EFFECT OF LYSINE TO ENERGY RATIO ON THE PRODUCTIVITY AND CARCASS CHARACTERISTICS OF INDIGENOUS VENDA CHICKENS AGED ONE TO THIRTEEN WEEKS AND RAISED IN CLOSED CONFINEMENT

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B.Tech. (Agric), M.Tech (Animal Production)

A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (ANIMAL NUTRITION) IN THE DEPARTMENT OF AGRICULTURAL ECONOMICS AND ANIMAL PRODUCTION, SCHOOL OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES, FACULTY OF SCIENCE AND AGRICULTURE, UNIVERSITY OF LIMPOPO, SOUTH AFRICA

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OCTOBER, 2013

DECLARATION

I declare that the thesis hereby submitted to the University of Limpopo for the degree of Doctor of Philosophy (Animal Nutrition) has not previously been submitted by me for a degree at this or any other university, that it is my own work in design and execution, and that all material contained therein has been duly acknowledged.

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

Alabi, Olushola John [redacted]

ACKNOWLEDGEMENTS

My appreciation goes to God for His presence, provision and protection all through my life journey. I am indeed grateful to my Promoter Prof. J.W. Ng’ambi who has been a father, brother and teacher for his tireless assistance, guidance, corrections and supervision accorded to me. My co-promoter, Prof. D. Norris is greatly acknowledged for his role in making sure this work sees the light of the day.

Special thanks to my Pastor (Dr) F.E. Mbajiorgu, the whole family and members of The Redeemed Christian Church of God, Trinity Parish Polokwane, your prayers have been answered. The church shall match forward; the gate of hell will never prevail against it in Jesus name (Amen).

Special appreciations are also extended to my parents, brothers and sisters for their prayers, understanding, encouragement, support and tolerance during the whole period of my study.

All members of staff and students of the School of Agricultural and Environmental Sciences are acknowledged. I would like to thank VLIR-UL, the Education Trust Fund (Nigeria) and Federal University of Technology, Minna, Nigeria for sponsorship and financial support I received during the entire period of my study.

Above all, I am most sincerely thankful to my lovely wife, my pillar of support and mother of my children. You have proved the Holy book right “***Whoso findeth a wife findeth a good*** **thing*****, and obtaineth favour of the LORD”*****.** To **my inheritance, my gift** ‘David and Daniel’, your coming has opened doors of blessing to me. The Lord will continue to keep and guide you, greater heights you will attain to the glory of God.

To God the Father, God the Son and God the Holy Spirit I return all glory, honour and adoration.

DEDICATION

This thesis is dedicated to my mentors, Late Prof. M. E. Aregheore, Late Dr. E.L. Shiawoya, Prof S. L. Lamai., my wife Uchenna Ijeoma Alabi and my lovely children David and Daniel.

ABSTRACT

Eight experiments were conducted to determine the effect of dietary lysine to energy ratio on the productivity and carcass characteristics of indigenous Venda chickens aged one to thirteen weeks and raised in closed confinement. The eight experiments were based on four different energy levels of 11, 12, 13 and 14 MJ of ME/kg DM. Each dietary energy level had four different levels of dietary lysine (8, 9, 11 and 14 g lysine/kg DM). Thus, different dietary lysine to energy ratios were calculated. Experiments 1 to 4 determined the effect of dietary lysine to energy ratio on productivity of unsexed Venda chickens aged one to seven weeks. Each experiment commenced with 160 unsexed day-old indigenous Venda chicks with an initial live weight of 30 ± 3 g per bird and was carried out for seven weeks. In each experiment, the chicks were randomly assigned to four treatments with four replications, each having 10 chicks. A complete randomized design was used for each experiment. All data were analysed by one-way analysis of variance. Where there were significant differences, the Duncan test for multiple comparisons was used to test the significance of differences between treatment means. A quadratic regression model was used to determine the ratios for optimum productivity in each experiment while a linear model was used to determine the relationships between dietary lysine to energy ratio and optimal responses in the variables measured. Results indicated that dietary lysine to energy ratio for optimal responses depended on the variable of interest. In Experiment 1, feed intake, growth rate, live weight, ME intake and nitrogen retention were optimized at different dietary lysine to energy ratios of 0.722, 0.719, 0.719, 0.670 and 0.712, respectively. There was a positive and strong relationship ($r^2 = 0.950$) between dietary lysine to energy ratio and feed conversion ratio (FCR). Results from Experiment 2 indicated that feed intake, growth rate, FCR, live weight, ME intake and nitrogen retention were optimized at dietary lysine to energy ratios of 0.719, 0.742, 0.788, 0.742, 0.734 and 0.789, respectively. In Experiment 3, dietary lysine to energy ratio did not have any effect ($P>0.05$) on all the parameters measured. However, quadratic analysis indicated that dietary lysine to energy ratios of 0.817, 0.883, 0.920, 0.898, 0.895 and 0.955 optimized feed intake, growth rate, FCR, live weight, ME intake and nitrogen retention of the chickens, respectively. Experiment 4 results showed that feed intake, growth rate, FCR, live weight ME intake and nitrogen retention were optimized at different dietary lysine to energy ratios of 0.906, 0.964, 1.023, 0.966, 0.963 and 0.951, respectively.

Experiments 5 to 8 determined the effect of dietary lysine to energy ratio on productivity, carcass characteristics, sensory attributes and haematological values of female indigenous Venda chickens aged eight to thirteen weeks. The layouts, treatments, design and execution were similar to those described for Experiments 1, 2, 3 and 4, respectively, except that Experiments 5 to 8 were for female indigenous Venda chickens aged eight to 13 weeks. These chickens were different from those used in Experiments 1 to 4. They were raised on a grower mash (16 % crude protein, 11 MJ of ME/kg DM and 180 g of lysine) prior to commencement of the study. Each experiment commenced with 120 eight weeks old female Venda chickens with an initial live weight of 412 ± 3 g per chicken. In each experiment, the chickens were randomly assigned to four treatments with five replicates, each having six chickens. Results obtained from Experiment 5 showed that feed intake, growth rate, FCR, live weight, ME intake, carcass weight, dressing percentage, breast meat, drumstick, wing weight, breast meat drip loss, juiciness, flavour, haemoglobin and pack cell volume were optimized at different dietary lysine to energy ratios of 0.672, 0.646, 0639, 0.649, 0.655, 0.656, 0.664, 0.669, 0.665, 0.663, 0.631, 0.708, 0.623, 0.556 and 0.609, respectively. In Experiment 6, the diets were formulated to have higher lysine to energy ratios than those in Experiment 5 by using a dietary lysine level of 9 g lysine/kg DM. Results from this experiment showed that feed intake, FCR, nitrogen retention, carcass weight, dressing percentage, breast meat, gizzard weights and breast meat pH at 2, 12 and 24 hours after slaughter were optimized at dietary lysine to energy ratios of 0.798, 0.613, 0.777, 0.742, 0.753, 0.729, 0.758, 0.752, 0.802 and 0.797, respectively. Red blood cell and haemoglobin values in this experiment were optimized at dietary lysine to energy ratios of 0.480 and 0.624, respectively.

In Experiment 7, dietary lysine to energy ratios of 0.79, 0.85, 0.92 and 1.00 g lysine/ MJ of ME were used. Dietary treatments in this experiment had no effect (P>0.05) on all the production parameters measured except feed and apparent metabolisable energy intakes. Quadratic analysis of the results indicated that dietary lysine to energy ratios of 0.964, 0.912, 0.900, 0.890, 0.910, 1.090, 0.934 and 0.895 optimized feed intake, apparent metabolisable energy, carcass, breast meat, drumstick weights and

breast meat drip loss, juiciness and flavour, respectively. A positive and very strong relationship (r^2 =0.998) was observed between dietary lysine to energy ratio and pack cell volume.

Experiment 8 diets were formulated to have higher dietary lysine to energy ratios than the other experiments. Results of this experiment indicated that all the production parameters were influenced ($P<0.05$) by dietary lysine to energy ratio except mortality. Feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention were optimized at dietary lysine to energy ratios of 0.996, 0.980, 0.991, 1.010, 0.957 and 0.993, respectively. Dietary lysine to energy ratios of 0.992, 0.974, 0.991, 0.992, 1.023, 0.981, 0.979 and 0.815 optimized carcass weight, dressing percentage, breast meat, drumstick, liver weights and breast meat tenderness, juiciness and flavour, respectively.

There were variations in the optimal lysine to energy ratios for different parameters investigated. In a diet containing 8 g of lysine per kg DM, 11.13 MJ of ME/kg DM and 150 g of CP/kg DM, dietary lysine to energy ratios of 0.719 and 0.649 are recommended for optimal live weight of Venda chickens aged one to seven and eight to 13 weeks, respectively. In a diet containing 9 g of lysine per kg DM, 12.13 MJ of ME/kg DM and 180 g of CP/kg DM, dietary lysine to energy ratios of 0.742 and 0.712 are recommended for optimal live weight of Venda chickens aged one to seven and eight to 13 weeks, respectively. In a diet containing 11 g of lysine per kg DM, 12.51 MJ of ME/kg DM and 220 g of CP/kg DM, dietary lysine to energy ratios of 0.878 and 0.894 are recommended for optimal live weight of Venda chickens aged one to seven and eight to 13 weeks respectively. In a diet containing 12 g of lysine per kg DM, 12.05 MJ of ME/kg DM and 240 g of CP/kg DM, dietary lysine to energy ratios of 0.996 and 1.010 are recommended for optimal live weight of Venda chickens aged one to seven and eight to 13 weeks, respectively.

The results obtained in this study showed that different production parameters of Venda chickens were optimized at different lysine to energy ratios. This implies that the nutritional requirements of these chickens are dynamic and thus, dietary lysine to energy for optimal production depends on the production parameter of interest. This has implications on ration formulation for indigenous chickens.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Poultry accounts for more than 30 % of all animal protein consumption worldwide (Permin *et al.,* 2000). It is estimated that by the year 2015 poultry will account for 40 % of all animal protein consumed by people (Permin *et al.,* 2000). This figure is expected to be higher in rural areas where indigenous chickens account for more than 80 % of poultry production (Guèye, 2009; 2003). However, indigenous chickens have low growth rates and high mortality rates (King'ori *et al.,* 2003). Causes of low growth rates and high mortality rates include poor nutrition, poor genetic potential, diseases and poor management skills. There is evidence that dietary lysine and energy levels are important in poultry production and health (Chen *et al.,* 2003; Priyankarage *et al.,* 2008). Some work has already been done at the University of Limpopo on optimal nutrient requirements for indigenous chickens (Mbajiorgu, 2010; Mbajiorgu *et al*., 2011). However, the effects of the relationship between dietary lysine and energy levels on productivity of indigenous chickens have not been extensively explored and results are not conclusive. This is particularly true with indigenous Venda chickens.

1.2 Problem statement

Venda chickens are economically, nutritionally and socially very important in rural areas of Limpopo province (Norris and Ng'ambi, 2006). However, these chickens are characterized by low productivity and high mortality values (Van Marle-Koster and Webb, 2000). These poor productivity values are attributed, mainly, to poor nutrition (Aini, 1990). There is evidence in broiler chickens that productivity can be improved by manipulation of dietary lysine to energy ratio (Tang *et al*., 2007). However, information on the effects of dietary lysine to energy ratio on optimal productivity and carcass characteristics of Venda chickens is limited and not conclusive. Such information would be used to improve productivity of Venda chickens.

1.3 Motivation

This study will generate information on dietary lysine and energy requirements of Venda chickens. Such information will help in the formulation of diets to optimize productivity of indigenous chickens. Optimization of productivity of the chickens will improve the economic, nutritional and social status of indigenous Venda chicken farmers in South Africa and Southern Africa as a whole.

1.4 Objectives

The objectives of this study were to determine

- i the effect of dietary lysine to energy ratio on feed intake, growth rate, feed conversion ratio, metabolisable energy, nitrogen retention, live weight and mortality of unsexed indigenous Venda chickens raised in closed confinement from a day old up to seven weeks of age.
- ii the effect of dietary lysine to energy ratio on feed intake, growth rate, feed conversion ratio, metabolisable energy, nitrogen retention, live weight, mortality, carcass characteristics, sensory attribute and blood profiles of indigenous Venda chickens raised in closed confinement from eight to 13 weeks of age.
- iii optimal responses in feed intake, growth rate, feed conversion ratio, metabolisable energy, nitrogen retention, live weight and carcass characteristics of Venda chickens to dietary lysine to energy ratio at different dietary protein levels.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Domestic chickens (*Gallus gallus*) were domesticated through the purposeful segregation and taming of a few individuals acquired from wild Junglefowl populations in Southeast Asia since 5, 400 years ago (Underhill, 1997). These chickens were likely domesticated from wild Red Junglefowl (Akishinonomiya *et al*., 1996), though some have suggested possible genetic contributions from other Junglefowl species (Eriksson *et al*., 2008; Nishibori *et al.,* 2005). The cultural and religious importance of chickens has contributed to their global distribution and acceptance (Simoons, 1994). Descendants of early domestic fowl have been distributed around the globe in overlapping waves and by multiple agents over at least two millennia. Contributing to the distribution of these chickens could be linked to human movement (Collias and Collias, 1996). This is because they do not fly well over long distances and are not equipped for swimming in that they lack webbed feet and glands for the production of water proofing oil (Kelly, 2006).

The introduction of the domesticated chicken in Africa is not well documented. However, it is believed that various domesticated chicken breeds were introduced from Europe during the era of colonization, leading to extensive mixing of local and domesticated chicken populations (MacDonald and Edwards, 1993).

There have been declines in the rearing of indigenous chickens, mainly due to their poor productive performance (Ben Larbi *et* al., 2013; Bhartti *et al.*, 1990) and an increase in commercially produced poultry meat and eggs from exotic poultry breeds (Guèye, 2003). This increased production of exotic chicken breeds was achieved because of improved intensive management strategies and research into nutrition and growth of the exotic chicken breeds. On the contrary, development of indigenous chickens in terms of nutrition, management and disease control have not been duly attended to (King'ori *et al*., 2007). Most studies aimed at improving the performance of indigenous chickens have been carried out, mainly, under scavenging conditions (Alders *et al.,* 2001; Sonaiya *et al.,* 1999) and cross breeding (Zaman *et al.,* 2004). However, it has been shown that their productivity under scavenging conditions is very low (Alders *et al.,* 2001). For chickens to be productive, they need feeds that will give them the necessary nutrients for body function, growth and meat production. Thus, it is very unlikely that nutrients in the feed under scavenging conditions especially, lysine and energy, will be present in the same ratio as required by the chickens for improved productivity. When there is imbalance in the nutrient intake heavy nutritional burden is placed on the chickens, thus, poor growth and development is to be expected. To attain a balanced diet in order to improve their productivity, intensive rearing conditions seem to be the most viable options (Mbajiorgu, 2010). Mohammad and Sohail (2008) stated that balance nutrition is an important factor in determining performance and productivity of chickens.

Numerous authors indicated that dietary lysine to energy ratio improved production parameters in broiler chickens (Hind *et al*., 2012; Mbajiorgu *et al*., 2011; Araujo *et al.*, 2005). Mbajiorgu *et al*. (2011) indicated that varying lysine to energy ratio in the diets has effect on productivity of Venda chickens. Therefore, determining the effect of dietary lysine to energy ratio on optimal productivity of indigenous Venda chickens raised in closed confinement from a day old up to 13 weeks of age will help to improve the economic, nutritional and social statues of indigenous chicken farmers.

2.2 Indigenous chicken production

Poultry, particularly chickens are the most widely kept livestock species in the world and, also, the most numerous (Moreki *et al*., 2010). The contribution of local poultry production to the nutritional and economic status of rural dwellers is well recognized (Norris and Ng'ambi, 2006). Reports from a number of development projects in Africa indicate that scavenging village chickens play a significant role in poverty alleviation and enhancement of gender equity among the disadvantaged communities (Tadelle, 1996). Although there is ample evidence of the important role that local chicken production plays in the lives of rural households, not much has been done in terms of improving the productivity of local chickens (Norris and Ng'ambi, 2006). Population increase, the need for high quality versatile foods especially protein, increasing levels of income and standards of living have created a tremendous demand for poultry products (FAO, 2002).

The rural poultry population in most African countries accounts for more than 60 percent of the total national poultry population, which has been accorded an asset value of US$5 750 million (Sonaiya, 1990). In Burkina Faso, about 25 million rural poultry produce 15 000 tonnes of meat, out of which 5 000 tonnes are exported at a value of US$19.5 million (Ouandaogo, 1990). In the United Republic of Tanzania, a survey indicated that out of 600 households in 20 villages, chickens were the only form of livestock found in most households (Collier *et al.*, 1986). Reports from Niger (Abdou and Bell, 1992), Ghana (van Veluw, 1987) and Mali (Kuit *et al*., 1986) indicated similar trends. Kenya has an estimated poultry population of 28.5 million. Of these, 22 million (76 %) are free-ranging indigenous chickens (King'ori *et* al., 2010). In Ethiopia, indigenous chicken production is based on the traditional scavenging system. The total poultry population is estimated at 36 million (FAO, 2008), which represents about 60 percent of the total chicken population of Ethiopia (Mekonnen *et al*., 1991). In Southern Africa, as in other developing countries (Muchadeyi *et al*., 2004; Mwalusanya *et al*., 2002), indigenous chickens are reared in an extensive system and to a lesser extent in a semi-intensive system. In all these subsistence farming systems, chickens are left to scavenge to meet their nutritional needs. Their feed resources vary depending on local conditions. Housing may not be provided and where it is available, usually, local and substandard materials are used. Proper health or vaccination programmes for disease control or management of the birds are not guaranteed because there are poorly developed disease control programmes

The main functions of indigenous chickens, from the farmer's perspective are the provision of meat and eggs for home consumption. Apart from increased quantitative production of animal protein in rural households, chicken meat and eggs provide protein of a higher biological value than that of red meat (Norman, 1973). Chicken meat and eggs are reported to complement staple diets of rural Africa due to the higher nutrient concentration. Small poultry production units of 12 laying hens per unit have been reported to increase the consumption of animal protein and reduced incidence of malnutrition in resource-poor households of South Africa (MacGregor and Abrams, 1996). Poultry production creates employment and promotes economic development in any society.

Culturally, indigenous chickens have been used in traditional medicine and for various cultural rites (Moreki *et al*., 2010; King'ori, 2004). Relative to other livestock species, chicken production has the advantages of having quick returns to investment and relatively simple management practices with numerous market outlets for products (King'ori *et al.*, 2010). Sale of poultry products, especially, eggs in low value units make chicken products affordable to the lower income earners (King'ori *et al.,* 2010; FAO, 1997). Indigenous chickens are, especially, attractive to poor households as they require low start-up capital and have low maintenance costs. Increasing landlessness occasioned by the high population growth notwithstanding, poultry production has become the investment of choice due to its low space requirements.

The productivity of indigenous poultry is normally low due to genotype, poor feed conversion efficiency and poor nutrition. Indigenous chickens are hardy, adapt well to the rural environments, survive on low inputs and adapt to fluctuations in available feed resources (Gichohi and Maina, 1992). These chickens are often left to scavenge for feed around the homestead and in the fields after crop harvests. Consumers' preference for indigenous chicken meat is attributed to the characteristic leanness, flavour and presumed organic product (King'ori *et al.,* 2010). Extensive chicken production is a suitable activity for rural women, youth, the landless and marginalized farmers who derive income as well as food from these birds. Chicken production, also, generates employment for various categories of people including poultry farmers, primary and secondary traders, processors and caterers.

Generally, in sub-Saharan Africa indigenous chickens are owned and managed by women and children and often are an essential part of female-headed households (King'ori *et al.,* 2010). Promotion of indigenous chicken production, therefore, economically empowers the rural youth and women (Guèye, 2009). There is potential for increasing production and productivity of indigenous chickens (King'ori *et al*., 2007; Okitoi and Mukisira, 2001). This can be done by promoting sound management practices such as appropriate housing and improved nutrition.

2.3 Nutritional requirements of chickens

For chickens to be healthy and productive, they must consume adequate amounts of all the necessary nutrients. Nutritional deficiencies lead to poor productivity and increased susceptibility to infections while nutritional excesses lead to wastage, nitrogen build-up and nutritional disorder (Richard, 2005). Thus, formulating balanced rations for optimal productivity is important. Management, in a way, to make a good balance among nutrition, health, and productivity in chickens is an essential factor in poultry production systems. Nutrition plays the most important role in influencing growth in livestock (McDonald *et al*., 2011). Carbohydrates, fats and proteins that the chicken utilizes as sources of energy or as parts of its metabolic machinery are essential requirements for growth. Chickens can adjust their feed intake over a considerable range of feed energy levels to meet their daily energy requirements (Mbajiorgu, 2010). Thus, dietary energy levels are used to set the levels of other nutrients including protein and amino acids. As a result, the concept of the energy to protein or protein to amino acid ratio has been used extensively in chicken feed formulation (NRC, 1994). Sub-optimum intake in energy to lysine ratio results in the degradation of amino acids to meet the energy needs of the birds, whereas energy to lysine ratios much higher than the optimum result in an inadequate intake of protein. These two conditions affect growth rate and body composition of the chickens negatively (Hind *et al.,* 2012).

