietary energy level was higher than those of 10.4 and 10.62 MJ of ME/kg DM observed by Gunawardana *et al.* (2009) and Perez-Bonilla *et al.* (2012), respectively.

Energy level in the diets of Venda hens affected egg production. There was a positive relationship between dietary energy level and egg production. Nemavhola & Ndlovu (2000) observed similar results to those of the current study in indigenous chicken hens. Similarly, King'ori *et al.* (2004) and Okitoi *et al.* (2009) reported that dietary energy level improved egg production in indigenous hens. Leeson & Summers (2000) and Rashid (2003) also found that higher dietary energy levels increased egg production in broiler breeder hens. However, Perez-Bonilla *et al.* (2012) observed that dietary energy level did not affect egg production in Hy-line layers. Similarly, Wu *et al.* (2005) observed no effect of dietary energy level on egg production in Bovans White and Delkb White hens. Zou & Wu (2005) found that increased energy level in the diet of 360 Hy-line W36 hens had no effect on egg production. These authors indicated that increased dietary energy level was not consistent with higher egg production but resulted in higher body weight of hens. Increases in dietary energy level in the present study resulted in increased hatchability of Venda eggs. However, Peebles *et al.* (2000) observed that hatchability was not affected by dietary energy level in broiler breeders. Results of the present study show a positive relationship between dietary energy level and hatchability. However, increased energy levels in the diet of Venda hens had a negative effect on chick hatch-weight of Venda eggs. Reasons for this are not clear and may require further studies. Moraes (2013) observed that maternal dietary energy did not affect chick hatch-weight of broiler breeder hens.

Results of the present study indicate that energy level in the diets of Venda hens had an effect on egg albumen, yolk and shell weights. Dietary energy levels of 10.55, 10.85 and 10.95 MJ of ME/kg DM optimized egg albumen, yolk and shell weights, respectively. Similarly, Peebles *et al.* (2000) found that increased dietary energy levels resulted in higher egg albumen and yolk weights in Arbor Acres broiler breeder hens. However, Guwanardana *et al.* (2009) found contrary results to those of the present study. These authors observed that increased dietary energy did not affect egg albumen, yolk and shell weights of White Leghorn hens. Similarly, Wu *et al.* (2007) observed no effect of energy level in the diets of Hy-line W-36 hens on the weights of the egg albumen, yolk and shell.

Energy level in the diet of Venda chickens did not affect egg albumen nitrogen, yolk nitrogen, shell calcium and shell phosphorus. Abdallah *et al.* (1993) observed no effects of dietary energy level on egg albumen, shell calcium and shell phosphorus of broiler breeder chickens. Similarly, Swiatkiewicz & Koreleski (2009) reported that dietary energy level had no effect on shell calcium and shell phosphorus in Bovan Brown hens.

The maternal dietary energy level improved the growth rate of unsexed Venda chickens aged one to seven weeks in the present study. These results are in agreement with those of Wilson (1997) who reported that hen nutrition can affect offspring development and performance through nutrient content of the egg and gene expression. The author further stressed that nutrient deposition in the egg depends heavily on maternal diet and metabolism. Spratt & Leeson (1987) found that the growth rate of broiler chicken offsprings at 20 days was influenced by the energy intake of the broiler breeder hen. The author reported that hens fed higher energy diets produced heavier offsprings. Similarly, Aitken *et al*. (1969) reported that broiler chickens from parents fed a high nutrient density diet were significantly heavier at 42 and 63 days in comparison with chickens from breeders fed low energy diets. However, Proudfoot & Hulan (1986) observed no effect on growth rate and live weight of the offspring at 42 days of three broiler strains when different levels of protein and energy were used in the maternal rearing. A dietary energy level of 11.2 MJ of ME/kg DM optimized growth rate of unsexed Venda chickens aged one to seven weeks in the present study. Increasing dietary energy above this point resulted in reductions in growth rates. The 11.2 MJ of ME/kg DM observed in this study is lower than the 11.51 and 13.22 MJ of ME/kg DM reported for broiler chickens aged 1 to 63 and 11 to 21 days by Zhu *et al*. (2012) and Romero *et al*. (2009), respectively.