To improve and maximize productivity, the nutritional needs of the chickens must be met optimally in terms of energy, protein and lysine (a base for all other amino acids) requirements. Studies have shown that changes in dietary energy concentration affect feed conversion efficiency in various ways, firstly, increasing dietary energy improves feed conversion ratio as less feed is taken in to satisfy the energy needs. And, secondly, growth rate is increased by increasing levels of dietary energy (Dublecz, *et al.,* 1997). On the other hand, dietary requirements for protein are actually requirements based on dietary lysine (the base for amino acids contained in the dietary protein) (NRC, 1994). The amino acids obtained from dietary protein are used by chickens to fulfill a diversity of functions such as growth, meat or egg production. In addition to this, lysine is an indispensable amino acid for non-ruminant animals (NRC, 1994). As such, it is used as the reference amino acid to which all other indispensable amino acids are rationed in the ideal protein pattern (Han and Baker, 1994). It has been observed that increasing lysine content in the diet causes an increase in broiler chicken growth, carcass protein retention and a decrease in fat retention (Rezaei *et al*., 2004). However, knowledge about energy and lysine requirements of indigenous chickens, such as the Venda chickens, is limited and variable.

2.4 Energy requirements of chickens

Poultry diets are composed primarily of a mixture of several feedstuffs such as cereal grains, soyabean meal, animal by-product meals, fats, vitamin and mineral premixes. These feedstuffs, together with water, provide the energy and nutrients namely proteins (amino acids), carbohydrates, lipids, minerals, and vitamins that are essential for the chicken's growth, reproduction and health. Energy by itself is not a nutrient but a property of energy yielding nutrients, primarily carbohydrates, fats and proteins when they are oxidized during metabolism. However, in formulating poultry diets, energy level is usually selected as the starting point. An appropriate energy level is one that most likely results in the lowest feed cost per unit of product. Summer and Leeson (1984) worked with increasing dietary energy levels up to 13.8 MJ ME/kg and reported that birds receiving low-energy diets showed lower body weight, although they were more efficient in transforming energy into weight. Similarly, Leeson *et al*. (1996) fed broiler chickens in the finishing period with 11.3 MJ ME/kg, 12 MJ ME/kg, 12.9 MJ ME/kg, and 13.8 MJ ME/kg and found a decrease in feed intake and an improvement in feed conversion efficiency with increasing energy levels. These authors also indicated that broiler chickens show good ability to control their feed intake according to the energy level of the diet and birds with lower intake tended to deposit less fat in the carcass. Low dietary energy levels in poultry feeds result in poor growth and high mortality rate of broiler chickens (Ghaffari *et al*., 2007). Similarly, high dietary energy levels result in poor growths and high mortality rates in broiler chickens (Richard, 2005) and indigenous chickens (Mohammad and Sohail, 2008). High dietary energy levels also cause deposition of excessive carcass fat in broiler chickens (Jackson *et al*., 1982; Summers *et al*., 1992; Ghaffari *et al*., 2007). Thus, optimal energy levels are important for high productivity in chickens.

Limited information indicates that indigenous chickens have lower energy requirements than the broiler chickens (Tadelle and Ogle, 2000). These authors reported that the energy requirement of indigenous chickens as determined from the chemical analysis of the crop contents is 11.99 MJ ME/kg. The NRC (1994) recommended that the required energy in growing indigenous chicken diets should be 12.14 MJ ME/kg. However, Payne (1990) recommended energy levels of 11.46 MJ ME/kg in feed of chickens aged one to six weeks of the growing period and 10.86 MJ ME/kg in feed of chickens aged 6 to 12 weeks of the growing period, respectively. Mbajiorgu (2010) concluded that a diet containing a crude protein content level of 178 g per kg DM and energy level of 14 MJ ME per kg DM allowed for optimal utilization of absorbed protein and energy for growth of Venda chickens between one and six weeks old. Contrary to what has been observed in broiler chickens, the author observed that Venda chickens increased their intake with increase in dietary energy to protein ratio. Thus, information on dietary energy requirements for indigenous chickens might be different from those of the exotic chickens. Information regarding the effect of lysine to energy ratio on productivity of indigenous chickens is limited, and this requires further studies.

The nutrient requirements of broiler chickens have frequently been expressed per unit of dietary metabolisable energy (Gonzalez-a and Pesti, 1993). This practice was based on the theory that birds will adjust their feed intake according to their ME requirements (NRC, 1984). However, this has been revised as "an absolute requirement for energy in terms of kilocalories per kilogram of diet cannot be stated because poultry adjust their feed intake to obtain their daily requirement (NRC, 1994)". Based on re-evaluation of the research data it was concluded that the practice of relating nutrient concentrations as a function of dietary ME seems to apply more to Leghorn type chickens fed diets with a low ME concentration. Leeson *et al*. (1996) showed that broiler chickens fed to 25 days and 49 days of age adjusted their feed intake to a constant energy intake over a range of dietary ME from 11.30 to 13.81 MJ/kg DM which indicated that broiler chickens retain an innate ability to eat to a fixed energy requirement rather than to physical capacity as was suggested by Newcombe and Summers (1984). Re-evaluation (Aftab, 2007) of the data of Leeson *et al*. (1996) showed that early feed intake to 25 days was not influenced by dietary ME concentrations over the range of 10.13 to 13.81 MJ/kg DM and that it was only at the lowest ME concentration of 1130 MJ/kg DM that a significant increase in feed intake was observed. Their results, also, showed that the effects of ME concentration on feed intake were very different between the early and later growth periods with the ME concentration having a far greater effect on increasing feed intake during the grower-finisher phase. Thus, the authors concluded that broiler chickens do indeed eat to a constant ME intake when viewed over the entire 49-day growing period. Provided that broiler chickens do adjust feed intake to a constant ME intake, an optimal ratio of energy to protein must exist that will result in optimum CP intake and body weight gain. Based on this principle, Gonzalez-a and Pesti (1993) evaluated the concept of an optimum ME to CP ratio in broiler chickens by a statistical evaluation of published data to determine if this ratio was a good predictor of body weight. The data revealed that there was no single optimal ME to CP ratio for all production parameters.

Body weight and feed intake could best be predicted by a quadratic model for both CP and ME levels. This implied that both nutrients affect body weight gain and feed intake and should be included in any model aimed at predicting optimum dietary ME and CP concentrations for maximum economic returns. Bartov (1987) investigated the effects of altering the ME to CP ratio on body weight gain to both 17- and 49-day old broiler chickens. The author formulated the diets by decreasing the CP concentration and increasing the ME. The results showed that broiler chickens respond to increasing dietary CP concentrations independent of the dietary ME level, thus, performance was improved on the high CP diets that had a narrow ME to CP ratio. However, Summers *et al.* (1992) reports showed that dietary ME or CP concentrations had no effect at the early life feed intake by broiler chickens.

Eits *et al*. (2002) studied the effect of ME and CP on carcass and protein deposition rates in broiler chickens. Protein deposition rates increased linearly with increasing lysine intake with no reduction in the efficiency of protein deposition at the highest level of lysine intake. Results from these authors, also, showed that ME intake had no effect on carcass protein deposition rates. Nor were there interactions between the supply of dietary amino acids and ME on carcass protein deposition rate. In other words, there was no evidence of a biphasic response in the form of a lower efficiency of lysine deposition at higher levels of lysine intake once dietary ME supply became limiting. The authors concluded that the lack of a biphasic response most likely was due to the increased catabolism of excess essential amino acids that provided sufficient amino acids to the extent that ME intake may not have been severely limiting.

Tadelle and Ogle (1996) reported that the protein requirements for optimal production parameters in indigenous chickens aged above 7 weeks varied between 16 and 18 %. Chemjor (1998) reported that a dietary protein level of 13 % was adequate for indigenous chickens aged between 14 and 21 weeks. King'ori *et al.* (2003) observed that indigenous chickens aged between 14 and 21 weeks performed better when on a dietary crude protein level of 16 % in terms of feed intake and growth. Similarly, Ndegwa *et al*. (2001) found that a dietary crude protein level of 17 g CP/kg was adequate for optimal feed intake and growth of indigenous chickens. All these authors did not relate protein levels for optimal productivity to energy levels. Mbajiorgu (2010) related productivity in indigenous Venda chickens to the relationship between protein and energy levels. Thus, the author indicated that diets containing crude protein content levels of 178 g/kg DM and 193 g/kg DM at an energy level of 14 MJ ME/kg DM allowed for optimal utilization of absorbed protein and energy for growth and productivity in unsexed indigenous Venda chickens aged between one and six weeks and male indigenous Venda chickens aged between seven and thirteen weeks, respectively. However, the above author did not determine the lysine to energy ratio for optimal productivity of indigenous chickens.

2.5 Lysine requirements of chickens

The amino acid requirements of broiler chickens, expressed either as a percentage of the diet or as a minimum daily requirement varies considerably as a result of factors such as physiological, breed, dietary, environmental, sex and genetic factors, thereby making an accurate estimate of broiler chicken nutritional requirements for all amino acids under all combinations of conditions and genotypes almost impossible to determine (Baker *et al*., 2002; Mack *et al*., 1999). However, it has been generally accepted that the dietary requirement for each of the essential amino acids can be expressed as a fixed proportion of the requirement for the other essential amino acids (Schutte and de Jong, 1998). Therefore, in an effort to simplify the determination of the amino acid requirements, research works on poultry have been directed at determining the requirements of a single reference amino acid under a range of different conditions with the assumption that the dietary requirement of all other amino acids can be expected to change in a fixed proportion to the reference amino acid. Thus, by definition, the "ideal ratio" of amino acids refers to the blend of essential amino acids in a diet known to satisfy, but not exceed the amino acid requirements for protein accretion and maintenance of chickens, with no deficiencies or excesses (Emmert and Baker, 1997). The advantage of applying such an ideal ratio of amino acids in meeting the amino acid requirements of any animal was that once this ideal ratio had been established for a certain age or period, research determining the amino acid requirements under a variety of different conditions need only focus on a single reference amino acid, with the requirement for the remaining amino acids being calculated relative to the reference amino acid. The important assumption of such an approach was that the requirement for the reference amino acid, as determined using the respective test diet, would not change once an ideal amino acid profile was applied in practical feed formulation. Although in practical diets fed to broiler chickens, methionine has been shown to be the first limiting amino acid, followed by lysine, the ideal amino acid profile concept has used lysine as the reference amino acid (Schutte and de Jong, 1998). This is because 1) lysine had been shown to be one of the main limiting amino acids in conventional poultry diets and can be supplemented in synthetic form; 2) it can be easily analysed.; 3) research work showed that dietary lysine had been shown to be used mainly for protein accretion and maintenance and was not used to synthesize other non-essential amino acids; and 4) there was a large pool of data that had investigated the lysine requirements of poultry under various conditions.

Since lysine was first selected as the preferred reference amino acid from which all other amino acid requirements may be deduced by application of an ideal amino acid profile, the determination of the lysine requirements of chickens under various conditions has been an ongoing focus area in poultry nutrition research. Holsheimer and Veerkamp (1992) while studying the interaction of lysine with dietary ME and CP, fed two strains of broiler chickens (Arbor Acres and Ross) from one to 56 days of age on two levels of ME (13.40 and 12.05 ME/kg DM), two ME/CP ratios (139 and 95) and two lysine/ME ratios (3.75 and 4.25 glMcal). Results of their study showed that lysine and CP had an effect on body weight gain but not on feed conversion efficiency. At the same CP level, increasing the lysine content resulted in significant improvement in body weight gain while dietary lysine had no effect on feed efficiency. Similarly, Holsheimer and Ruesink (1998) studied the effect of varying lysine and ME in diets of broiler chickens. The authors fed three levels of dietary ME (13.60, 12.55 and 11.51 MJ/kg DM) and two lysine to ME ratios (3.53 and 4 g/Mcal ME) from one to14 days of age. From 15 to 49 days the authors fed dietary lysine to energy ratios of 1.10, 1.2 and 1.3. At 21 days the highest body weight gain was observed on the group fed a diet containing a 1.3 lysine to energy ratio. Increasing lysine at any ME level increased body weight gain and feed efficiency. During the finisher stage (15-49 days) body weight gain and feed efficiency were optimized at a 1.2 lysine to energy ratio. Lowest carcass fat was achieved at dietary lysine to energy ratio of 1.1. The authors did not observe an effect of the treatments on carcass fat of finishing weights.

The NRC (1994) recommended 1.1 % total lysine for broiler chicken starter for the starting (1-21 days post-hatch) broiler chickens. However, there is evidence that the NRC (1994) recommendations of lysine for starting broiler chicks were insufficient to support the maximal broiler performance in terms of live weight, carcass yield and feed efficiency. Kidd *et al.* (1997) fed broiler chicks on two levels of dietary lysine of 1.10 and 1.20 % from 1-18 days. Their results showed that increasing dietary lysine from 1.10 to 1.20 % of the diet improved gain and FCR. Similar results were obtained by Knowles and Southern (1998). Kidd and Fancher (2001) concluded that dietary lysine of minimal and maximal performance ranges between 1.18 and 1.22 % for broiler chickens. Similar conclusions were reported by Si *et al.* (2004) who studied the relationship of dietary lysine and the other essential amino acids as it affects the performance of broiler chickens during one to 21, one to 42 or one to 56 days of age. Si *et al*. (2004) determined the lysine requirement of broiler chicks for three-phases during 1-63 days of age. Three levels of lysine (NRC 1994, +0.15, and +0.3) were studied in each phase. Increasing lysine levels to +0.15 of the NRC (1994) resulted in improved body weight gain and feed efficiency at 21 days but not in latter stages. Breast yield at 63 days of age was significantly higher at +0.3 lysine group compared with the low levels. Requirement for breast yield appeared to be similar to that of feed efficiency, while the requirement for body weight gain was lower.

For the growing and finishing phase, the NRC (1994) recommendations were, 1.0 and 0.9, respectively. The latter investigations with these age periods, however, tended to partially agree (Corzo *et al*., 2002; Si *et al.*, 2004). However, Kidd *et al.*

(1997), Mack *et al*. (1999) and Si *et al*. (2004) disagreed with the NRC's (1994) suggested lysine levels during these phases. Han and Baker (1994) investigated the digestible lysine requirements of male and female broiler chickens during 21-42 days of age using a basal diet of 0.63 % total lysine supplemented with synthetic lysine to get 0.51, 0.61, 0.71, 0.81, 0.91, 1.01 and 1.11 % digestible lysine. Their results showed that body weight gain and feed conversion efficiency were optimized at dietary lysine levels of 0.85 and 0.89 % (male) and 0.78 and 0.85 % (female), respectively. They also demonstrated that male broiler chickens have higher digestible lysine requirements than the females and the requirements for feed efficiency were higher than for body weight gains while requirements for maximum breast meat yield were not greatly different from that of feed efficiency. Corzo *et al*. (2002) reported that during 42-56 days of age, there was progressive increments in dietary lysine levels (0.75 to 1.15 % of diet) in the diets of broiler chickens while other amino acids were balanced, dietary lysine treatment had no effect on body weight gain, breast yield and abdominal fat, while FCR was optimized at 0.85 % lysine.

It was concluded that the recommendations of the NRC (1994) of 0.85 % lysine for 42-56 days is sufficient to support the maximum performance of finishing male broiler chickens. Similarly, Si *et al.* (2004) concluded that the NRC (1994) recommendations for the 56 day broiler chickens were sufficient to support the optimum performance. Contrary to these reports, findings of some other researchers indicated that the NRC (1994) recommendations for growing and finishing phases were too low. Kidd *et al.* (1997) fed broiler chickens on two levels of lysine [100 and 105 % of NRC (1994)] and recommended that supplemental lysine to 105 of the NRC was (1994) needed to optimize the 18-54 day FCR. Mack *et al*. (1999) conducted an experiment to evaluate the digestible lysine requirement of ISA and ROSS broiler chickens. A basal diet (17.2 CP; 3158 kcal/kg DM) was fortified with L-lysine to achieve six dietary levels of digestible lysine. The results of their study indicated that digestible lysine requirements of 1.02, 1.16 and 0.96 (Ross) while 0.94, 1.15 and 1.03 (Isa), respectively, were required for weight gain, feed efficiency and breast meat yield. Si *et al.* (2004) concluded that the lysine recommendation of the NRC (1994) may be inadequate for 42 days; these authors recommended a lysine requirement of NRC +1 for 1-42 days of age.

Evidence that the efficiency of utilization of amino acids may depend upon genotype were also provided. Fatufe *et al.* (2004) studied the response of dietary lysine on the performance and the efficiency of lysine utilization of growing male chicken lines by feeding graded-levels of lysine diets ranging from 0.38 to 1.68 to layer and broiler chickens. The results showed that protein accretion approached 95 of the estimated maximum with dietary lysine of 1.25 % (broiler chickens) and 1.04 % (layers), respectively.

Lysine also exhibits specific effects on carcass composition (Leclercq, 1998; Rezaei *et al.,* 2004). Rezaei *et al.* (2004) showed that a positive response in breast meat yield was achieved by increasing lysine level in the diet. Similarly, Holsheimer and Ruesink (1998) showed that breast meat yield was increased in male broiler chickens fed diets containing increasing lysine levels from 1 to 14 days of age. Several authors have shown that the dietary lysine levels required by broiler chickens to achieve maximum FCR (Baker *et al*., 2002; Han and Baker, 1993) or breast meat yield (Kerr *et al*., 1999) were higher than that required for maximum body weight gain with the lysine level at which a plateau was achieved in the response variable being in the order of body weight < breast meat < FCR (Leclercq, 1998). No study was found on the lysine requirements for indigenous chickens. King'ori *et al.* (2003) expressed similar sentiments. Some studies (Han and Baker, 1991; NRC, 1994; Labadan *et al.,* 2001, Ng'ambi *et al*., 2009) have been carried out to determine the dietary lysine to crude protein ratio requirements for optimum weight gain, breast meat yield and feed conversion ratio of broiler chickens. Most of these studies indicated that different ratios are required for different production parameters. However, some studies (NRC, 1984; Labadan *et al.,* 2001; Rezaei *et al.,* 2004) indicated that single ratios cater for all the production parameters. No study was found on the effect of dietary lysine to energy ratio on productivity of indigenous chickens.

In a study aimed at comparing the lysine requirements of slow and fast-growing strains of broiler chickens from 8 - 21 days of age, Han and Baker (1991) reared chicks derived from either a New Hampshire X Columbian cross or a commercial Hubbard broiler strain on identical diets to 7 days of age after which a series of ten experimental diets containing graded levels of digestible lysine ranging from 0.51 to 1.41 %. The basal diet was then supplemented with graded levels of synthetic L-lysine at the expense of starch to create the ten experimental diets that differed only in their digestible lysine content. Response variables measured included body weight gain, FCR or whole carcass protein. Results of this study showed that although the Hubbard strain grew faster than the New Hampshire X Columbian chickens, the substantially higher feed intake of the Hubbard broiler chickens resulted in there being no difference in the digestible lysine requirement of both strains when this amino acid was expressed as a percentage of the diet. On that basis, the broken line model resulted in an estimated digestible lysine requirement for body weight gain of 0.93 % and 0.96 % for the New Hampshire X Columbian and Hubbard strains, respectively, and FCR was optimized at a digestible lysine of 0.99 % for both strains. Since the broken line model was known to result in a slight underestimation of the nutrient requirement, the authors suggested the digestible lysine levels that resulted in maximum body weight gain and FCR for both strains should be no more than 1.01 and 1.21 %, respectively. Using a similar method, Labadan *et al*. (2001) results showed that dietary lysine levels of 1.28, 1.32 and 1.21% optimized body weight gain, breast meat yield, and FCR, respectively. In another study, Kidd and Fancher (2001) used a similar dose response methodology to estimate the lysine requirement of Ross 344 X Ross 508 broiler chickens from 1 to 18 days and reported that total lysine requirement for body weight gain lie between 1.19 and 1.22 % and between 1.17 and 1.21 % for FCR.

No study was found on lysine requirements for optimal productivity in indigenous chickens. Similarly, limited studies were found on lysine to energy ratio requirements for optimal productivity in indigenous chickens. There was, therefore, need to determine such requirements for indigenous Venda chickens.

2.6 Dietary lysine to energy ratio for optimal productivity and carcass characteristics of chickens

Lysine requirements for broiler chickens have attracted so much research attentions (Ng’ambi *et al*., 2009; Labadan *et al.,* 2001; Han and Baker, 1991; NRC, 1994). Several studies showed that dietary lysine has an effect on the growth and carcass characteristics (Rezaei *et al.,* 2004; Leclercq, 1998; Holsheimer and Ruesink, 1998; Han and Baker, 1991) in broiler chickens. Similarly, studies have shown that changes in dietary energy levels of chickens have an influence on the production parameters

(Mbajiorgu *et al*., 2011; Dozier *et al*., 2007; Ghaffari *et al*., 2007). However, finding the effect of one nutrient while keeping the other constant is inadequate and the deficiency or excess of one nutrient may affect other nutrients. For example, high intakes of folic acid supplements may mask or delay the diagnosis of vitamin B_{12} deficiency. The antagonism between dietary lysine and arginine are well known (Waldroup *et al.*, 2006; D'mello, 1994). Studies have shown that White Leghorn chickens eat to meet their energy requirements (NRC, 1994) but increasing the energy level of the diets of these chickens will make other nutrients to be imbalanced. This, therefore, brings us to the concept of optimization of nutrients in poultry feed. The law of diminishing returns states that " as more investment in an area is made, overall return on the investment increases until it gets to a peak (optimal level) when additional investment will lead to a decrease in output assuming all other variables remain fixed". This concept is very important in feed formulation. Limited and variable information is available on dietary lysine to energy ratio for optimal productivity and carcass characteristics.

Presented in Tables 2.01 and 2.02 are summaries of dietary lysine to energy ratios for optimal productivity and carcass characteristics of chickens.

It is concluded that information on dietary protein, energy and lysine requirements for optimal productivity of indigenous chickens is limited and variable. Similarly, information on the effects of relationships between dietary protein, energy and lysine on optimal productivity of indigenous chickens is limited. Sub-optimal levels result in low productivity of the chickens. Thus, nutrient requirement levels for optimal productivity and carcass characteristics of Venda chickens have to be determined.

Table 2.01 A summary of lysine to energy ratio requirements for optimal productivity of chickens

Variable	Breed	Age	Optimal L:E ratio	Author(s)
Feed intake	Ross broiler chickens	14 to 42 days	1.07	Hind *et al*. (2012)
	Male broiler chickens	44 to 55 days	0.74	Araujo *et al*. (2005)
	Male Venda chickens	7 to 13 weeks	0.71	Mbajiorgu *et al*. (2011)

	Ross 308 broiler chickens	21 to 42 days	0.843	Berri *et al*. (2008)
Weight gain	Ross broiler chickens	14 to 42 days	1.05	Hind *et al*. (2012)
	Male broiler chickens	44 to 55 days	0.62	Araujo *et al*. (2005)
	Male Venda chickens	7 to 13 weeks	0.76	Mbajiorgu *et al*. (2011)
	Ross 308 broiler chickens	4 to 6 weeks	0.75	NRC (1994)
FCR	Unsexed Ross broiler chickens	14 to 42 days	1.04	Hind *et al*. (2012)
	Male broiler chickens	44 to 55 days	1.84	Araujo *et al*. (2005)
	Male Venda chickens	7 to 13 weeks	0.81	Mbajiorgu *et al*. (2011)
Live weight	Ross broiler chickens	14 to 42 days	0.98	Hind *et al*. (2012)
	Arber Acres broiler chickens	1 to 56 days	0.58	Tang *et al.* (2007)
	Male Venda chickens	7 to 13 weeks	0.85	Mbajiorgu *et al*. (2011)
	Ross 308 broiler chickens	21 to 42 days	0.895	Berri *et al*. (2008)
ME intake	Male broiler chickens	44 to 55 days	0.71	Araujo *et al*. (2005)
N retention	Male Venda chickens	7 to 13 weeks	0.61	Mbajiorgu *et al*. (2011)

Table 2.02 A summary of lysine to energy ratio requirements for optimal carcass characteristics of chickens

Variable	Breed	Age	Optimal L:E ratio	Author(s)
Carcass weight	Male broiler chickens	44 to 55 days	0.84	Araujo *et al*. (2005)
	Male Venda chickens	7 to 13 weeks	1.36	Mbajiorgu *et al*. (2011)
	Ross 308 broiler chickens	21 to 42 days	0.90	Berri *et al*. (2008)
Dressing percentage	Male broiler chickens	44 to 55 days	1.11	Araujo *et al*. (2005)
	Arber Acres broiler chickens	1 to 56 days	0.70	Tang *et al.* (2007)
Breast meat yield	Male broiler chickens	44 to 55 days	0.57	Araujo *et al*. (2005)
	Male Venda chickens	7 to 13 weeks	0.81	Mbajiorgu *et al*. (2011)
	Male broiler chickens	2 to 6 weeks	0.74	Labadan *et al*. (2001)
Drumstick	Male broiler chickens	44 to 55 days	0.80	Araujo *et al*. (2005)
	Ross 308 broiler chickens	21 to 42 days	0.526	Berri *et al*. (2008)
	Arber Acres broiler chickens	1 to 56 days	0.56	Tang *et al.* (2007)
Thigh	Ross 308 broiler chickens	21 to 42 days	0.778	Berri *et al*. (2008)
	Arber Acres broiler chickens	1 to 56 days	0.48	Tang *et al.* (2007)
Wings	Male broiler chickens	44 to 55 days	0.74	Araujo *et al*. (2005)
Fat pad	Male broiler chickens	44 to 55 days	0.96	Araujo *et al*. (2005)
	Ross 308 broiler chickens	21 to 42 days	0.83	Berri *et al*. (2008)
	Male Venda chickens	7 to 13 weeks	1.12	Mbajiorgu *et al*. (2011)

2.7 Effect of dietary lysine to energy ratio on carcass sensory attributes

To determine the acceptance of meat or food products, consumers consider several characteristics, such as its sensory characteristics, its nutritional value and its impact on health (Muchenje *et al*., 2008). Chicken meat is considered better than red meat because of comparably low levels of fat, cholesterol and high levels of iron (Jaturasitha *et al*., 2008).

Meat eating quality can be defined in terms of the sensory attributes of tenderness, juiciness and flavour (Lawrie, 1998). Sensory assessments of meat have been shown to be influenced by various factors. Among others, Sveinsdóttir *et al*. (2009) established that availability and familiarity of food affect sensory scores. The influence of nutrition on the meat quality cannot be underestimated. The nutrition of the animal influences many chemical composition, properties and structure of the indigenous chicken muscles (Wattanachant, 2008).

Meat pH, tenderness and water holding capacity are attributes of muscle texture that have been studied most extensively (Tang *et al*., 2007; Apple *et al*., 2004). Meat pH is determined by muscle glycogen content and its degradation rate. A rapid pH drop results in earlier onset of rigour and greater degree of rigor shortening, which determines the tenderness of meat (Botha *et al*., 2008). Muscle contraction is also controlled by the glycogen reserves ante-mortem and their breakdown rate postmortem. Studies of dietary effect on meat quality were focused on vitamins and trace minerals. Carpenter *et al*. (1997) reported a decrease in shear force values when $CaCl_2$ was injected into the muscle of lambs, supplementing Mg to diets 5 days before slaughter increased pH value and decreased water drip loss (D'souza *et al*., 1998). Addition of magnesium diets increased the redness of the longissimus thoracis muscles of growing-finishing pigs (Apple *et al*., 2000). Other studies reported that chromium and iron had different effects on tenderness, water drip loss, and colour of poultry meat (Ruiz *et al*., 2000).

Dietary composition and/or feed additives have been shown to affect muscle colour of pigs (Stoller *et al*., 2003), sheep and cattle (Boleman *et al*., 1996), and meat tenderness of cows (Boleman *et al*., 1996) and beef steers (Bruce *et al*., 1991). Conjugated linoleic acid decreased breast muscle redness of broiler chickens (Du and

Ahn, 2002). Deficiency in lysine had an effect on the development of the pectoralis major muscles and the sartorius muscles in growing chickens (Tesseraud *et al*., 1996). However, there is limited information on the effect of dietary lysine to energy ratio on meat quality and sensory attributes.

Low amino acid contents in animal feed lead to subnormal haemoglobin. The amino acids of the diet may affect iron absorption in the intestine (Lönnerdal and Chen 1990). Mahdavi *et al*. (2012) concluded that lysine requirements for broiler chickens' performance were lower than for breast meat yield and immune responses.

CHAPTER 3

EFFECT OF DIETARY LYSINE TO ENERGY RATIO ON GROWTH AND PRODUCTIVITY OF UNSEXED INDIGENOUS VENDA CHICKENS AGED ONE TO SEVEN WEEKS AND RAISED IN CLOSED CONFINEMENT

3.1 Introduction

Indigenous chickens are nutritionally, economically and culturally very important to rural households of Sub-Saharan Africa and especially in South Africa (Alders 2001; Alabi *et al.*, 2012). However, they have low growth and high mortality rates (Gondwe, 2004). Poor nutrition is one of the main causes of low growth and high mortality rates of indigenous chickens (Ndegwa *et al*., 2001). These chickens are usually kept on free rrange and moving around all the time, thus, the management could, also, contributed to their low productivity. There is evidence that dietary lysine to energy ratio affects productivity of broiler chickens (Priyankarage *et al.,* 2008; Araujo *et al*., 2005). NRC (1994) reported lysine to energy ratios of 0.89 and 0.75 for optimal growth rates of broiler chickens at the starter and grower phases, respectively. However, Hind *et al.* (2012) and Parr and Summers (1991) did not observe any improvement in the productivity of broiler chickens with increase in dietary lysine to energy ratio above those of the NRC (1994). Other authors (Rezaei *et al*., 2004; Holsheimer and Veerkamp, 1992) did not observe any effect of lysine to energy ratio on the productivity of broiler chickens. Thus, results of the effects of dietary lysine to energy ratio on productivity of broiler chickens are not conclusive. Similarly, information on the effect of dietary lysine to energy ratio on productivity of indigenous Venda chickens is limited. Mbajiorgu *et al*. (2011) indicated that varying lysine to energy ratio in the diets has effect on productivity of Venda chickens. Thus, it is important that more studies should be done to ascertain the responses of indigenous chickens to differing dietary lysine to energy ratios. Therefore, the objective of this part of the study was to determine lysine to energy ratio levels for optimal feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy, nitrogen retention and mortality of Venda chickens aged one to seven weeks and raised in closed confinement.

3.2 Materials and methods

3.2.1 Study site

This study was conducted at the Animal Unit of the University of Limpopo, South Africa. The ambient temperatures around the study area ranged between 20 and 36℃

in summer and between 10 and 25℃ in winter. The University of Limpopo lies at latitude 27.55˚S and longitude 24.77˚E. It receives a mean annual rainfall of less than 400 mm (Kutu and Asiwe, 2010).

3.2.2 Experimental procedures, treatments and design

Four experiments were conducted to determine the effect of dietary lysine to energy ratio on productivity of Venda chickens aged between one and seven weeks. Four dietary lysine levels of 8, 9, 11 and 12 g/kg DM feed were used at four different energy levels of 11, 12, 13 and 14 MJ of ME/kg DM. Thus, the diets ended up with different dietary lysine to energy ratios (Tables 3.01, 3.02, 3.03 and 3.04, for Experiments 1, 2, 3 and 4, respectively). Each experiment commenced with 160 unsexed day-old indigenous Venda chicks with an initial live weight of 30 ± 3 g per bird and carried out for a period of seven weeks. The chicks were obtained from the University of Limpopo Hatchery Unit. In each experiment a complete randomized design was used. The chicks were randomly assigned to four treatments with four replicates, each replicate having 10 birds. Light was provided 24 hours daily. Water and feed were provided *ad libitum* throughout the experimental period. The diets were compounded with the help of Voorslagvoere Milling Company, Mokopane, South Africa. The feed ingredients of the diets are given in Tables 3.05, 3.06, 3.07 and 3.08 for Experiments 1, 2, 3 and 4, respectively.

3.2.3 Data collection

The initial live weights of chicks were taken at the commencement of each experiment. Thereafter, average live weights per bird were measured at weekly intervals by weighing the chickens in each pen and the total weight was divided by the total number of birds in each pen. These live weights were used to calculate growth rates of the chickens. Weekly mean feed intakes were determined until termination of the experiment. These weights were used to calculate daily mean feed intake. Feed conversion ratio per pen was calculated as total feed consumed divided by the weight gain of the birds in that pen. Mortalities were recorded daily during the study period. Digestibility was measured when the chickens were between 42 and 49 days old. Digestibility was conducted in specially designed metabolic cages having automated and separate watering and feeding troughs. Two birds per replicate were randomly selected from each experiment and transferred to metabolic cages for measurement of apparent digestibility of nutrients. A three-day acclimation period was allowed prior to a four-day collection period. Droppings voided by each bird were collected on a daily basis at 08.00h. Care was taken to avoid feathers, scales, feeds and debris mixing with the droppings.

Table 3.01 Dietary treatments for Experiment 1*

Diet code	Diet description	L:E ratio (g lysine /MJ ME/kg DM)
$L_8 E_{11}$	Diet containing 8 g lysine/kg DM, 11 MJ ME/kg DM and 150 g crude protein/kg DM	0.73
$L_8 E_{12}$	Diet containing 8 g lysine/kg DM, 12 MJ ME/kg DM and 150 g crude protein/kg DM	0.67
$L_8 E_{13}$	Diet containing 8 g lysine/kg DM, 13 MJ ME/kg DM and 150 g crude protein/kg DM	0.62
$L_8 E_{14}$	Diet containing 8 g lysine/kg DM, 14 MJ ME/kg DM and 150 g crude protein/kg DM	0.57

* Laboratory determined ME (NIRA) and CP

Table 3.02 Dietary treatments for Experiment 2*

Diet code	Diet description	L:E ratio (g lysine /MJ ME/kg DM)
L_9 E_{11}	Diet containing 9 g lysine/kg DM, 11 MJ ME/kg DM and 180 g crude protein/kg DM	0.82
L_9 E_{12}	Diet containing 9 g lysine/kg DM, 12 MJ ME/kg DM and 180 g crude protein/kg DM	0.75
L_9 E_{13}	Diet containing 9 g lysine/kg DM, 13 MJ ME/kg DM and 180 g crude protein/kg DM	0.69
L_9 E_{14}	Diet containing 9 g lysine/kg DM, 14 MJ ME/kg DM and 180 g crude protein/kg DM	0.64

* Laboratory determined ME (NIRA) and CP

Table 3.03 Dietary treatments for Experiment 3*

Diet code	Diet description	L:E ratio (g lysine /MJ ME/kg DM)
L_{11} E_{11}	Diet containing 11 g lysine/kg DM, 11 MJ ME/kg DM and 220 g crude protein/kg DM	1.00
L_{11} E_{12}	Diet containing 11 g lysine/kg DM, 12 MJ ME/kg DM and 200 g crude protein/kg DM	0.92
L_{11} E_{13}	Diet containing 11 g lysine/kg DM, 13 MJ ME/kg DM and 220 g crude protein/kg DM	0.85
L_{11} E_{14}	Diet containing 11 g lysine/kg DM, 14 MJ ME/kg DM and 220 g crude protein/kg DM	0.79

* Laboratory determined ME (NIRA) and CP

Table 3.04 Dietary treatments for Experiment 4*

Diet code	Diet description	L:E ratio (g lysine /MJ ME/kg DM)
L_{12} E_{11}	Diet containing 12 g lysine/kg DM, 11 MJ ME/kg DM and 240 g crude protein/kg DM	1.09
L_{12} E_{12}	Diet containing 12 g lysine/kg DM, 12 MJ ME/kg DM and 240 g crude protein/kg DM	1.00
L_{12} E_{13}	Diet containing 12 g lysine/kg DM, 13 MJ ME/kg DM and 240 g crude protein/kg DM	0.92
L_{12} E_{14}	Diet containing 12 g lysine/kg DM, 14 MJ ME/kg DM and 240 g crude protein/kg DM	0.86

* Laboratory determined ME (NIRA) and CP

Table 3.05 Diet composition for Experiment 1

	Experimental diet			
Ingredient (%)	L_8 E_{11}	L_8 E_{12}	L_8 E_{13}	L_8 E_{14}
Maize	45.19	65.80	64.70	59.02
Wheat Bran	31.32	5.66	-	-
Full fat Soya	0.51	1.41	24.75	30.00
Hipro Soya	19.12	23.12	6.33	3.13
Oil	-	-	-	3.62
Limestone	2.64	2.51	2.42	2.40
Monocalcium Phosphate	-	0.39	0.65	0.70
Salt	0.47	0.45	0.46	0.46
Methionine	0.16	0.16	0.17	0.18
Lysine	0.18	0.12	0.12	0.11
Threonine	0.05	0.02	0.03	0.02
Choline	0.07	0.07	0.07	0.07
Vit/Min PMX	0.20	0.20	0.20	0.20
Cocci	0.05	0.05	0.05	0.05
AGP	0.03	0.03	0.03	0.03
NSP enzyme	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00

Table 3.06 Diet composition for Experiment 2

	Experimental diet			
Ingredient (%)	L_9 E_{11}	L_9 E_{12}	L_9 E_{13}	L_9 E_{14}
Maize	43.16	65.79	58.39	53.39
Wheat Bran	28.11	-	-	-
Full fat Soya	2.00	2.01	30.00	30.00
Hipro Soya	22.89	27.83	7.37	8.02
Oil	-	-	0.11	4.45
Limestone	2.64	2.73	2.44	2.42
Monocalcium Phosphate	-	0.49	0.54	0.58
Salt	0.44	0.45	0.46	0.46
Methionine	0.20	0.20	0.21	0.21
Lysine	0.15	0.11	0.09	0.07
Threonine	0.05	0.03	0.03	0.03
Choline	0.07	0.07	0.07	0.07
Vit/Min PMX	0.20	0.20	0.20	0.20
Cocci	0.05	0.05	0.05	0.05
AGP	0.03	0.03	0.03	0.03
NSP enzyme	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00

Table 3.07 Diet composition for Experiment 3

	Experimental diet			
Ingredient (%)	L_{11} E_{11}	L_{11} E_{12}	L_{11} E_{13}	L_{11} E_{14}
Maize	41.98	53.84	44.03	42.11
Wheat Bran	18.18	-	-	-
Full fat Soya	2.11	12.02	35.00	30.00
Hipro Soya	33.93	30.26	16.00	17.82
Oil	-	-	1.08	6.10
Limestone	2.57	2.48	2.47	2.44
Monocalcium Phosphate	-	0.25	0.31	0.36
Salt	0.44	0.44	0.45	0.46
Methionine	0.26	0.26	0.28	0.28
Lysine	0.11	0.06	-	0.04
Threonine	0.05	0.03	0.03	0.03
Choline	0.07	0.07	0.07	0.07
Vit/Min PMX	0.20	0.20	0.20	0.20
Cocci	0.05	0.05	0.05	0.05
AGP	0.03	0.03	0.03	0.03
NSP enzyme	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00

Table 3.08 Diet composition for Experiment 4

	Experimental diet			
Ingredients (%)	L_{12} E_{11}	L_{12} E_{12}	L_{12} E_{13}	L_{12} E_{14}
Maize	40.89	47.34	40.86	35.74
Wheat Bran	13.11	-	-	-
Full fat Soya	2.71	18.14	35.00	35.00
Hipro Soya	39.57	30.73	18.39	19.13
Oil	-	-	1.91	6.26
Limestone	2.53	2.50	2.49	2.46
Monocalcium Phosphate	-	0.14	0.20	0.24
Salt	0.44	0.44	0.45	0.46
Methionine	0.29	0.29	0.30	0.31
Lysine	0.07	0.03	0.02	0.01
Threonine	0.03	0.02	0.02	0.02
Choline	0.07	0.07	0.07	0.07
Vit/Min PMX	0.20	0.20	0.20	0.20
Cocci	0.05	0.05	0.05	0.05
AGP	0.03	0.03	0.03	0.03
NSP enzyme	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00

3.2.4 Chemical analysis

Dry matter of the feeds, feed refusals and faecal samples were determined by drying the samples in the oven for 24 hours at a temperature of 105 ˚C. Faeces were freeze-dried before analysis (AOAC, 2005). Ash content of the feeds, feed refusals and faeces were analysed by ashing a sample at 600 ˚C in a muffle furnace overnight. Gross energy values for feeds and faeces were measured in a bomb calorimeter (AOAC, 2005) at the Animal Production Laboratory of the University of Limpopo. The apparent metabolisable energy and nitrogen retention contents of the diets for each experiment were calculated as described by AOAC (2005). Lysine, Ca, and P contents were analysed by ion–exchange chromatography (AOAC, 2005).