Results of the present study indicate that live weight was improved by the maternal dietary energy level. Spratt & Leeson (1987) reported that body weight of broiler chicken progenies on a diet containing 1.88 MJ of ME/kg DM were higher than those with diets of 1.36 and 1.61 MJ of ME/kg DM. Maternal dietary energy level of 11.92 MJ of ME/kg DM increased average live weight of broiler chicks aged one day compared with those on 11.09 MJ of ME/kg DM (Zhu *et al*., 2012). The live weight of unsexed Venda chickens aged 49 days was optimized at a dietary energy level of 10.73 MJ of ME/kg DM. This level is lower than the 13.32 MJ of ME/kg DM reported by Romero *et al*. (2009) for broiler chickens aged 38 days. This may be attributed to breed differences (Spratt & Leeson, 1987).

The feed conversion ratio of unsexed Venda chickens aged one to 49 days, in the present study was improved by the maternal dietary energy treatment. As the maternal energy level increased the feed conversion efficiency improved. Zhu *et* al. (2012), De Brum et al. (1996), Proudfoot & Hulan (1986) and Spratt & Leeson (1987) did not observe any effect of maternal dietary energy treatment on the progeny's feed conversion ratio of broiler chickens. The difference might be due to the breed used. There was no information on the effect of maternal dietary energy level on the feed conversion ratio on indigenous chickens.

Maternal dietary energy level had no effect on progeny feed intake, dry matter digestibility, metabolisable energy and nitrogen retention of unsexed Venda chickens aged one to seven weeks. Similarly, dry matter intake, metabolisable energy, nitrogen retention, feed intake, live weight, feed conversion ratio of both male and female Venda chickens aged eight to 13 weeks were not influenced by the maternal dietary energy levels. Moraes (2013) found results similar to the current study in Hubbarb broiler breeder hens: maternal dietary energy level had no effect on live weight and feed conversion ratio of progeny chickens aged 1 to 39 days. Similarly, Pearson & Herron (1982) reported that there were no differences in growth rates, feed conversion ratio and mortality of progenies produced by broiler breeder hens fed varying dietary energy levels. Growth rate and sex were influenced by maternal dietary energy levels in the present study. Male Venda chickens from hens offered 11.5 MJ of ME/kg DM had higher feed intake than female chickens. Aitken *et al*. (1969) reported that growth rate was improved with a high density diet in broiler chickens aged 42 and 63 days. A similar result was reported by Spratt & Leeson (1987) in male broiler chickens. These authors reported that the male progeny produced by hens fed higher dietary energy level had better growth rates than the female progenies. This could be explained by differences in body composition (Zuidhof *et al.*, 2005), plasma hormone levels (Gonzales *et al.,* 2003) and even differences in muscle development (Henry & Burke, 1998). However, Zhu *et al.* (2012) and Moraes (2013) observed an interaction between maternal dietary energy level and sex of progenies which affected growth performance in offsprings of broiler chickens.

Results of the present study show that dietary energy level in Venda hens affected growth rate, live weight and feed conversion ratio of the progeny chickens in the starter phase. However, only the growth rate of the progeny was affected in the grower phase. Thus, the effects of maternal dietary energy level on intake, live weight and feed conversion ratio of Venda chicken progenies diminished with age. Similar results were observed by Zhu *et al*. (2012).

Energy level in the diets of indigenous Venda hens affected the breast, wing, gizzard and abdominal fat weights of their male progenies. However, carcass weights characteristics of female progenies were not affected by energy level in the diets of Venda hens. There were no studies found on the subject of the effect of dietary energy level of indigenous hens on carcass characteristics of their progenies. However, Lopez & Leeson (1994) found no effect of the maternal dietary energy level on carcass yield of the progeny of broiler breeders. Similarly, Zhu *et al.* (2012) observed that varying the maternal dietary energy level between 11.09 and 11.92 MJ of ME/kg DM in Chinese yellow broiler hens did not affect abdominal fat weight of the progeny. Nawaz *et al*. (2006) and Jackson *et al.* (1982), also, reported no effect of maternal dietary energy on abdominal fat weight in the progenies.

5.2 Conclusion

Energy level in the diets of Venda hens affected feed intake, egg weight, egg production, hatchability and chick hatch-weight. A single dietary energy level of 10.70 MJ of ME optimized feed intake and egg weight of Venda hens. Egg production, egg hatchability and chick hatch-weight of Venda chickens improved linearly with increase in dietary energy level. Thus, increasing the energy level in the diet of Venda hens resulted in more eggs produced and higher egg hatchability, but reduced chick hatch-weights. Dietary energy level affected Venda hen egg albumen, yolk and shell weights. Thus, different dietary energy levels of 10.55, 10.85 and 10.95 MJ of ME per kg DM optimized egg albumen, yolk and shell weights. Nitrogen contents of the egg albumen and yolk were not affected by energy level in the diets of Venda hens. Similarly, egg shell calcium and phosphorus were not affected by dietary energy level of Venda hens.

Dietary energy level of Venda hens effected growth rate, live weight and feed conversion ratio of unsexed progenies aged one to seven weeks. However, no effect of dietary energy level in the diets of Venda hens on feed intake of the unsexed progeny was observed. Different dietary energy levels of 10.8, 10.7, 11.2 and 11.5 MJ of ME/kg DM for Venda hens optimized feed intake, live weight, growth rate and feed conversion ratio, respectively, of the unsexed chicken progenies. Increasing the dietary energy level of Venda hens did not affect nutrient digestibility in the unsexed progenies aged 7 weeks.

There was no effect of dietary energy level in Venda hens observed on feed intake, live weight and feed conversion ratio of male and female progenies aged eight to 13 weeks. However, growth rate of the male progenies was affected by energy level of Venda hens. Thus, increased dietary energy level in Venda hens resulted in higher growth rate of the male progeny. It is, also, concluded that as the progenies of Venda hens aged, the effect of maternal dietary energy level on growth performance diminished. Nutrient digestibility in the progeny aged eight to 13 weeks was not affected by dietary energy level of Venda hens.

Energy level in the diets of Venda hens did not have an effect on carcass, liver and heart weight of male and female progenies aged eight to 13 weeks. However, the breast meat, wing, gizzard and abdominal fat weights of the male progeny were affected by dietary energy level of Venda hens.

5.3 Recommendations

Dietary energy level in indigenous Venda hens affect egg production and egg quality. This merits further investigations in order to find out biological reasons for the effect of energy level in the diets of hens on egg production and egg quality, and, also, the effect on the progenies of Venda hens. This is important because meeting nutrient requirements is essential in improving the productivity of indigenous Venda chickens.

CHAPTER 6

REFERENCES

Abdallah, A.G., Harms, R.H. & EL-Husseiny, O., 1993. Various methods of measuring shell quality in relation to percentage of cracked eggs. *Poultry Science* 72 (11): 2038–2043.

Adeyemo, A.I., & Longe, O.G, 1996. Performance of layers fed on four levels of dietary energy. Journal of Applied Animal Research 10: 91-94.

Aitken, J.R., Biely, J., Nikilaiczuk, N., Bobblee, A.R., Slinger, J., 1969. Comparison of laying rations with and without animal protein at the Canadian random sample egg production test. *British Poultry Science*10: 247-253.

Alders, R.G., Spradbrow, P.B., Young, M.P., Mata, B.V., Meers, J., Lobo, Q.J.P. & Copland, R., 2001. Improving rural livelihood through sustainable Newcastle disease control in village chickens: priorities for intervention. The proceedings of the institutions for Tropical Veterinary Medicine 10th international conference on "Livestock, Community and environment" 20-30rd August 2001, pg 199-205, Copenhagen, Denmark.

AOAC, 2000. Association of Analytical Chemists Official Methods of Analysis, 17th edition, Washington, D.C.,

ARC, 2006. The Indigenous Poultry Breeds of South Africa., Pretoria

Bireck, E. K., 2002. Feed and nutrient intake of free-ranging chickens in Nakuru District, Kenya. MSc. Thesis, Egerton University, Njoro, Kenya.

Bohnsack, C.R., Harms. R.H., Merkel, W.D. & Russell, G.B., 2005. Performance of commercial layers when fed diets with four contents of corn oil or poultry fat. Journal applied poultry research 11: 68-76.

Ciftci, I., Yenice, E., Gokceyrek, D. & Ozturk, E., 2003. Effects of energy level and enzyme supplementation in wheat based layer diets on hen performance and egg quality. *Acta Agriculture Scandinavica, Section A–Animal Science* 53: 113-119.