3.2.5 Statistical analysis

Data on feed intake, digestibility, growth rate, feed conversion ratio, metabolisable energy, nitrogen retention, live weight and mortality of the chickens were analysed by one-way analysis of variance (SAS, 2008). Where there were significant differences ($P<0.05$), Duncan test for multiple comparisons was used to test the significance of differences between treatment means (SAS, 2008). The dose-related optimal responses to dietary lysine to energy ratio were modelled using the following quadratic equation:

$$Y = a + b_1x + b_2x^2 + \epsilon$$

Where Y = live weight, feed intake, growth rate, feed conversion ratio, metabolisable energy or nitrogen retention; a = intercept; b_1 and b_2 = coefficients of the quadratic equation; x = dietary lysine to energy ratio level and $-b_1/2b_2$ = x value for optimal response, ϵ is the error. The quadratic model was fitted to the experimental data by means of the NLIN procedure of SAS (SAS, 2008). The quadratic model was used because it gave the best fit.

The relationship between responses in feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy and nitrogen retention and dietary lysine to energy ratios were modelled using a linear regression equation (SAS, 2008) of the form: $Y = a + bx$

Where Y = feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy or nitrogen retention; a = intercept; b = coefficient of the linear equation; x = dietary lysine to energy ratio.

The efficiency of dietary lysine and energy utilization for optimal productivity across the four experiments were calculated at each level of dietary lysine and metabolisable energy contents, respectively, as lysine intake/growth rate and metabolisable energy intake/growth rate and were regressed against the dietary lysine to energy ratio. The dose-related dietary lysine level and energy utilization for productivity across the four experiments were modelled using the quadratic equation as indicated above.

3.3 Results and discussion

3.3.1 Experiment 1

Results

Results of the nutrient composition of the diets used in Experiment 1 are presented in Table 3.09. The diets had a similar lysine content of 8 g/kg DM but different energy levels. The energy levels were 11, 12, 13 and 14 MJ of ME/kg DM (determined in the laboratory using NIRA), thus forming lysine to energy (L:E) ratios of 0.72 (UL_8E_{11}), 0.67 (UL_8E_{12}), 0.62 (UL_8E_{13}) and 0.57 (UL_8E_{14}), respectively.

Results of the effect of dietary lysine to energy ratio on feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen (N) retention and mortality of unsexed Venda chickens aged one to seven weeks are presented in Table 3.10. Dietary lysine to energy ratio had an effect ($P<0.05$) on all the parameters measured except feed conversion ratio (FCR) and mortality values which were similar ($P>0.05$) for all the treatments. Unsexed Venda chickens offered diets having lysine to energy ratios of 0.67 or 0.73 had similar ($P>0.05$) feed intakes; however, their intakes were higher ($P<0.05$) than those on diets having lysine to energy ratios of 0.62 or 0.57. Chickens on diets having lysine to energy ratios of 0.62 or 0.57 had similar ($P>0.05$) feed intakes. The growth rates and live weights of unsexed Venda chickens on diets having lysine to energy ratios of 0.67 or 0.73 were similar ($P>0.05$). However, growth rates and live weights of chickens on a diet having a lysine to energy ratio of 0.67 were higher ($P<0.05$) than those on diets having 0.62 or 0.57 lysine to energy ratios. Chickens on diets having lysine to energy ratios of 0.73 or 0.62 had similar ($P>0.05$) growth rates and live weights. Similarly, chickens on diets having 0.62 or 0.57 lysine to energy ratios had the same ($P>0.05$) growth rates and live weights. However, unsexed Venda chickens on a diet having a lysine to energy ratio of 0.73 had higher ($P<0.05$) growth rates and live weights than those on a diet having a lysine to energy ratio of 0.57. Unsexed Venda chickens offered diets having lysine to energy ratios of 0.62 or 0.67 had similar ($P>0.05$) ME values. However, chickens on a diet having a lysine to energy ratio of 0.62 had a higher ($P<0.05$) ME value than those on diets containing 0.73 or 0.57 lysine to energy ratios. Chickens on diets having lysine to energy ratios of 0.67 and 0.73 had similar ($P>0.05$) ME values. However, chickens on a diet having a lysine to energy ratio of 0.73 had a higher ($P<0.05$) ME value than those on a diet having a lysine to energy ratio of 0.57. Unsexed Venda chickens offered a diet having a lysine to energy ratio of 0.73 had a higher ($P<0.05$) N-retention than those on diets having lysine to energy ratios of 0.67, 0.62 or 0.57. Chickens on a diet having a lysine to energy ratio of 0.67 had a higher ($P<0.05$) N-retention than those on lysine to energy ratios of 0.62 or 0.57. Similarly, chickens on a diet having a lysine to energy ratio of 0.62 had a higher ($P<0.05$) N-retention than those on a lysine to energy ratio of 0.57.

Results of the effect of dietary lysine to energy ratio on optimal feed intake, growth rate, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens aged one to seven weeks are presented in Figures 3.01 to 3.05, respectively and Table 3.11. Feed intake, growth rate, live weight, apparent metabolisable energy and nitrogen retention in unsexed Venda chickens were optimized at dietary lysine to energy ratios of 0.722 ($r^2 = 0.938$), 0.719 ($r^2 = 0.849$), 0.719 ($r^2 = 0.850$), 0.670 ($r^2 = 0.889$) and 0.714 ($r^2 = 0.998$), respectively (Figures 3.01, 3.02, 3.03, 3.04 and 3.05, respectively and Table 3.11).

Table 3.09 Nutrient composition of diets used in Experiment 1 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed)

		Nutrient					
Treatment	L:E ratio	Dry matter	Lysine	ME*	Protein	Calcium	Phosphorus
$L_8 E_{11}$	0.73	884.80	8	10.79	220	10	5.5
$L_8 E_{12}$	0.67	882.05	8	11.79	220	10	5.5
$L_8 E_{13}$	0.62	886.38	8	12.79	220	10	5.5
$L_8 E_{14}$	0.57	891.39	8	13.80	220	10	5.5

L:E ratio: lysine to energy ratio (g/MJ ME)

* ME determined in the laboratory using NIRA

Table 3.10 Effect of dietary lysine to energy ratio (g/MJ ME) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g feed/g live weight gain), live weight (g/bird aged 49 days), apparent metabolisable energy (MJ of ME/kg), crude protein intake (g/bird/day), nitrogen retention (g/bird/day) and mortality (%) of unsexed Venda chickens aged one to seven weeks

	Dietary lysine to energy ratio (g/MJ ME)				
Variable	0.57	0.62	0.67	0.73	SE
Feed intake	26.94^{b}	30.12^{b}	40.72^{a}	39.97^{a}	1.799
Growth rate	6.4^{c}	7.1^{bc}	9.3^{a}	8.8^{ab}	0.39
FCR	4.20	4.24	4.38	4.54	0.192
Live weight	313.4^{c}	347.9^{bc}	454.2^{a}	431.1^{ab}	19.26
ME	9.57^{c}	10.58^{a}	10.48^{ab}	10.34^{b}	0.109
N-retention	1.24^{d}	1.48^{c}	1.59^{b}	1.63^{a}	0.039
Mortality	0.33	0.34	0.31	0.33	0.005

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

ME : Metabolisable energy

N-retention : Nitrogen retention

SE : Standard error

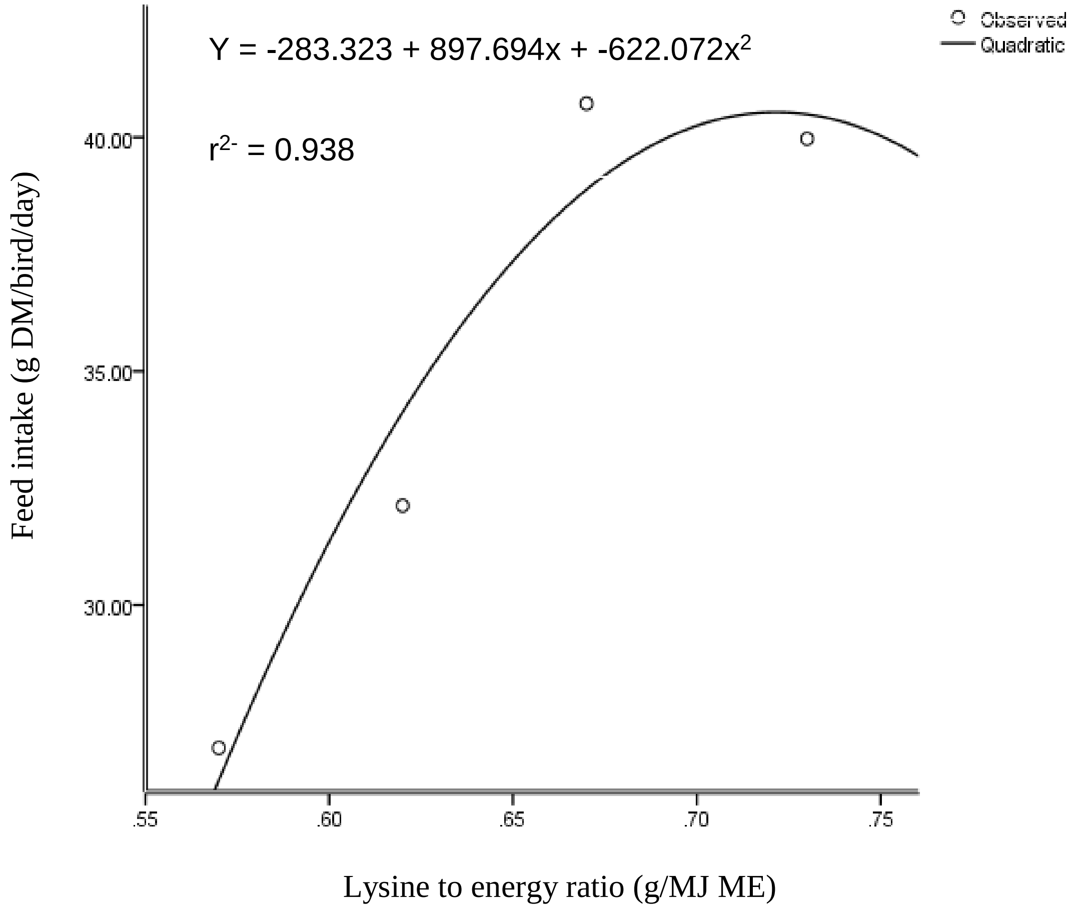


Figure 3.01 Effect of dietary lysine to energy ratio on feed intake of unsexed Venda chickens aged one to seven weeks

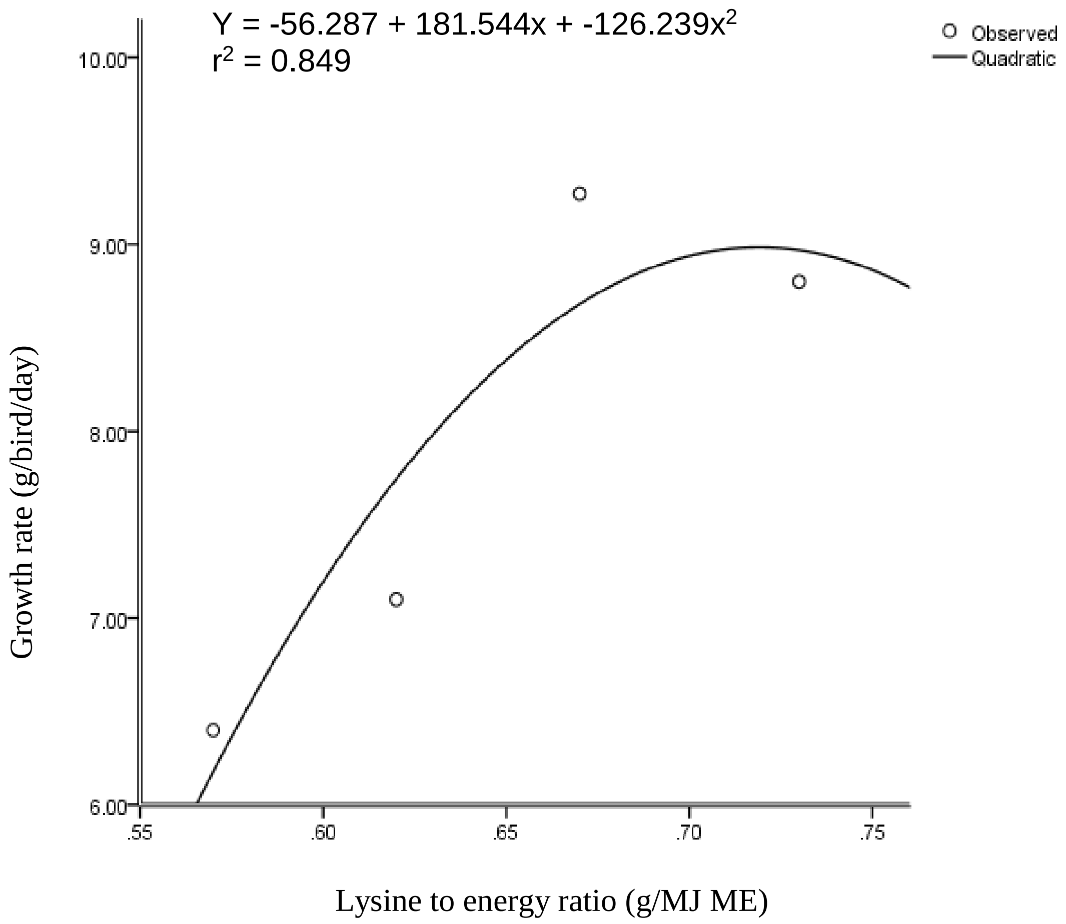


Figure 3.02 Effect of dietary lysine to energy ratio on growth rate of unsexed Venda chickens aged one to seven weeks

$Y = -2770.217 + 8932.467x + -6213.511x^2$

$r^2 = 0.850$

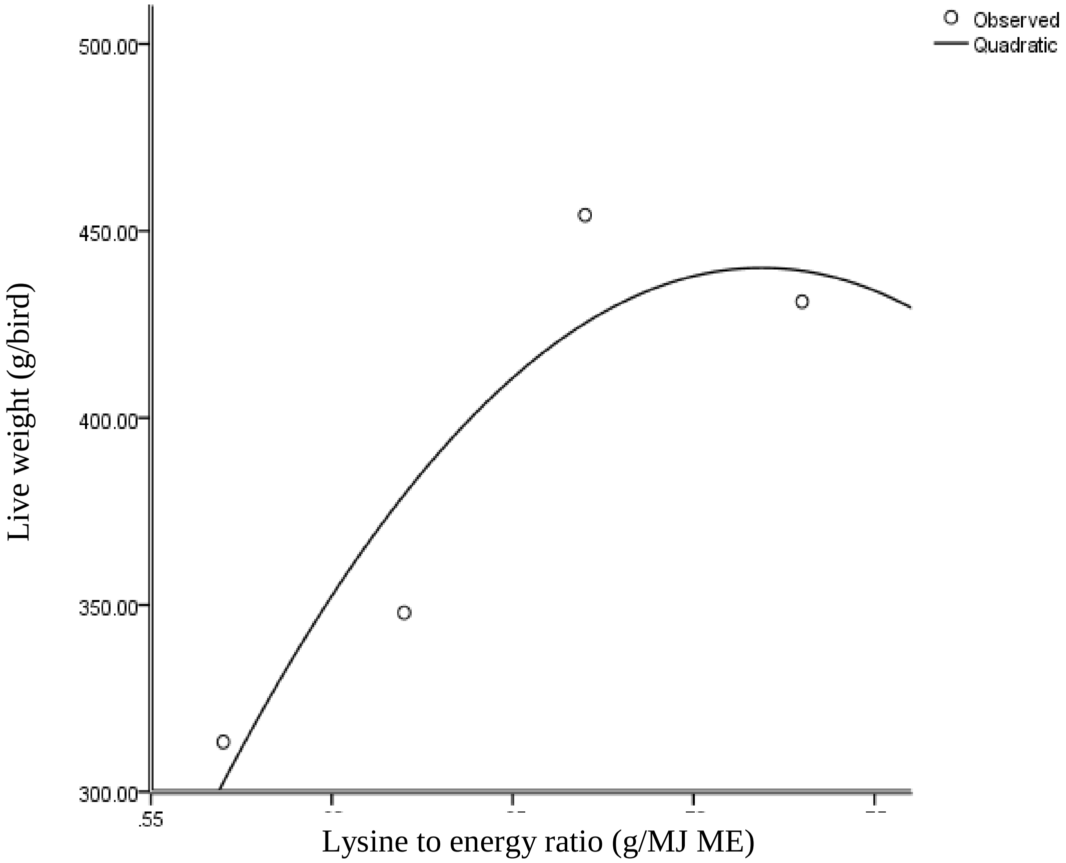
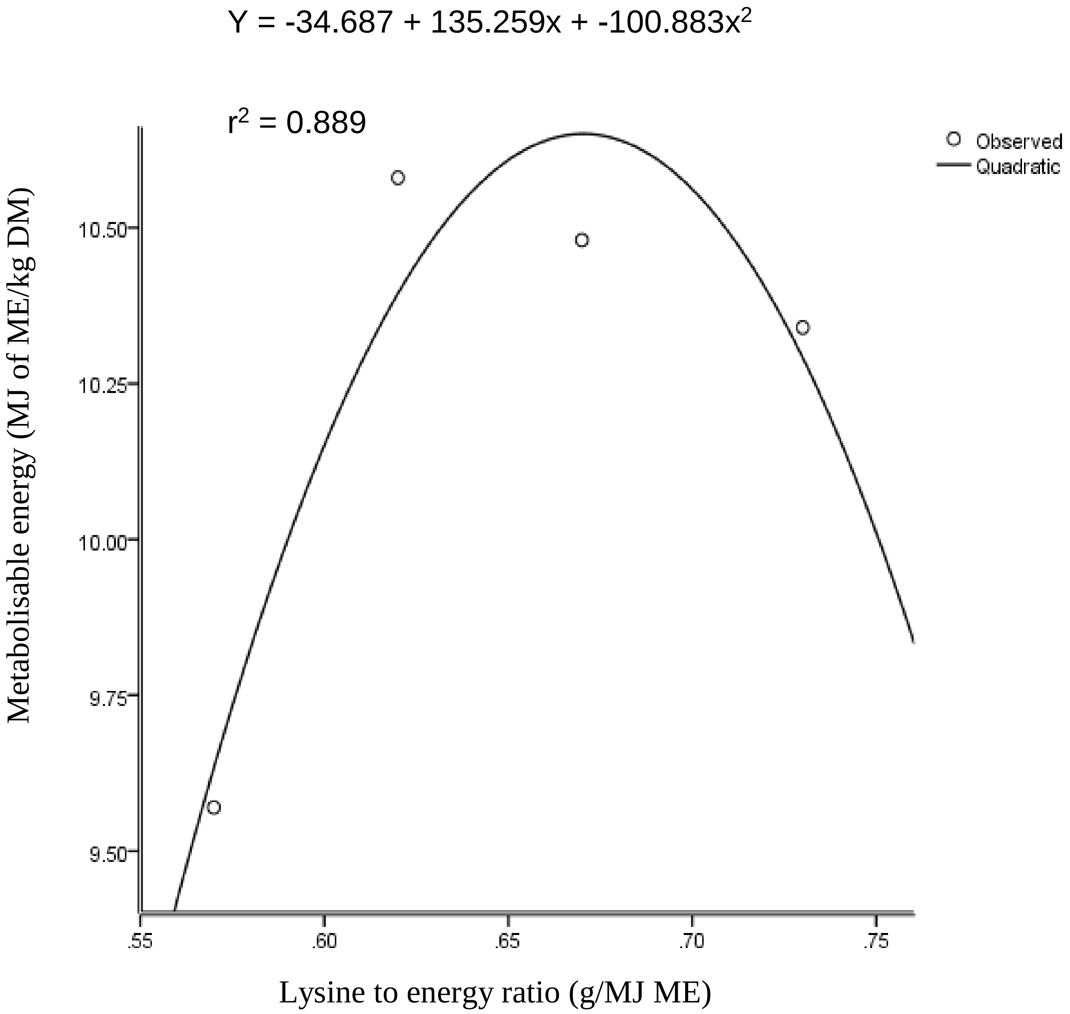


Figure 3.03 Effect of dietary lysine to energy ratio on live weight of unsexed Venda chickens aged 49 days



$Y = -34.687 + 135.259x + -100.883x^2$

$r^2 = 0.889$

Figure 3.04 Effect of dietary lysine to energy ratio on apparent metabolisable energy of unsexed Venda chickens aged seven weeks