De Brum, P.A.R., Penz, A.M., Guidoni, A.L., Albino,L.F.T. & Bello, F.F. (1996) Effect of protein level of broiler breeder hen diets on offspring performance. *Brazilian Society of Animal Science*, 25: 458-469.

Deeming, D.C., 2002. Embryonic development and utilization of egg components. In: Avian Incubation Behavior, Environment, and Evolution. Ed. Deeming, D.C., Oxford University Press, Oxford. pp. 43-53.

Dessie, T. & Ogle, B., 1997. Effects of maize (Zea mays) and noug (Guizotia abyssitiopia) cake supplementation on egg production performance of local birds under scavenging conditions in the Central Highlands of Ethiopia. Proceedings INFPD workshop, M`Bour, Senegal, December 9-13, 1997, pp155-168.

Dessie, T., 1996. Studies on Village Poultry Production Systems in Central Highlands of Ethiopia. M.Sc Thesis, Swedish University of Agricultural Science, Uppsala, Sweden.

Enting, H., Veldman, A., Verstegen, M.W.A. & van der Aa, P. J., 2007. The effect of low-density diets on broiler breeder development and nutrient digestibility during the rearing period. *Poultry Science* 86: 720-726.

Fanimo, A.O., Mudama E., Umukoro, T.O. & Oduguwa, O.O. 1996. Substitution of shrimp waste meal for fish meal in broilers. *Chinese Journal of Animal Science* 3: 12-14.

Faroog, M., Durrani, F.R., Chand, N., Usman, M. & Khurshid, A., 2000. Egg characteristics of Desi and Fayumi birds maintained under variable management conditions. *Journal of Animal health and Production* 20: 15-21.

Gonzalez, E.A., Ramirez – Avila, L. & Segura-Correa, J.C .2003. Genetic parameters for body weights of Creole chickens from Southern Mexico sing an animal model. Livestock Research in Rural Development, 15 January, 2003. http://www.cipav.org.co/lrrd/lrrd 15/1/ prad 151.htm.

Grobas, S., Mendez, J., De Blas, C. & Mateos G.G., 1999. Laying hen productivity as affected by energy, supplemental fat, and linoleic acid concentration of the diet. *Poultry Science* 78: 1542–1551.

Gueye, E.F., 2003. Information dissemination for family poultry research and development. *Livestock Research for Rural Development* 15: 2-5.

Gunawardana, P., Wu,G. Kun-Yaun, x., Bryant, M.M. & Roland, D.A, Sr., 2009. Effect of dietary energy on performance, egg components, egg solids, egg quality and profits in seven commercial Leghorn strains during second cycle phase two. *Journal of Applied Poultry Research* 8 (4): 323-327.

Harms, R.H., Russell, G.B. & Sloan, D.R., 2000. Performance of four strains of commercial layers with major changes in dietary energy. *Journal of Applied Poultry Research* 9: 535-541.

Henry, M.H. & Burke, W.H., 1998. Sexual Dimorphism in broiler chick embryos and embryonic muscle development in late incubation. *Poultry Science* 77: 728-736.

Jackson, S., Summers, J.D. & Leeson, S., 1982. Effects of dietary protein and energy on broiler performance and production costs. *Poultry Science* 61: 2232-2240.

Kemp, C. & Kenny, M., 2007. Breeder nutrition and chick quality. *The poultry site International hatchery practice* 19: 1-4.

Kingori, A.M, Tuioek, H.K, Muiri, A.M, Wachira, A.M. & Birch, H.K., 2004. The influence of energy intake on egg production of indigenous chicken. Demand-driven Agricultural Research for Sustainable Natural Resource Base, Food Security and Incomes; Proceedings of the 8th KARI Biennial Scientific Conference. Agricultural Research Institute, Nairobi (Kenya).

Leeson, S. & Summers, S.D., 2000. Broiler Breeder Production. University Books, Guelph, Ontoria.

Leeson, S., Caston, L. & Summers, J.D., 1996. Broiler response to dietary energy. *Poultry Science* 75: 529-535.

Lopez, G., & Leeson, S., 1994. Egg weight and offspring performance of older broiler breeders fed low-protein diets. *Journal of Applied Poultry Research* 3: 164-170.

Moraes, T.G.V., 2013. Effect of broiler breeder nutrition on reproductive and offspring performance. MSc dissertation. University of Alberta, Canada.

Mbajiorgu, C.A., 2010. Effect of dietary energy and protein ratio level on growth and productivity of indigenous Venda chickens raised in close confinement from day-old up to 13 weeks of age. PhD Thesis, Department of Animal Production, Faculty of Science and Agriculture, University of Limpopo, South Africa.

McDonald, P., Edwards, R.A. Greenhalgh, J.F.D. & Morgan, C.A., 2010. Animal Nutrition. 7th Edition. Longman Scientific and Technical publishers, New York. USA.

Mohammed, S.A. & Sohail, H.K., 2008. Effect of different energy protein ration on the performance of Deshi Native chickens during growing phase. *Asian Journal of Poultry Science* 2 (1): 42-47.

Nahm, K.H., 2001. Effects of storage length and weight loss during incubation on the hatchability of ostrich eggs (Struthiocamelus). *Poultry Science* 80: 1667-1670.

Nasr J., Yaghobfar, A., EbrahimNezhad, Y., & NazerAdl, K., 2011. Effects of amino acids and metabolizable energy on egg characteristics and broiler breeder performance. *African Journal of Biotechnology* 10 (49): 10066-10071.

Nawaz, H., Mushtaq, T. & Yaqoob, M., 2006. Effect of varying levels of energy and protein on live performance and carcass characteristics of broiler chick. *Journal Poultry Science* 43: 388-393.

Nemavhola, Z. & Ndlovu, L.R., 2000. The effect of diets on growth rate and meat quality of the indigenous chickens. *South African Journal of Animal Science* 30 (4): 95-96.

Nemavhola, Z., 2001. The effect of diets on production performance and meat quality of the indigenous chickens. MSc Animal Production Dissertation, University of Limpopo, South Africa.

Noble, R.C., Speake, B.K., Mccartney, R., Foggin, C.M. & Deeming, D.C., 1996. Yolk lipids and their fatty acids in wild and captive ostrich (Struthiocamelus). *Comparative Biochemistry and Physiology* 113: 753-756.

Norris, D. & Nga`mbi, J.W., 2006. Genetic parameters estimate for body weight in local Venda chickens. *Tropical Animal Health and Production* 38:7-8.

NRC., 1994.Nutrient Requirements of Poultry. 9th edition. National Academic Press, Washington, D.C.

Okitoi, L.O., Kabuage, L.W., Muinga, R.W. & Badamana, M.S., 2009. The performance response of scavenging chickens to nutrient intake from scavengeable resources and from supplementation with energy and protein. *Livestock Research for Rural Development* 21 (10).

Okitoi, L.O., Udo, M.J., Mukisira, E.A., De Jong, R. & Kwakkel, R.P., 2006. Evaluation of low-input Interventions for improved productivity of indigenous chickens in Western Kenya. *Journal of Agriculture in the Tropics and Subtropics* 39: 178-181.

Pearson, R.A. & Herron, K.M., 1982. Effects of maternal energy and protein intakes on the incidence of malformations and malpositions of the embryo and time of death during incubation. *British Poultry Science*. 23:71-77.

Peebles, E.D., Zumwalt, C.D., Doyle, S.M. Gerard, P.D. Latour, M.A., Boyle, C.R. & Smith, T.W., 2000. Effects of breeder age and dietary fat source and level on broiler hatching egg characteristics. *Poultry Science* 79:698-704.

Peebles ED, Zumwalt CD, Gerard P.D, Latour M.A. & Smith T.W., 2002. Market age live weight, carcass yield and liver characteristics of broiler offspring from breeder hens fed diets differing in fat and energy contents. *Poultry Science* 81: 23-29.

Pesti, G.M., 1991. Response surface approach to studying the protein and energy requirements of laying hens. *Poultry Science* 70: 103–114.

Perez-Bonilla, A., Novoa, S., Garcia, J., Mohiti-Asli, M., Frikha, M. & Mateos G.G., 2012. Effects of energy concentration of the diet on productive performanceand egg quality of brown egg-laying hens differing in initial body weight. *Poultry Science* 91 : 3156–3166.