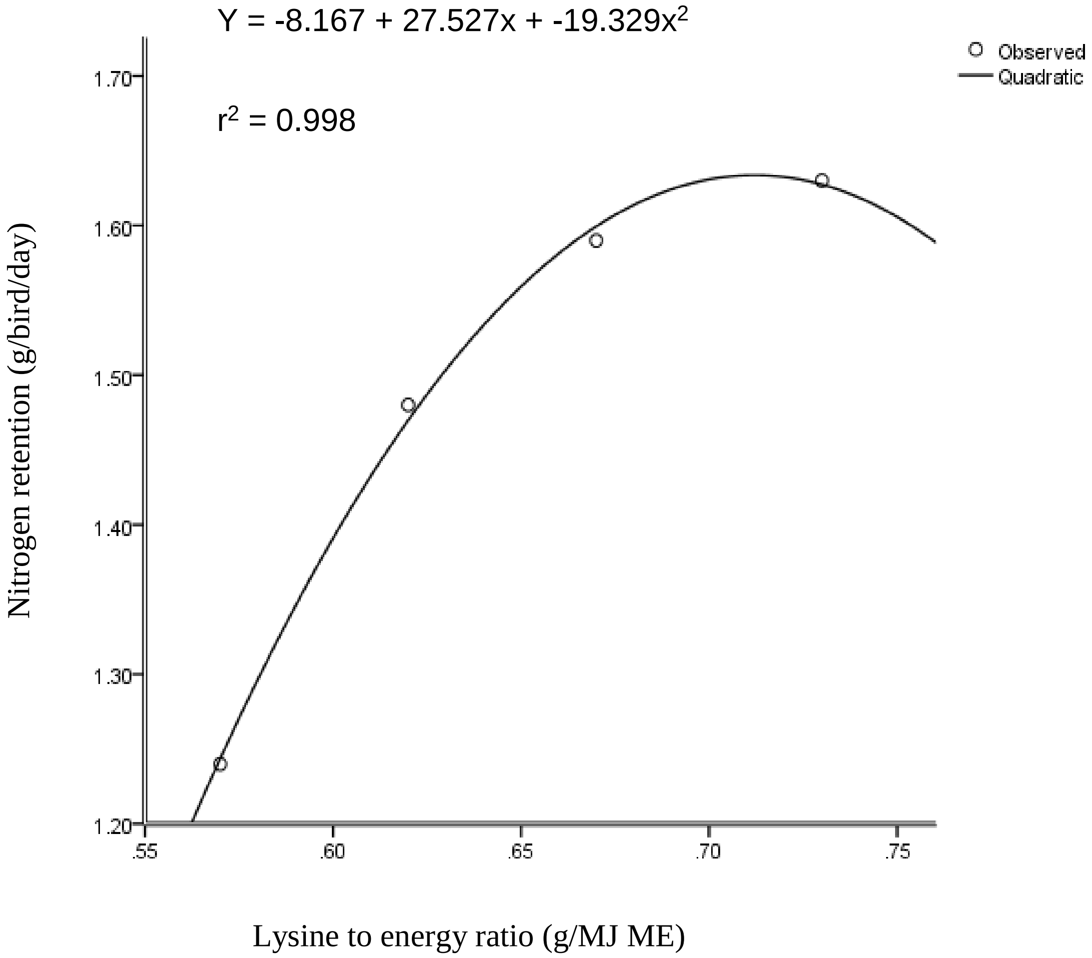


Figure 3.05 Effect of dietary lysine to energy ratio on nitrogen retention of unsexed Venda chickens aged seven weeks

Table 3.11 Dietary lysine to energy ratios for optimal feed intake (g/bird/day), growth rate (g/bird/day), live weight (g/bird aged 49 days), apparent metabolisable energy (MJ of ME/kg DM) and nitrogen retention (g/bird/day) of unsexed Venda chickens aged one to seven weeks

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Feed intake	$Y = -283.323 + 897.694x - 622.072x^2$	0.938	0.722	40.536
Growth rate	$Y = -56.287 + 181.544x - 126.239x^2$	0.849	0.719	8.982
Live weight	$Y = -2770.217 + 8932.467x - 6213.51x^2$	0.850	0.719	440.084
ME	$Y = -34.687 + 135.259x - 100.883x^2$	0.889	0.670	10.650
N-retention	$Y = -8.167 + 27.527x - 19.329x^2$	0.998	0.712	1.634

L:E ratio : lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Discussion

In this study, the diets were isonitrogenous but with different energy levels. The diets had a similar lysine content of 8 g/kg DM but different energy levels of 11, 12, 13 and 14 MJ of ME/kg DM (determined in the laboratory using NIRA). Thus, lysine to energy ratios of 0.58, 0.62, 0.67 and 0.73 were calculated and used. These cover both low and high dietary lysine to energy ratios. The diets contained similar levels of other nutrients which met the chickens' requirements as recommended by the NRC (1994).

Feed intake increased as dietary lysine to energy ratio increased until a lysine to energy ratio of 0.722 for optimal DM intake of 40.54 g per bird per day was reached. Thereafter, an increase in the dietary lysine to energy ratio resulted in a decrease in feed intake. A decrease in intake was possibly because the diets provided higher dietary lysine to energy ratios than those required by the chickens (NRC, 1994). Thus, the chickens were able to meet their lysine requirements with reduced intake (Leeson *et al*., 1996). It can, thus, be concluded that a dietary lysine to energy ratio of 0.722, in a diet of 8 g of lysine per kg DM, 11.08 MJ of ME/kg DM and 150 g of CP/kg DM, supported an optimal intake of unsexed Venda chickens aged one to seven weeks. Mbajiorgu *et al*. (2011) reported that lysine to energy ratio did not have effect on the feed intake of unsexed Venda chickens aged one to six weeks. In their study, feed intake was optimized at a lower dietary lysine to energy ratio of 0.61. The reason for the different lysine to energy ratios for optimal intakes between the present study and that of Mbajiorgu *et al*. (2011) may be because in their study they had fixed dietary energy and protein levels but differing lysine levels. Thus, the lysine to energy ratio in their study was for that particular dietary energy level. Aftab (2007) reported a higher dietary lysine to energy ratio of 0.92 for optimal intake in broiler chickens aged one to three weeks. Broiler chickens need more lysine for growth and hence have a higher dietary lysine to energy ratio than indigenous chicken breeds (NRC,1994).

Growth rate and live weight of Venda chickens increased as dietary lysine to energy ratio increased until a lysine to energy ratio of 0.719 for optimal growth rate and live weight was reached. Thereafter, both growth rate and live weight declined as the lysine to energy ratio increased. Thus, a dietary lysine to energy ratio of 0.719 optimized both growth rate and live weight of unsexed Venda chickens aged one to seven weeks. Plumstead *et al*. (2007) observed that body weight gain in broiler chickens increased when dietary ME was increased from 12.55 to 12.97 MJ/kg with no further improvement when dietary energy level was increased to 13.39 MJ/kg. However, the authors did not determine the optimum level. The ratio observed in the present study is lower than 1.20 estimated for optimal growth rates of Venda chickens by Mbajiorgu *et al*. (2011). Similarly, the lysine to energy ratio of 0.719 for optimal growth rate of Venda chickens in the present study is lower than a ratio of 0.89 (NRC, 1994), and those of 0.93, 0.91 and 0.81 at dietary energy levels of 11.30, 12.13 and 12.97 MJ of ME/kg DM, respectively, for broiler chickens (Aftab, 2007). Thus, broiler chickens require more lysine for growth than the indigenous chicken breeds (NRC, 1994), and hence, they have a higher lysine to energy ratio for optimal growth.

Apparent metabolisable energy (ME) intake increased as dietary lysine to energy ratio increased until a lysine to energy ratio of 0.67 for optimal ME of 10.65 MJ per kg DM was reached. Thereafter, an increase in the dietary lysine to energy ratio resulted in a decrease in ME intake. An optimum ME intake was, thus, achieved at a dietary lysine to energy ratio of 0.670, in a diet containing 8 g of lysine per kg DM, 11 MJ of ME/kg DM and 150 g of CP/kg DM. The estimated optimal lysine to energy ratio in this study is lower than the 1.04 reported by Mbajiorgu *et al* (2011) for unsexed Venda chickens. Dozier *et al.* (2007) observed that increasing dietary energy from 13.25 to 13.81 MJ of ME/kg in the diets of broiler chickens resulted in a linear increase in ME intake.

A dietary lysine to energy ratio of 0.712 optimized nitrogen retention of unsexed Venda chickens aged one to seven weeks. Mbajiorgu *et al.* (2011) observed that a lysine to energy ratio of 0.96 optimized nitrogen retention in Venda chickens aged one to six weeks. However, in their study they had a fixed dietary protein and energy values but varied the lysine levels.

In the present study dietary to energy ratio had no effect on mortality rate of Venda chickens aged one to seven weeks. This is similar to the observation made by Mbajiorgu *et al.* (2011).

3.3.2 Experiment 2

Results

Results of the nutrient composition of the diets used in Experiment 2 are presented in Table 3.12. The diets had a similar lysine content of 9 g/kg DM but different energy levels. The energy levels were 11, 12, 13 and 14 MJ ME/kg DM (determined in the laboratory using NIRA), thus, forming lysine to energy (L:E) ratios of 0.82 (L_9E_{11}), 0.75 (L_9E_{12}), 0.69 (L_9E_{13}) and 0.64 (L_9E_{14}), respectively.

Results of the effect of dietary lysine to energy ratio on feed intake, growth rate, feed conversion ratio (FCR), live weight, apparent metabolisable energy and nitrogen (N) retention of unsexed Venda chickens aged one to seven weeks are presented in Table 3.13. Dietary lysine to energy ratio had effect ($P<0.05$) on all the parameters measured except feed intake and mortality values which were similar ($P>0.05$) for all the treatments. Unsexed Venda chickens offered diets having lysine to energy ratios of 0.75 or 0.69 had similar ($P>0.05$) growth rates and live weights. Similarly, chickens offered diets having lysine to energy ratios of 0.69 or 0.82 had the same ($P>0.05$)

growth rates and live weights. However, chickens on a diet having a lysine to energy ratio of 0.75 had higher ($P<0.05$) growth rates and live weights than those on diets having 0.82 or 0.64 lysine to energy ratios. Chickens on a diet having a lysine to energy ratio of 0.82 had higher ($P<0.05$) growth rates and live weights than those on a diet having a lysine to energy ratio of 0.64. Unsexed Venda chickens offered diets having lysine to energy ratios of 0.82, 0.75 or 0.69 had similar ($P>0.05$) FCR values. Chickens offered diets having lysine to energy ratios of 0.69 or 0.64 had similar ($P<0.05$) FCR values. However, chickens offered diets having lysine to energy ratios of 0.82 or 0.75 had better ($P<0.05$) FCR values than those on a diet having a lysine to energy ratio of 0.64. Chickens on diets having lysine to energy ratios of 0.69, 0.75 or 0.82 had similar ($P>0.05$) ME values; their values were, however, higher ($P<0.05$) than those on a diet having a 0.64 lysine to energy ratio. Unsexed Venda chickens offered diets having lysine to energy ratios of 0.82 or 0.75 had similar ($P>0.05$) N-retention values; their values were, however, higher than those of chickens on diets having lysine to energy ratios of 0.69 or 0.64. Similarly, chickens on a diet having a lysine to energy ratio of 0.69 had higher ($P<0.05$) N-retention values than those on a diet having lysine to energy ratio of 0.64.

Table 3.12 Nutrient composition of diets used in Experiment 2 (units are in g/kg DM except energy as MJ of ME/kg DM feed and dry matter as g/kg feed)

		Nutrient					
Treatment	L:E ratio	Dry matter	Lysine	Energy*	Protein	Calcium	Phosphorus
$L_9 E_{11}$	0.82	885.33	9	10.79	220	10	5.5
$L_9 E_{12}$	0.75	882.80	9	11.79	220	10	5.5
$L_9 E_{13}$	0.69	888.19	9	12.79	220	10	5.5
$L_9 E_{14}$	0.64	892.86	9	13.80	220	10	5.5

L:E ratio: lysine to energy ratio (g/MJ ME)

*: ME determined in the laboratory using NIRA

Results of the effect of dietary lysine to energy ratio on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens aged one to seven weeks are presented in Figures 3.06

to 3.10, respectively and Table 3.14. Growth rate, FCR, live weight, ME and nitrogen retention were optimized at dietary lysine to energy ratios of 0.742 ($r^2 = 0.991$), 0.788 ($r^2 = 0.964$), 0.742 ($r^2 = 0.992$), 0.754 ($r^2 = 0.868$) and 0.789 ($r^2 = 0.991$), respectively (Figures 3.06, 3.07, 3.08, 3.09 and 3.10, respectively and Table 3.14).

Table 3.13 Effect of dietary lysine to energy ratio (g/MJ ME) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g feed/g live weight gain), live weight (g/bird aged 49 days), apparent metabolisable energy (MJ of ME/kg), nitrogen retention (g/bird/day) and mortality (%) of unsexed Venda chickens aged one to seven weeks

	Dietary lysine to energy ratio (g/MJ ME)				
Variable	0.64	0.69	0.75	0.82	SE
Feed intake	36.39	39.12	38.50	34.78	0.800
Growth rate	7.4^{c}	8.5^{ab}	9.0^{a}	8.0^{bc}	0.23
FCR	4.92^{a}	4.66^{ab}	4.30^{b}	4.36^{b}	0.114
Live weight	362.5^{c}	414.4^{ab}	440.6^{a}	391.6^{bc}	11.01
ME	9.32^{b}	10.40^{a}	10.33^{a}	10.21^{a}	0.126
N-retention	1.89^{c}	2.26^{b}	2.42^{a}	2.47^{a}	0.060
Mortality	0.38	0.39	0.38	0.41	0.003

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

ME : Metabolisable energy

N-retention : Nitrogen retention

SE : Standard error

$$Y = -74.205 + 224.165x + -151.103x^2$$
$$r^2 = 0.991$$

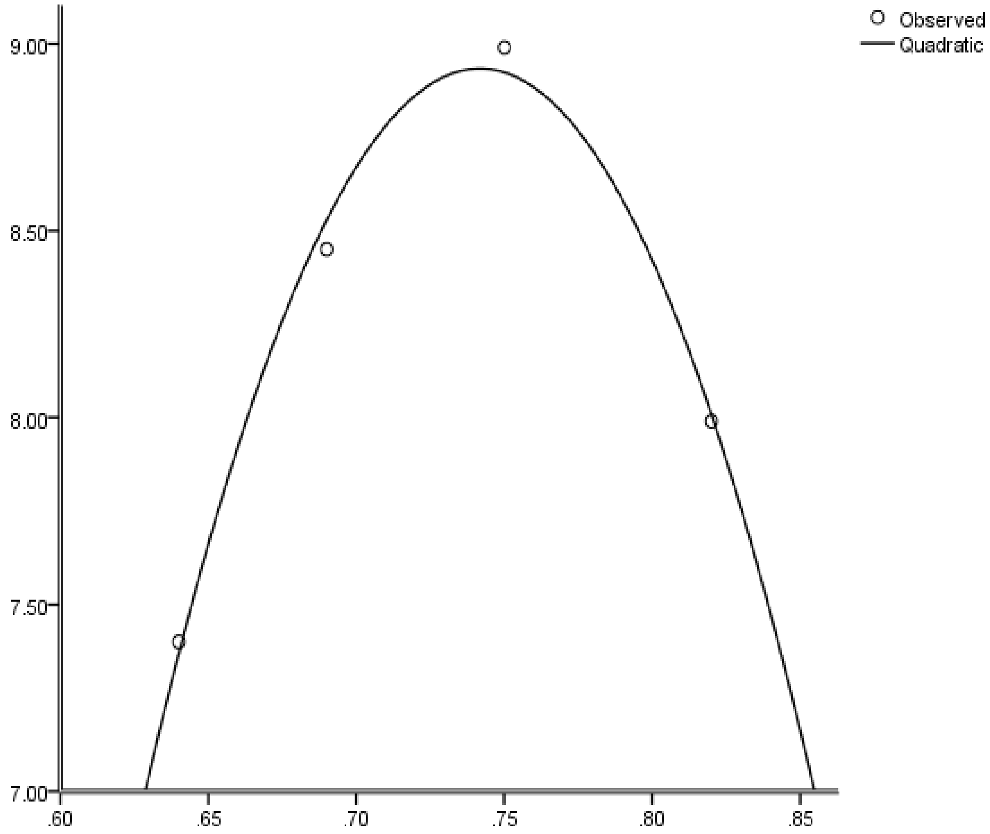


Figure 3.06 Effect of dietary lysine to energy ratio on growth rate of unsexed Venda chickens aged one to seven weeks

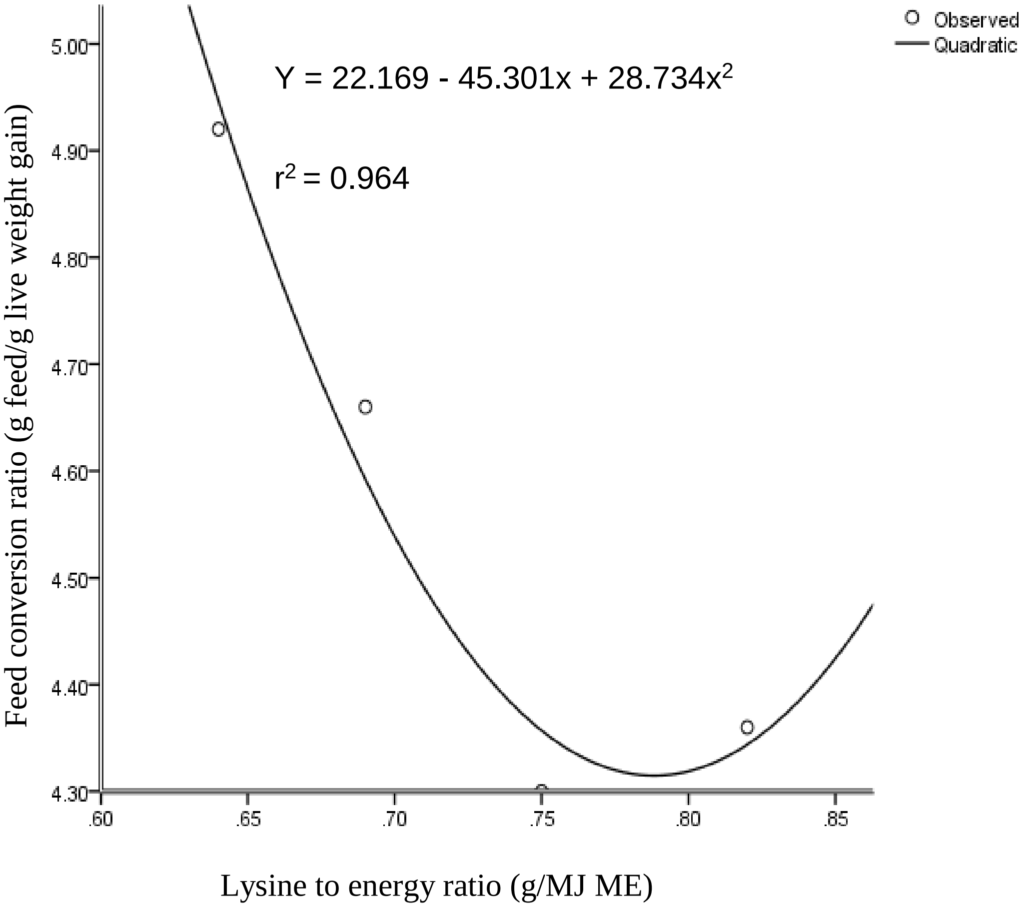


Figure 3.07 Effect of dietary lysine to energy ratio on feed conversion ratio of unsexed Venda chickens aged one to seven weeks

$$Y = -3653.735 + 11032.817x - 7437.094x^2$$

$$r^2 = 0.992$$

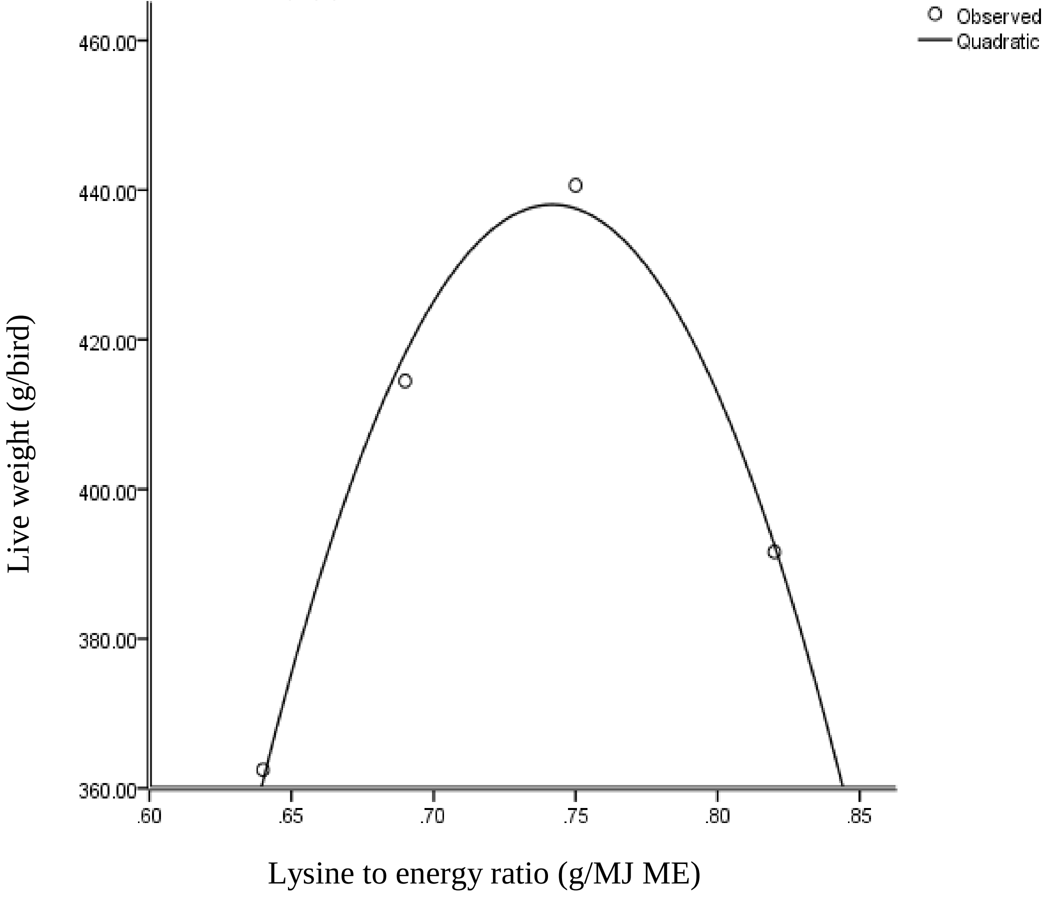


Figure 3.08 Effect of dietary lysine to energy ratio on live weight of unsexed Venda chickens aged 49 days