Proudfoot, F.G. & Hulan, H.W., 1987. Interrelationships among lighting, ambient temperature, and dietary energy and broiler chicken performance. *Poultry Science* 66 (11): 1744-1749.

Rashid, M.M., 2003. Nutritional status of scavenging chickens with special emphasis on energy and protein supplementation under rural conditions in Bangladesh. M.Sc. Thesis, The Royal Veterinary and Agricultural University, Denmark.

Rashid, N., Barua, A. & Bulbul, S. M., 1995. A study on the performance of Khaki-Champbell, Deshi and khaki Champbell x Deshi ducks with and without extra feeding under rural conditions of Bangladesh. *Asian-Australian Journal of Animal Science* 8: 375–378.

Romero, L.F., Zuidhof, M.J., Renema, R.A., Robinson, F.E. & Naeima, A., 2009. Nonlinear mixed models to study metabolizable energy utilization in broiler breeder hens. *Poultry Science* 88: 1310-1320.

SAS, 2008. Statistical Analysis System. User's Guide. Statistics, 9th edition. SAS Institute, Inc., Raleigh, North Caroline, USA.

Schroeder, W.J., 1994. Effect of dietary protein and energy level on pullet cost. *Poultry Science* 75: 973-978.

Spratt, R.S. & Leeson, S., 1997. Effect of protein and energy intake of broiler breeder hen on performance of broiler chicken offspring. *British Poultry Science* 66: 1489-1494.

Spratt, R.S. & Leeson, S., 1987. Broiler breeder performance in response to diet protein and energy. *Poultry Science* 66: 683-693.

Sugahara, K. 2003. Energy utilization of growing chicks in various nutritional conditions. *Asian-Australian Journal of Animal Science* 16: 903-909.

Summers, J.D. & Leeson, S., 1983. Factors effecting early egg size. *Poultry Science* 62: 1155-1159.

Swatson, H.K., Nsahali, I.V. & Byelwa, B.K., 2001. The status of smallholder poultry production in the Alfred District of Kwazulu- Natal, South Africa: Priorities for intervention. Livestock and Community proceedings of the institutions for Tropical Veterinary Medicine, 10th International Conference on 20-30th August 2001. pp 143-149. Copenhagen, Denmark.

Swiatkiewicz, S. & Koreleski, J., 2009. Effect of crude glycerin level in the diet of laying hens on egg performance and nutrient utilization. *Poultry Science* 88 (3): 615-619.

Tadelle, D., 1996. Studies on village poultry production systems in the central highlands of Ethiopia. Msc.Thesis, Swedish University of Agricultural Science,

Tadelle, D., Million. T., Alemu. Y. & Peters. K.J., 2003.Village chickens production system in Ethopia: 2. Use of patterns and performance valuation and chicken products and socio- economic functions of chickens. *Livestock Research for Rural Development* 15: 34-40.

Whitehead, C.C., 1989. Nutrition of the breeding bird and developing embryo. In: Avian Incubation. Tullet, S.G. Butterworth-Heinemann, London. pp. 227-238.

Wilson, H.R., 1997. Effect of maternal nutrition on hatchability. *Poultry Science* 76:134-143.

Wu, G., Bryant, M.M, Voitle, R.A. & Roland, D.A., 2005. Effect of dietary energy on performance and egg composition of Bovans white and Dekalb white hens during phase I. *Poultry Science* 84: 1610-1615.

Wu, G., Gunawardana, P., Bryant, M.M. & Roland, D.A., 2007. Effect of dietary energy and protein on performance, egg composition, egg solids, egg quality of Hy-line W-36 hens during phase 2. *International Journal of Poultry Science* 6: 739-744.

Zou, S.G. & Wu, Y.Z., 2005.Effect of supplemental fat on performance of laying hens. *International Journal of Poultry Science* 4 (12): 998-1000.

Zhu, C., Jiang, Z.Y., Jiang, S.Q., Zhou, G.L., Lin, Y.C., Chen, F. & Hong, P., 2012. Maternal energy and protein affect subsequent growth performance, carcass yield, and meat colour in Chinese Yellow broilers. *Poultry Science* 91:1896-1878.

Zuidhof, M. J. 2005. Mathematical characterization of broiler carcass yield dynamics. *Poultry Science* 84: 1108-1122.