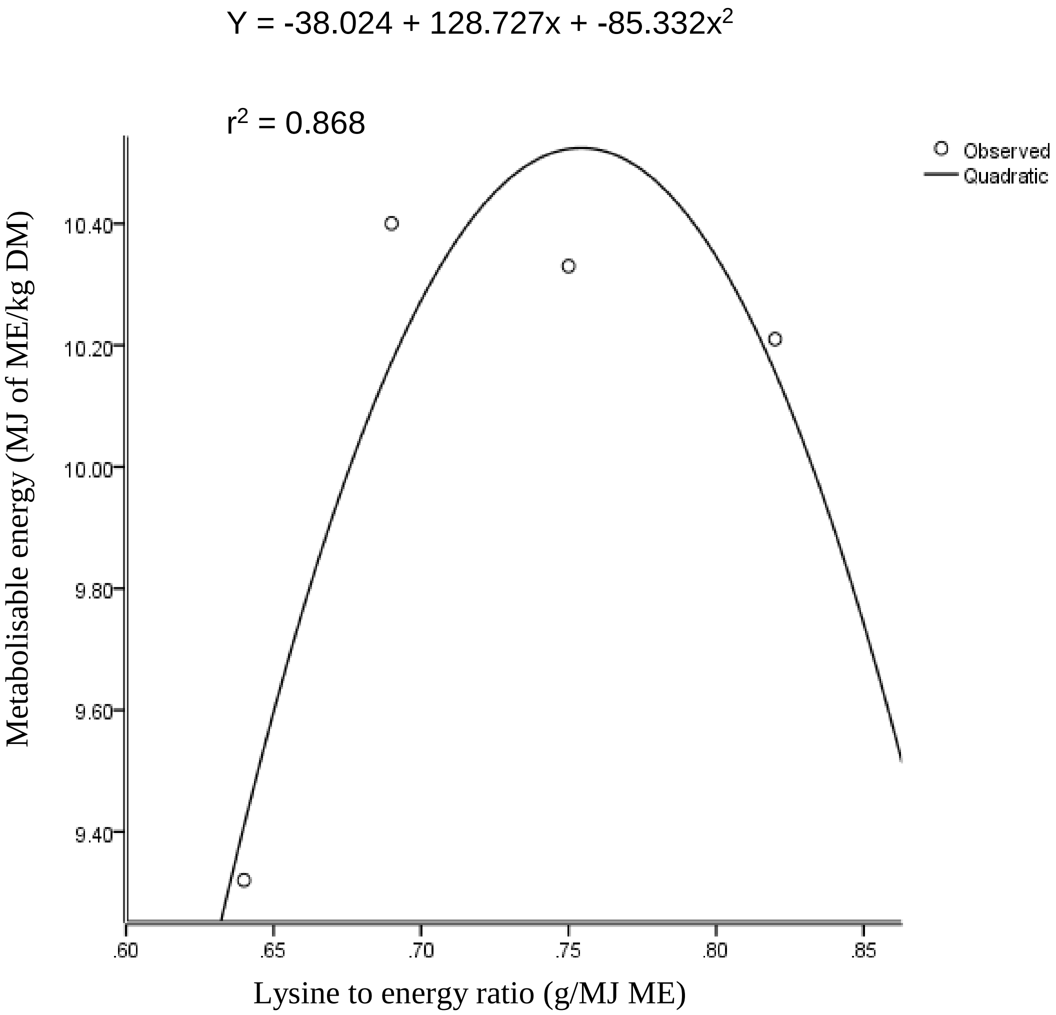


Figure 3.09 Effect of dietary lysine to energy ratio on apparent metabolisable energy of unsexed Venda chickens aged seven weeks

$Y = -13.852 + 41.400x + -26.225x^2$

$r^2 = 0.991$

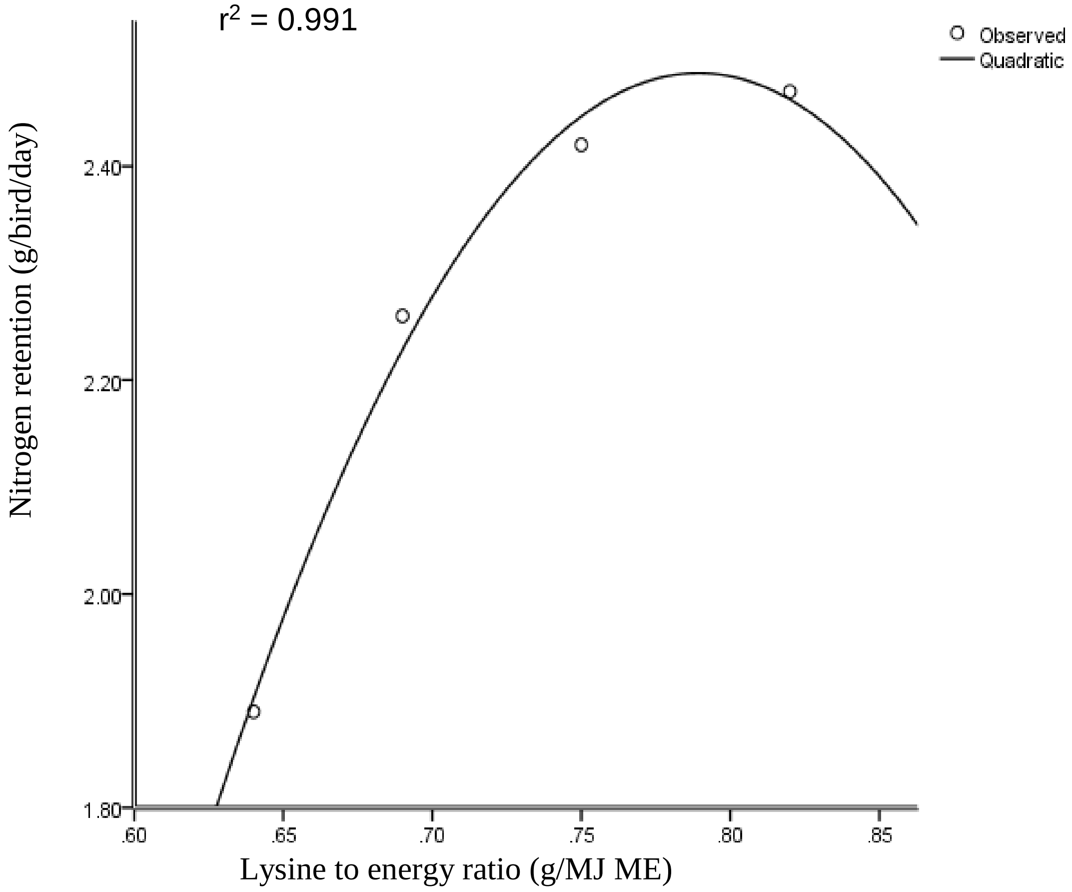


Figure 3.10 Effect of dietary lysine to energy ratio on nitrogen retention of unsexed Venda chickens aged seven weeks

Table 3.14 Dietary lysine to energy ratios for optimal growth rate (g/bird/day), feed conversion ratio (g feed/g live weight gain), live weight (g/bird aged 49 days), apparent metabolisable energy (MJ of ME/kg DM) and nitrogen retention (g/bird/day) of unsexed Venda chickens aged one to seven weeks

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Growth rate	$Y = -74.205 + 224.165x + -151.103x2$	0.991	0.742	8.934
FCR	$Y = 22.169 - 45.301x + 28.734x^2$	0.964	0.788	4.314
Live weight	$Y = -3653.735 + 11032.82x -7437.094x^2$	0.992	0.742	438.019
ME	$Y = -38.024 + 128.727x + -85.332x^2$	0.868	0.754	10.524
N-retention	$Y = -13.852 + 41.400x + -26.225x^2$	0.991	0.789	2.487

L:E ratio : lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Discussion

This experiment was designed to provide a higher dietary lysine level than that provided in Experiment 1. However, similar to Experiment 1, the diets were isonitrogenous but with different energy levels. The diets had a similar lysine content of 9 g/kg DM but different energy levels of 11, 12, 13 and 14 MJ ME/kg DM (determined in the laboratory using NIRA). Thus, dietary lysine to energy ratios of 0.64, 0.69, 0.75 and 0.82 were used. These cover both low and high dietary lysine to energy ratios. The diets contained similar levels of other nutrients which met the chickens' requirements as recommended by the NRC (1994).

Feed intake in the present study was not influenced by dietary treatment. Mbajiorgu *et al*. (2011), also, reported that lysine to energy ratio did not have effect on the feed intake of unsexed Venda chickens aged one to six weeks. However, Aftab (2007) found a significant ME to lysine interaction on feed intake when graded levels of dietary lysine to metabolisable energy diets were fed to broiler chickens aged 5 to 21 days. Similar to Experiment one, feed intake increased as dietary lysine to energy ratio increased until a dietary lysine to energy ratio of 0.719 for optimal DM intake of 39.179

g per bird per day was reached. Thereafter, an increase in the dietary lysine to energy ratio resulted in a decrease in feed intake. According to the NRC (1994), chickens have the ability to adjust their feed intake to accommodate a wide range of diets with differing energy contents. It, thus, means dietary lysine to energy ratio above 0.719 might be above the level these chickens require for optimum productivity, hence, the reduction in feed intake. It can, thus, be concluded that a dietary lysine to energy ratio of 0.719, in a diet of 9 g of lysine per kg DM, 12.52 MJ of ME/kg DM and 180 g of CP/kg DM, supported an optimal intake of unsexed Venda chickens aged one to seven weeks. Mbajiorgu *et al*. (2011) reported that feed intake was optimized at a lower dietary lysine to energy ratio of 0.61 in Venda chickens aged one to six weeks. Aftab (2007) reported that a dietary lysine to energy ratio of 0.74 optimized feed intakes when broiler chickens were fed diets varying in lysine levels but at a constant dietary energy level of 12.97 MJ of ME/kg DM.

Dietary lysine to energy ratio had effect on growth rate and live weight of unsexed Venda chickens aged one to seven weeks. This is in line with the report of Mbajiorgu *et al.* (2011) on Venda chickens aged one to six weeks. A dietary lysine to energy ratio of 0.742 optimized growth rates (8.93 g/bird aged 49 days) and live weights (438.02 g/bird aged 49 days) of Venda chicken in the present study. Increasing dietary lysine to energy ratio above this point resulted in reductions in growth rates and live weights of the chickens. It, thus, implies that dietary lysine to energy ratio of 0.742 in a diet of 9 g of lysine per kg DM, 12.01 MJ of ME/kg and 180 g of CP/kg DM supported optimal growth rates and live weights of Venda chickens aged one to seven weeks. A lysine to energy ratio of 0.75 was reported to optimize body weight gain in a diet containing 12.13 MJ of ME/kg (Rhone-Poulenc, 1993). However, Mbajiorgu *et al*. (2011) and Aftab (2007) reported that higher dietary lysine to energy ratios of 1.20 and 0.91 at ME of 13.38 and 12.13 MJ/kg DM, respectively, supported optimal growth rate. The NRC (1994) reported that a lysine to energy ratio of 0.89 supported optimal growth rate in broiler chickens. The variations in results observed by the various authors and this study can be attributed to diet formulation and breed differences.

Dietary lysine to energy ratio had an effect on FCR and nitrogen retention of Venda chickens aged one to eight weeks. Dietary lysine to energy ratios of 0.788 and 0.789 supported optimal FCR and nitrogen retention in unsexed Venda chickens aged one to seven weeks. A dietary lysine to energy ratio of 0.788 for optimal FCR is close to 0.796 reported by Rhone-Poulenc (1993). However, it is lower than the 1.05 reported by Han and Baker (1991) and 0.90 reported by Labadan *et al* (2001) in broiler chickens aged one to 21 days. The differences might be attributed to the different breeds of the chickens. The lysine to energy ratios for optimal FCR and nitrogen retention were higher than those that supported feed intake, growth rate, live weight and ME intake. This is in line with the results obtained by Aftab (2007).

Apparent metabolisable energy intake increased significantly as dietary lysine to energy ratio increased until a ratio of 0.754 was reached. Thus, increasing the dietary lysine to energy ratio above this led to a decrease in ME intake. Hence, it might be concluded that dietary lysine to energy ratio of 0.754 in a diet containing 9 g of lysine per kg DM, 11.94 MJ of ME/kg DM and 180 g of CP/kg DM supported optimal ME intake in unsexed Venda chickens aged one to seven weeks. This ratio is in lower than a lysine to energy ratio of 1.04 reported by Mbajiorgu *et al.* (2011) in Venda chickens aged one to six weeks. The difference might be attributed to differences in dietary formulation.

Dietary lysine to energy ratio had no effect on the mortality of unsexed Venda chickens aged one to seven weeks. This is in line with the observation made by Mbajiorgu *et al*. (2011).

3.3.3 Experiment 3

Results

Results of the nutrient composition of the diets used in Experiment 3 are presented in Table 3.15. The diets had a similar lysine content of 11 g/kg DM but different energy levels. The energy levels were 11, 12, 13 and 14 MJ ME/kg DM (determined in the laboratory using NIRA), thus, forming lysine to energy (L:E) ratios of 1.00 ($L_{11}E_{11}$), 0.92 ($L_{11}E_{12}$), 0.85 ($L_{11}E_{13}$) and 0.79 ($L_{11}E_{14}$), respectively.

Results of the effect of lysine to energy ratio on feed intake, growth rate, feed conversion ratio (FCR), live weight, apparent metabolisable energy and nitrogen (N) retention of unsexed Venda chickens aged one to seven weeks are presented in Table 3.16. Dietary lysine to energy ratio had no effect on all the parameters measured.

Table 3.15 Nutrient composition of diets used in Experiment 3 (units are in g/kg DM except energy as MJ of ME/kg DM feed and dry matter as g/kg feed)

		Nutrient					
Treatment	L:E ratio	Dry matter	Lysine	Energy*	Protein	Calcium	Phosphorus
$L_{11} E_{11}$	1.00	885.41	11	10.79	220	10	5.5
$L_{11} E_{12}$	0.91	885.43	11	11.79	220	10	5.5
$L_{11} E_{13}$	0.85	891.44	11	12.79	220	10	5.5
$L_{11} E_{14}$	0.79	895.79	11	13.80	220	10	5.5

L:E ratio::lysine to energy ratio (g/MJ ME)

* : ME determined in the laboratory using NIRA

Table 3.16 Effect of dietary lysine to energy ratio (g/MJ ME) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g feed /g live weight gain), live weight (g/bird aged 49 days), apparent metabolisable energy (MJ of ME/kg DM), nitrogen retention (g/bird/day) and mortality (%) of unsexed Venda chickens aged one to seven weeks

	Dietary lysine to energy ratio (g/MJ ME)				
Variable	0.79	0.85	0.91	1.00	SE
Feed intake	35.38	36.02	34.29	32.82	1.266
Growth rate	8.3	9.0	8.6	8.1	0.80
FCR	4.25	4.01	4.04	4.07	0.164
Live weight	408.4	441.9	419.2	396.8	7.52
ME	7.70	9.27	8.87	7.87	0.314
N-retention	1.47	1.49	1.50	1.50	0.006
Mortality	0.45	0.44	0.48	0.42	0.002

ME : Metabolisable energy

N-retention : Nitrogen retention

SE : Standard error

Discussion

Experiment 3 was formulated to have higher lysine to energy than those in Experiments 1 and 2. Thus, a dietary lysine level of 11 g/kg DM was used to formulate four dietary lysine to energy ratios of 0.79, 0.85, 0.92 and 1.00.

Dietary lysine to energy ratio had no effect on all production parameters studied. It is possible that the dietary lysine to energy ratios required for these parameters were lower than or equal to the ratios used in the present study.

3.3.4 Experiment 4

Results

Results of the nutrient composition of the diets used in Experiment 4 are presented in Table 3.18. The diets had a similar and higher lysine content of 12 g/kg DM but different energy levels. The energy levels were 11, 12, 13 and 14 MJ ME/kg DM (determined in the laboratory using NIRA), thus forming lysine to energy (L:E) ratios of 1.09 ($L_{12}E_{11}$), 1.00 ($L_{12}E_{12}$), 0.92 ($L_{12}E_{13}$) and 0.86 ($L_{12}E_{14}$), respectively.

The effects of lysine to energy ratio on feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen (N) retention of unsexed Venda chickens aged one to seven weeks are presented in Table 3.19. Dietary lysine to energy ratio affected ($P<0.05$) growth rate, FCR and live weight. However, feed intake, ME value, N-retention and mortality were not influenced ($P>0.05$) by dietary treatments. Unsexed Venda chickens offered a diet having a lysine to energy ratio of 0.92 had higher ($P<0.05$) growth rates than those on diets having lysine to energy ratios of 1.00, 0.86 or 1.09. Chickens on a diet having a lysine to energy ratio of 1.00 had higher ($P<0.05$) growth rates than those on diets having dietary lysine to energy ratios of 0.86 or 1.09. Similarly, chickens on a diet having a lysine to energy ratio of 0.86 had higher ($P<0.05$) growth rates than those on a diet having a lysine to energy ratio of 1.09. Unsexed Venda chickens offered diets having lysine to energy ratios of 1.00 or 1.09 had similar ($P>0.05$) FCR; their ratios were, however, better ($P<0.05$) than those of chickens on diets having 0.92 or 0.86 lysine to energy ratios. Similarly, chickens on a diet having a lysine to energy ratio of 0.92 had better ($P<0.05$) FCR than those of chickens on a diet having a lysine to energy ratio of 0.86. Live weights of chickens on a diet having a lysine to energy ratio of 1.00 were higher ($P<0.05$) than those of chickens on diets having lysine to energy ratios of 0.92, 1.09 or 0.86. Chickens on a diet having a lysine to energy ratio of 0.92 had higher ($P<0.05$) live weights than those of chickens on diets having 1.09 and 0.86 lysine to energy ratios. Similarly, chickens on a diet having a lysine to energy ratio of 1.09 had higher ($P<0.05$) live weights than those birds on a diet having a lysine to energy ratio of 0.86.

Results of the effect of dietary lysine to energy ratio on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens aged one to seven weeks are presented in Figures 3.11 to 3.13, respectively and Table 3.20. Growth rate, feed conversion ratio and live weight were optimized at dietary lysine to energy ratios of 0.962 ($r^2 = 0.821$) and 1.023 ($r^2 = 0.992$), respectively (Figures 3.11 and 3.12 and 3.13, respectively and Table 3.20).

Table 3.18 Nutrient composition of diets used in Experiment 4 (units are in g/kg DM except energy as MJ of ME/kg DM feed and dry matter as g/kg feed)

		Nutrient					
Treatment	L:E ratio	Dry matter	Lysine	Energy*	Protein	Calcium	Phosphorus
L_{12} E_{11}	1.09	880.56	12	10.79	240	10	5.5
L_{12} E_{12}	1.00	887.31	12	11.79	240	10	5.5
L_{12} E_{13}	0.92	892.92	12	12.79	240	10	5.5
L_{12} E_{14}	0.86	897.61	12	13.80	240	10	5.5

L:E ratio : lysine to energy ratio (g/MJ ME)

***** **:** ME determined in the laboratory using NIRA

Table 3.19 Effect of dietary lysine to energy ratio (g/MJ ME) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g feed/g live weight gain), live weight (g/bird aged 49 days), apparent metabolisable energy (MJ of ME/kg), nitrogen retention (g/bird/day) and mortality (%) of unsexed Venda chickens aged one to seven weeks

	Dietary lysine to energy ratio (g/MJ ME)				
Variable	0.86	0.92	1.00	1.09	SE
Feed intake	29.70	32.00	28.10	25.10	0.839
Growth rate	7.50 ^{c}	8.90 ^{a}	8.20 ^{b}	7.20 ^{d}	0.20
FCR	3.96 ^{a}	3.60 ^{b}	3.43 ^{c}	3.49 ^{c}	0.056
Live weight	302.47 ^{d}	387.55 ^{b}	397.43 ^{a}	361.84 ^{c}	11.912
ME	7.63	8.74	8.79	6.94	0.235
N-retention	1.15	1.30	1.22	1.01	0.032
Mortality	0.35	0.34	0.38	0.38	0.004

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

ME : Metabolisable energy

N-retention : Nitrogen retention

SE : Standard error

$Y = -79.525 + 183.324 - 95.271\ x^2$
$r^2 = 0.821$

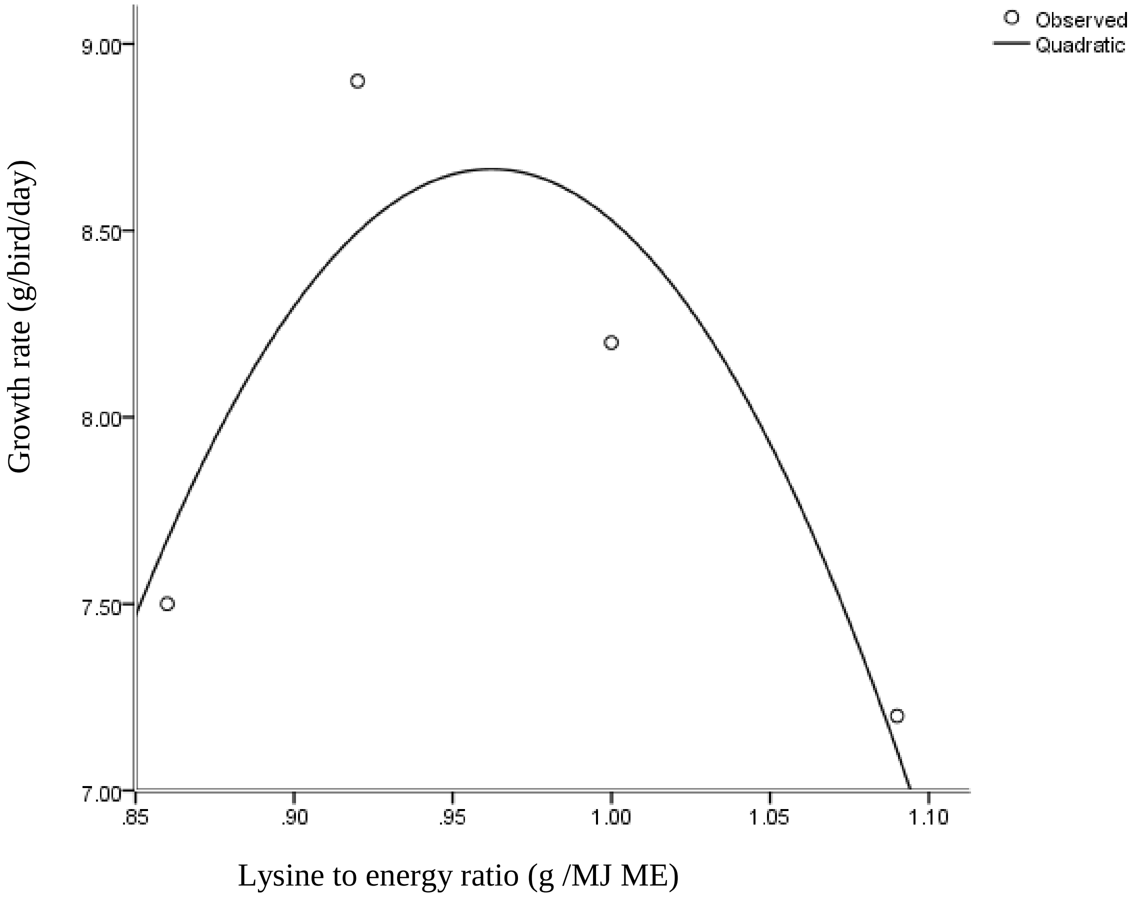


Figure 3.11 Effect of dietary lysine to energy ratio on growth rate of unsexed Venda chickens aged one to seven weeks

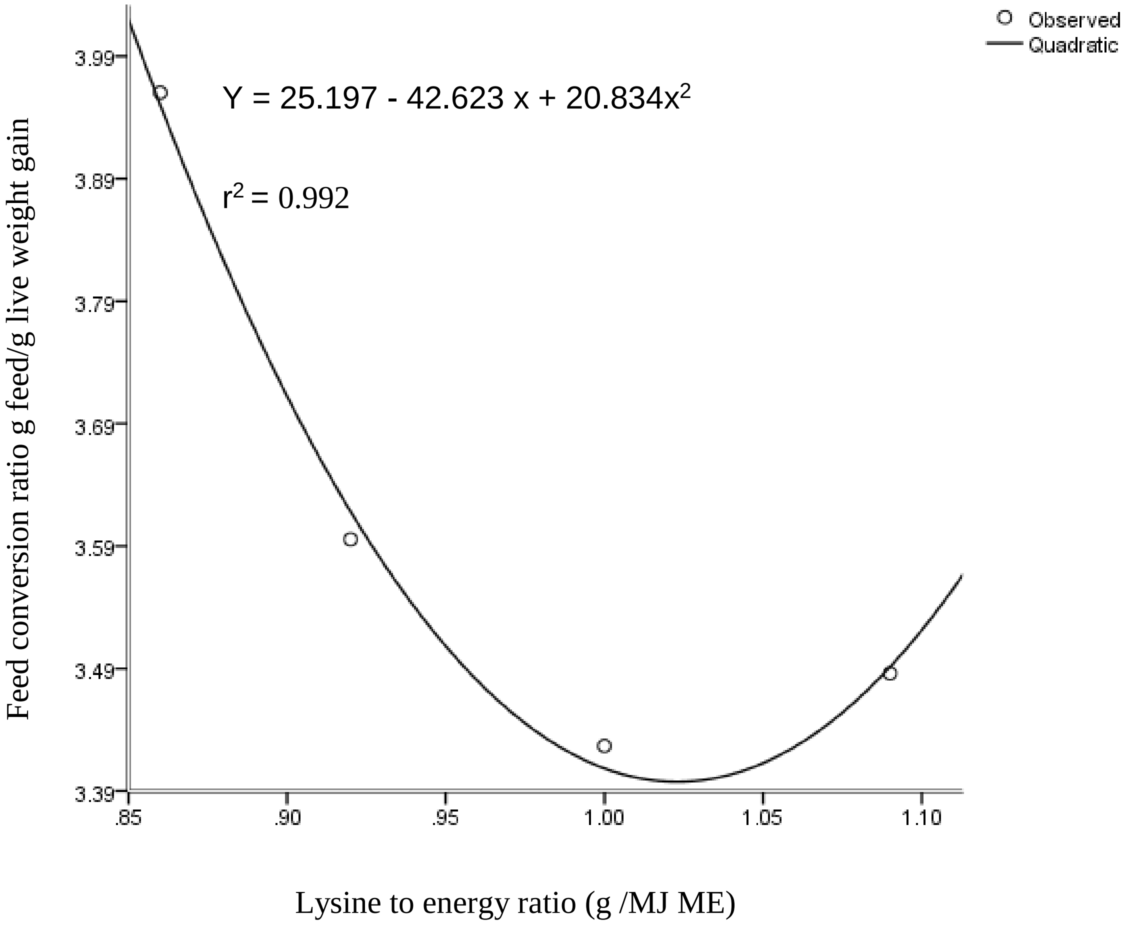


Figure 3.12 Effect of dietary lysine to energy ratio on feed conversion ratio of unsexed Venda chickens aged one to seven weeks

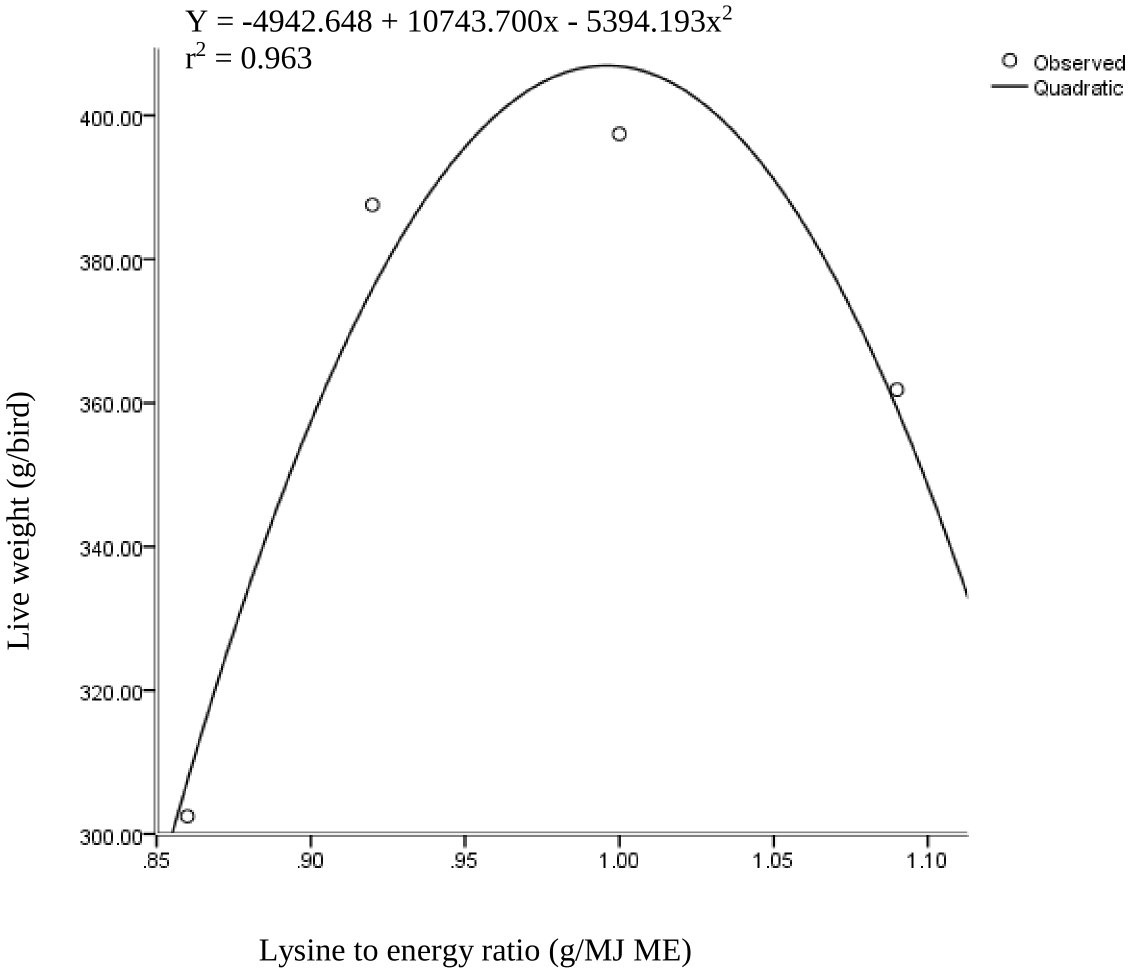


Figure 3.13 Effect of dietary lysine to energy ratio on live weight of unsexed Venda chickens aged 49 days

Table 3.20 Dietary lysine to energy ratios for optimal growth rate (g/bird/day), feed conversion ratio (g feed/g live weight gain) and live weight (g/bird aged 49 days) of unsexed Venda chickens aged one to seven weeks

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Growth rate	$Y = -79.525 + 183.324 - 95.271x^2$	0.821	0.962	8.665
FCR	$Y = 25.197 - 42.623\ x + 20.834x^2$	0.992	1.023	3.397
Live weight	$Y = -4942.648 + 10743.70x - 5394.193x^2$	0.963	0.996	406.95

L:E ratio : lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Discussion

The diets used in this experiment contained a high lysine content of 12 g/kg DM and four varying energy levels of 11, 12, 13 and 14 MJ of ME/kg DM, respectively. Thus, diets with high dietary lysine to energy ratios of 0.86, 0.92, 1.00 and 1.09 were formulated and used.

The results of the present study indicate that dietary lysine to energy ratio had no effect on feed intake, ME intake, nitrogen retention and mortality of unsexed Venda chickens aged one to seven weeks. This is similar to the results of Mbajiorgu *et al.* (2011) Venda chickens aged one to six weeks. It is possible that the dietary lysine to energy ratios required for optimal feed intake, ME intake, nitrogen retention and mortality of these chickens were lower than or equal to the ratios used in the present study.

An optimal growth rate of 8.67 g/bird/day was attained at a dietary lysine to energy ratio of 0.962. This ratio is higher than the 0.89 reported by the NRC (1994) and 0.932 observed by Aftab (2007) for broiler chickens. However, it is lower than the 1.20 found by Mbajiorgu *et al.* (2011). The biological reasons for the differences in these results are not clear. Further studies are required to explore such reasons. It can, thus, be noted that in a diet containing 12 g of lysine per kg DM, 12.47 MJ of ME/kg DM and

240 g of CP/kg, growth rate of unsexed Venda chickens aged one to seven weeks was optimized at a dietary lysine to energy ratio of 0.962.

Dietary lysine to energy ratio of 1.023 optimized FCR of unsexed Venda chickens aged one to seven weeks. A similar ratio on broiler chickens was reported by Han and Baker (1991). However, this ratio is higher than 0.99 and 0.90 reported by Morris *et al.* (1987) and Labadan *et al*. (2001) for broiler chickens, respectively. The 1.023 ratio is, however, lower than the 1.17 reported by Mbajiorgu *et al.* (2011) in Venda chickens aged one to six weeks.

Results of the effect of dietary lysine to energy ratio in this study showed that at the age of 49 days live weight increased as the dietary ratio increased until a dietary lysine to energy ratio above 0.996 was reached. Thereafter, live weight decreased with increase in dietary lysine to energy ratio. No previous study was found on this parameter.

CHAPTER FOUR

EFFECT OF DIETARY LYSINE TO ENERGY RATIO ON GROWTH, CARCASS CHARACTERISTICS, MEAT SENSORY ATTRIBUTES AND HAEMATOLOGICAL VALUES OF FEMALE INDIGENOUS VENDA CHICKENS AGED EIGHT TO THIRTEEN WEEKS AND RAISED IN CLOSED CONFINEMENT

4.1 Introduction

Limited studies are available on the effect of dietary lysine to energy ratio for optimal feed intake, growth rate, feed conversion ratio, live weight, digestibility and carcass characteristics of female indigenous Venda chickens aged eight to 13 weeks. Most poultry nutritional studies, especially at the finisher stage, are on male indigenous chickens (Mbajiorgu *et al.,* 2011; Araujo *et al*., 2005), thus, there is limited information of the effect of nutrition on the growth and carcass characteristics of female indigenous chickens. Furthermore, no literature on the effect of such diets on breast meat pH at different time intervals, drip loss, breast meat tenderness, juiciness and flavour was found. Similarly, no study was found on the effect of dietary lysine to energy ratio on haematological values of female indigenous Venda chickens.

Mbajiorgu *et al.* (2011) reported dietary lysine to energy ratios of 1.20 and 0.76 g/MJ ME supported optimum growth rates at the starter and grower stages, respectively, in male Venda chickens aged eight to 13 weeks. These authors also reported that not all parameters were optimised at the same dietary lysine to energy ratio. Tang *et al*. (2007) showed that live weight and dressing percentage increased as the dietary energy increased in Arbor Acres broiler chickens. The authors, also, reported that higher dietary lysine contents improved breast meat weight. In the same study it was reported that dietary lysine levels influenced meat drip loss and that higher dietary energy levels increased meat pH values 24-hours post-mortem.

Information on the effects of dietary lysine to energy ratio on productivity and carcass characteristics of indigenous broiler chickens is limited and not conclusive. In fact, not much information was found on the effects of dietary lysine to energy ratio on productivity and carcass characteristics of indigenous Venda chickens. Therefore, it was necessary to ascertain effects of dietary lysine to energy ratio on productivity and carcass characteristics of indigenous chickens aged 13 weeks. The objective of this study was, therefore, to determine the effects of dietary lysine to energy ratio on productivity and carcass characteristics of indigenous female Venda chickens aged eight to 13 weeks.

4.2 Materials and methods

4.2.1 Study site

This study was conducted at the Animal Unit of the University of Limpopo, as described in Chapter 3, Section 3.2.1

4.2.2 Experimental procedures, dietary treatments and design

Four experiments designated as Experiments 5, 6, 7 and 8, were conducted. Experiments 5, 6, 7 and 8 determined the effects of dietary lysine to energy ratio at dietary crude protein levels of 240, 220, 180 and 150 g per kg DM, respectively, on feed intake, growth rates, live weight, FCR, ME intake, N-retention and carcass characteristics of indigenous Venda chickens aged eight to 13 weeks. The layouts, treatments, design and execution were similar to those described for Experiments 1, 2, 3 and 4, respectively, except that Experiments 5 to 8 were for female indigenous Venda chickens aged eight to 13 weeks. These chickens were different from those used in Experiments 1 to 4. These had been raised on a grower mash (16 % crude protein, 11 MJ of ME/kg DM energy and 10 g of lysine/kg DM). Each experiment commenced with 120 eight weeks old female Venda chickens with an initial live weight of 412 ± 3 g per bird. In each experiment, the chickens were randomly assigned to four treatments (Tables 4.01, 4.02, 4.03 and 4.0 6, 7 and 8, respectively) with five replicates, each having six chickens. Thus, 20 floor pens were used for each experiment. A complete randomized design was used for each experiment. The diets were compounded with the help of Voorslagvoere Milling Company, Mokopane, South Africa. The feed ingredients of the diets are given in Tables 4.05 to 4.08 for Experiments 5, 6, 7 and 8, respectively. The experiments were terminated when the chickens were 13 weeks old. Light was provided 24 hours daily while feed and water were provided *ad libitum* throughout the experimental periods.

Table 4.01 Dietary treatments for Experiment 5*

Diet code	Diet description	L:E ratio (g lysine /MJ ME/kg DM)
$FL_8\,E_{11}$	Diet containing 8 g lysine/kg DM, 11 MJ ME/kg DM and 150 g crude protein/kg DM	0.72
$FL_8\,E_{12}$	Diet containing 8 g lysine/kg DM, 12 MJ ME/kg DM and 150 g crude protein/kg DM	0.66
$FL_8\,E_{13}$	Diet containing 8 g lysine/kg DM, 13 MJ ME/kg DM and 150 g crude protein/kg DM	0.61
$FL_8\,E_{14}$	Diet containing 8 g lysine/kg DM, 14 MJ ME/kg DM and 150 g crude protein/kg DM	0.57

* Laboratory determined ME (NIRA) and CP

Table 4.02 Dietary treatments for Experiment 6*

Diet code	Diet description	L:E ratio (g lysine /MJ ME/kg DM)
$FL_9\,E_{11}$	Diet containing 9 g lysine/kg DM, 11 MJ ME/kg DM and 180 g crude protein/kg DM	0.82
$FL_9\,E_{12}$	Diet containing 9 g lysine/kg DM, 12 MJ ME/kg DM and 180 g crude protein/kg DM	0.75
$FL_9\,E_{13}$	Diet containing 9 g lysine/kg DM, 13 MJ ME/kg DM and 180 g crude protein/kg DM	0.69
$FL_9\,E_{14}$	Diet containing 9 g lysine/kg DM, 14 MJ ME/kg DM and 180 g crude protein/kg DM	0.64

* Laboratory determined ME (NIRA) and CP

Table 4.03 Dietary treatments for Experiment 7*

Diet code	Diet description	L:E ratio (g lysine /MJ ME/kg DM)
FL_{11} E_{11}	Diet containing 11 g lysine/kg DM, 11 MJ ME/kg DM and 220 g crude protein/kg DM	1.00
FL_{11} E_{12}	Diet containing 11 g lysine/kg DM, 12 MJ ME/kg DM and 200 g crude protein/kg DM	0.92
FL_{11} E_{13}	Diet containing 11 g lysine/kg DM, 13 MJ ME/kg DM and 220 g crude protein/kg DM	0.85
FL_{11} E_{14}	Diet containing 11 g lysine/kg DM, 14 MJ ME/kg DM and 220 g crude protein/kg DM	0.79

* Laboratory determined ME (NIRA) and CP

Table 4.04 Dietary treatments for Experiment 8*

Diet code	Diet description	L:E ratio (g lysine /MJ ME/kg DM)
FL_{12} E_{11}	Diet containing 12 g lysine/kg DM, 11 MJ ME/kg DM and 240 g crude protein/kg DM	1.09
FL_{12} E_{12}	Diet containing 12 g lysine/kg DM, 12 MJ ME/kg DM and 240 g crude protein/kg DM	1.00
FL_{12} E_{13}	Diet containing 12 g lysine/kg DM, 13 MJ ME/kg DM and 240 g crude protein/kg DM	0.92
FL_{12} E_{14}	Diet containing 12 g lysine/kg DM, 14 MJ ME/kg DM and 240 g crude protein/kg DM	0.85

* Laboratory determined ME (NIRA) and CP

Table 4.05 Diet composition for Experiment 5

Ingredient (%)	Experimental diet			
	$FL_8\ E_{11}$	$FL_8\ E_{12}$	$FL_8\ E_{13}$	$FL_8\ E_{14}$
Maize	45.19	65.80	64.70	59.02
Wheat Bran	31.32	5.66	-	-
Full fat Soya	0.51	1.41	24.75	30.00
Hipro Soya	19.12	23.12	6.33	3.13
Oil	-	-	-	3.62
Limestone	2.64	2.51	2.42	2.40
Monocalcium Phosphate	-	0.39	0.65	0.70
Salt	0.47	0.45	0.46	0.46
Methionine	0.16	0.16	0.17	0.18
Lysine	0.18	0.12	0.12	0.11
Threonine	0.05	0.02	0.03	0.02
Choline	0.07	0.07	0.07	0.07
Vit/Min PMX	0.20	0.20	0.20	0.20
Cocci	0.05	0.05	0.05	0.05
AGP	0.03	0.03	0.03	0.03
NSP enzyme	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00

Table 4.06 Diet composition for Experiment 6

	Experimental diet			
Ingredient (%)	FL_9 E_{11}	FL_9 E_{12}	FL_9 E_{13}	FL_9 E_{14}
Maize	43.16	65.79	58.39	53.39
Wheat Bran	28.11	-	-	-
Full fat Soya	2.00	2.01	30.00	30.00
Hipro Soya	22.89	27.83	7.37	8.02
Oil	-	-	0.11	4.45
Limestone	2.64	2.73	2.44	2.42
Monocalcium Phosphate	-	0.49	0.54	0.58
Salt	0.44	0.45	0.46	0.46
Methionine	0.20	0.20	0.21	0.21
Lysine	0.15	0.11	0.09	0.07
Threonine	0.05	0.03	0.03	0.03
Choline	0.07	0.07	0.07	0.07
Vit/Min PMX	0.20	0.20	0.20	0.20
Cocci	0.05	0.05	0.05	0.05
AGP	0.03	0.03	0.03	0.03
NSP enzyme	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00

Table 4.07 Diet composition for Experiment 7

Ingredient (%)	Experimental diet			
	FL_{11} E_{11}	FL_{11} E_{12}	FL_{11} E_{13}	FL_{11} E_{14}
Maize	41.98	53.84	44.03	42.11
Wheat Bran	18.18	-	-	-
Full fat Soya	2.11	12.02	35.00	30.00
Hipro Soya	33.93	30.26	16.00	17.82
Oil	-	-	1.08	6.10
Limestone	2.57	2.48	2.47	2.44
Monocalcium Phosphate	-	0.25	0.31	0.36
Salt	0.44	0.44	0.45	0.46
Methionine	0.26	0.26	0.28	0.28
Lysine	0.11	0.06	-	0.04
Threonine	0.05	0.03	0.03	0.03
Choline	0.07	0.07	0.07	0.07
Vit/Min PMX	0.20	0.20	0.20	0.20
Cocci	0.05	0.05	0.05	0.05
AGP	0.03	0.03	0.03	0.03
NSP enzyme	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00

Table 4.08 Diet composition for Experiment 8

	Experimental diet			
Ingredients (%)	$FL_{12}\ E_{11}$	$FL_{12}\ E_{12}$	$FL_{12}\ E_{13}$	$FL_{12}\ E_{14}$
Maize	40.89	47.34	40.86	35.74
Wheat Bran	13.11	-	-	-
Full fat Soya	2.71	18.14	35.00	35.00
Hipro Soya	39.57	30.73	18.39	19.13
Oil	-	-	1.91	6.26
Limestone	2.53	2.50	2.49	2.46
Monocalcium Phosphate	-	0.14	0.20	0.24
Salt	0.44	0.44	0.45	0.46
Methionine	0.29	0.29	0.30	0.31
Lysine	0.07	0.03	0.02	0.01
Threonine	0.03	0.02	0.02	0.02
Choline	0.07	0.07	0.07	0.07
Vit/Min PMX	0.20	0.20	0.20	0.20
Cocci	0.05	0.05	0.05	0.05
AGP	0.03	0.03	0.03	0.03
NSP enzyme	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00

4.2.3 Data collection

The initial live weights of chickens were taken at the commencement of each experiment. Thereafter, average live weights per bird were measured at weekly intervals. These live weights were used to calculate growth rates of the chickens. Weekly mean feed intakes were determined until termination of the experiment. These intakes were used to calculate daily mean feed intakes (McDonald *et al*., 2011). Feed conversion ratio per pen was calculated as total feed consumed divided by the weight gain of the birds in that pen. Mortalities were recorded daily during the study period. Digestibility was measured when the chickens were 13 weeks old as described in Section 3.2.3

At 91 days of age all remaining female Venda chickens per pen in each experiment were slaughtered by cervical dislocation to determine carcass characteristics. Prior to this, blood samples were collected. Blood samples were taken from jugular vein during slaughtering. The blood was received in a 10 ml test tube containing EDTA. Haematological (red blood cells, white blood cells, haemoglobin, packed volume cells, mean corpuscular volume, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration) values were determined. Carcass parts and abdominal fat were weighed. Fat surrounding the gizzard and intestines extending to the bursa were considered as abdominal fat (Mendonca and Jensen, 1989).

At slaughter, 30 minutes, 2 hours, 12 hours and 24 hours after slaughter the breast meat pH was tested at a depth of 2.5 cm below the surface using a Model 191 pH meter equipped with a spear-like electrode (Knick, Berlin, Germany). All the pH measurements were conducted on the anterior end of the right breast. The pH meter was standardized by a three-point method against standard buffers of pH 4.0, 7.0 and 9.0. At the end of each slaughtering and pH measurement, meat samples from each breast part of the slaughtered bird were taken and stored in the refrigerator for sensory evaluation.

Meat samples which had been frozen at -20 ˚C were thawed for 24 hours in a room temperature for sensory evaluation. The samples were broiled (grilled) on the oven rack set for 160 ˚C. The oven was allowed to preheat for 20 minutes. The meat samples were grilled for approximately 50 minutes and turned every 25 minutes.

Tongs were used for turning to avoid piercing which could let the moisture to escape. The samples were cut into smaller pieces of 1.5 cm thick according to their treatments and replicates. A taste panel of assessors evaluated the meat for tenderness, juiciness and flavour (American Meat Science Association, 1995). The Sensory Evaluation Panel consisted of members of staff and students of the University of Limpopo (Turfloop campus). Panellists rated the samples on a five-point scale as presented in Table 4.09.

4.2.4 Chemical analysis

Dry matter of the feeds, feed refusals and meat samples were determined by drying the samples in the oven for 24 hours at a temperature of 105 ˚C. Faeces were freeze-dried before analysis (AOAC, 2005). Ash content of the feeds, feed refusals, faeces and meat samples were analysed by ashing a sample at 600 ˚C in a muffle furnace overnight. Gross energy values for feeds and faeces were measured in a bomb calorimeter (AOAC, 2005) at the Animal Production Laboratory of the University of Limpopo. The apparent metabolisable energy and N-retention contents of the diets for each experiment were calculated according to AOAC (2005).

Hematological parameters (red blood cells, white blood cells, haemoglobin, packed volume cells, mean corpuscular volume, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration) were measured using a Beckman Coulter ACT diff Haematology Analyser (Beckman-Coulter, USA).

4.2.5 Statistical analysis

Data on feed intake, digestibility, growth rate, food conversion ratio, metabolisable energy, nitrogen retention, live weight, mortality, carcass characteristics, breast meat pH, sensory attributes and haematological parameters were analysed by one-way analysis of variance (SAS, 2008). Where there were significant differences ($P<0.05$), Duncan test for multiple comparisons was used to test the significance of differences between treatment means (SAS, 2008). The dose-related optimal responses to dietary lysine to energy ratio were modelled using the following quadratic equation:

$$Y = a + b_1x + b_2x^2 + \epsilon \text{ (as defined in Section 3.2.5)}$$

The relationships between optimal responses in feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy and nitrogen retention across the five experiments and dietary lysine to energy ratio levels were modelled using a linear regression equation (SAS, 2008) of the form:

$$Y = a + bx \text{ (as defined in Section 3.2.5)}$$

The efficiency of dietary lysine and energy utilization for optimal growth rate across the four experiments were calculated at each level of dietary lysine and metabolisable energy contents, respectively, as lysine intake/growth rate and metabolisable energy intake/growth rate, and were regressed against the dietary lysine to energy ratio. The dose-related optimal dietary lysine level and energy utilization for feed intake and growth rate across the four experiments were modelled using the quadratic equation as indicated above (SAS, 2008).

Table 4.09 Evaluation scores used by sensory panel

	Sensory Attributes		
Score	Tenderness	Juiciness	Flavour
1	Too tough	Much too dry	Very bad flavour
2	Tough	Dry	Bad flavour
3	Neither tough nor tender	Neither dry nor juicy	Neither bad nor good tender
4	Tender	Juicy	Good flavour
5	Too tender	Too juicy	Very good flavour

4.3 Results and discussion

4.3.1 Experiment 5

Results

The nutrient composition of the diets used in Experiment 5 is the same as those presented in Table 3.09 (Experiment 1). The diets had a similar lysine content of 8 g/kg DM but different energy levels. The energy levels were 11, 12, 13 and 14 MJ of ME/kg DM (determined in the laboratory using NIRA), thus forming lysine to energy ratios of 0.73 (FL_8E_{11}), 0.67 (FL_8E_{12}), 0.62 (FL_8E_{13}) and 0.57 (FL_8E_{14}), respectively.

The effects of dietary lysine to energy ratio on feed intake, growth rate, feed conversion ratio (FCR), live weight, apparent metabolisable energy, nitrogen (N) retention and mortality of female Venda chickens aged eight to thirteen weeks are presented in Table 4.10. Dietary lysine to energy ratio had an effect ($P<0.05$) on feed intake, apparent metabolisable energy, growth rate, FCR and live weights of the chickens. Indigenous female Venda chickens offered a diet having a lysine to energy ratio of 0.67 had a higher ($P<0.05$) feed intake than those on diets having lysine to energy ratios of 0.73, 0.62 or 0.57 which had similar ($P>0.05$) feed intakes. Chickens on diets having lysine to energy ratios of 0.62 or 0.67 had similar ($P>0.05$) growth rates. Similarly, chickens offered diets having lysine to energy ratios of 0.73 or 0.57 had the same ($P>0.05$) growth rates. However, chickens on diets having lysine to energy ratios of 0.62 or 0.67 had higher ($P<0.05$) growth rates than those offered diets having lysine to energy ratios of 0.57 or 0.73.

Female Venda chickens offered a diet having a lysine to energy ratio of 0.62 had better ($P<0.05$) FCR values than those of birds on diets having lysine to energy ratios of 0.67, 0.57or 0.73. Similarly, chickens offered a diet having a lysine to energy ratio of 0.67 had a better ($P<0.05$) FCR than those on a diet having a lysine to energy ratio of 0.73. However, chickens on diets having lysine to energy ratios of 0.73 or 0.57 had similar ($P>0.05$) FCR values. Chickens on a diet having a lysine to energy ratio of 0.62 had higher ($P<0.05$) ME intakes than those on diets having lysine to energy ratios of 0.67, 0.73 or 0.57. Chickens on a diet having a lysine to energy ratio of 0.67 had higher ($P<0.05$) ME intakes than those offered diets having lysine to energy ratios of 0.73 or

0.57. However, chickens on diets having lysine to energy ratios of 0.73 and 0.57 had similar ($P>0.05$) ME intakes. Nitrogen retention and mortality of the chickens were not influenced ($P>0.05$) by the dietary treatments.

Feed intake, growth rate, FCR, live weight, apparent metabolisable energy and nitrogen retention of female Venda chickens were optimized at dietary lysine to energy ratios of 0.672 ($r^2 = 0.575$), 0.646 ($r^2 = 0.969$), 0.639 ($r^2 = 0.880$), 0.649 ($r^2 = 0.906$) and 0.655 ($r^2 = 0.760$), respectively (Figures 4.01, 4.02, 4.03, 4.04 and 4.05, respectively and Table 4.11).

Table 4.10 Effect of dietary lysine to energy ratio (g/MJ ME) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g feed/g live weight gain), live weight (g/bird aged 91 days), apparent metabolisable energy (MJ/kg DM), nitrogen retention (g/bird/day) and mortality (%) of female Venda chickens aged eight to thirteen weeks

	Dietary lysine to energy ratio (g/MJ ME)				
Variable	0.57	0.62	0.67	0.73	SE
Feed intake	99.92^{b}	101.58^{b}	114.75^{a}	104.73^{b}	2.049
Growth rate	13.1^{b}	17.9^{a}	16.9^{a}	12.5^{b}	0.68
FCR	7.60^{ab}	5.76^{c}	6.79^{b}	8.37^{a}	0.292
Live weight	1259.3^{c}	1361.7^{b}	1443.0^{a}	1229.7^{c}	23.68
ME	9.54^{c}	11.58^{a}	10.80^{b}	10.18^{c}	0.213
N-retention	1.18	1.46	1.65	1.54	0.053
Mortality	0.01	0.00	0.00	0.00	0.001

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

ME : Metabolisable energy

N-retention : Nitrogen retention

SE : Standard error

$Y = -402.856 + 1526.121x - 1135.502x^2$

$r^2 = 0.575$

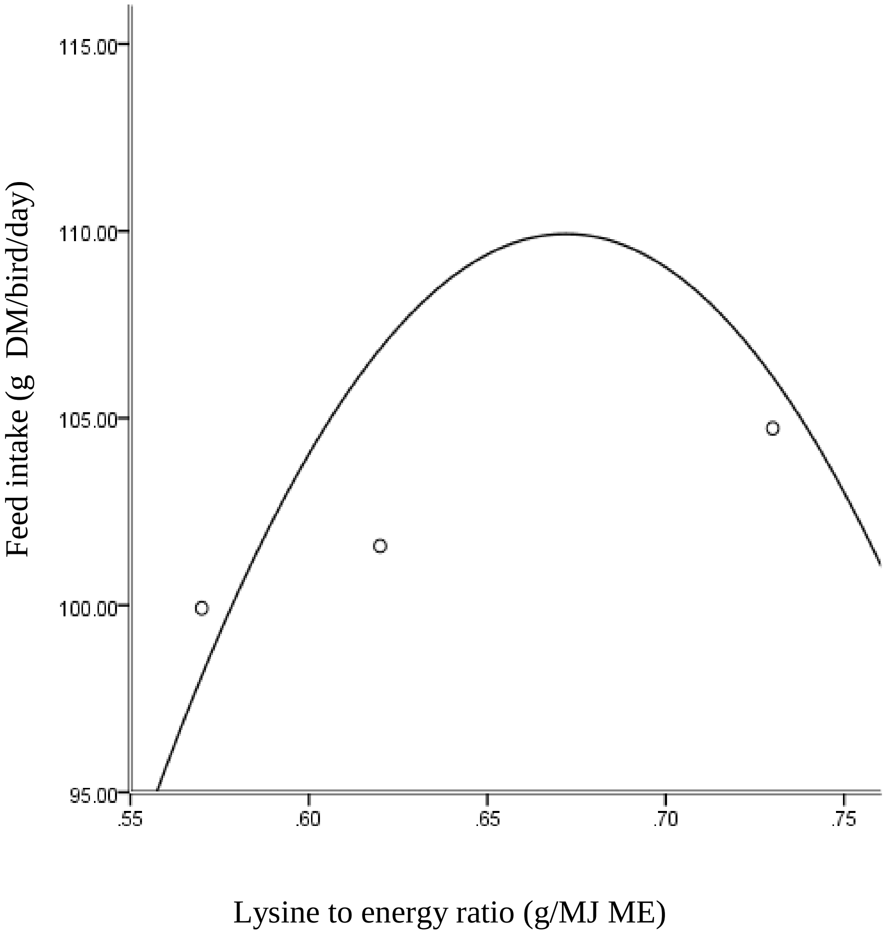


Figure 4.01 Effect of dietary lysine to energy ratio on feed intake of female Venda chickens aged eight to 13 weeks

$Y = -309.454 + 1013.112x - 783.877x^2$
$r^2 = 0.969$

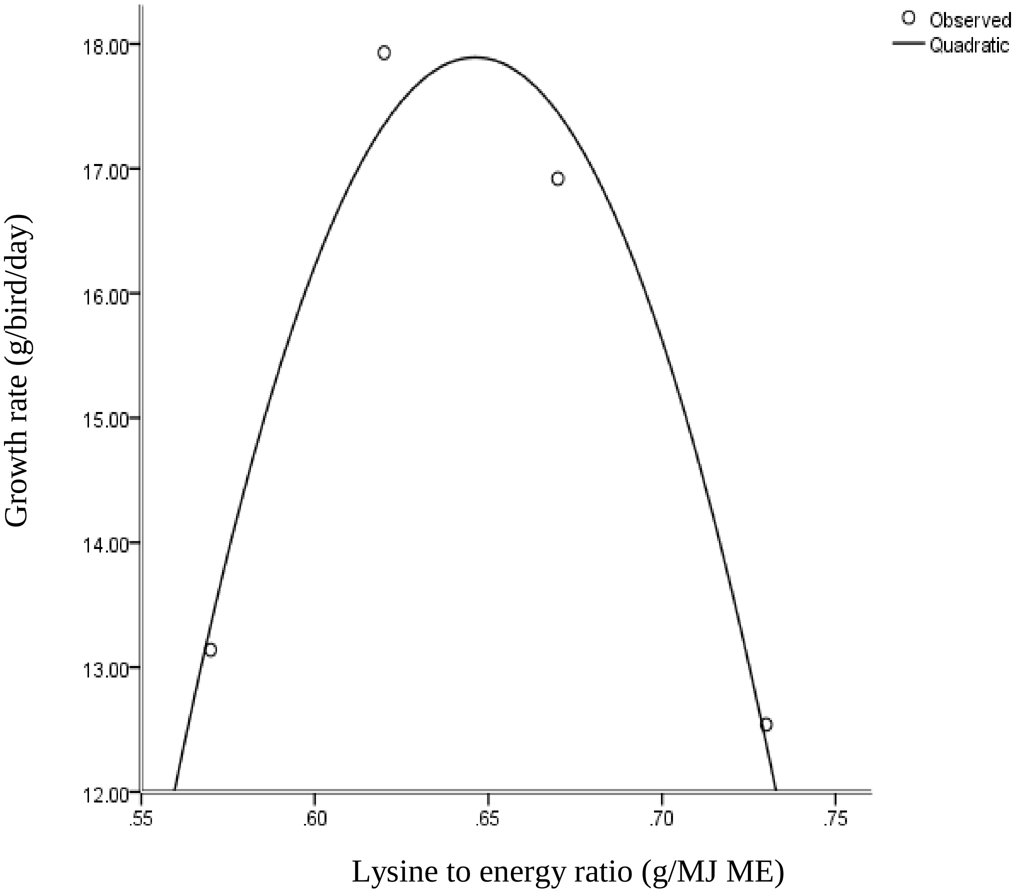


Figure 4.02 Effect of dietary lysine to energy ratio on growth rate of female Venda chickens aged eight to 13 weeks

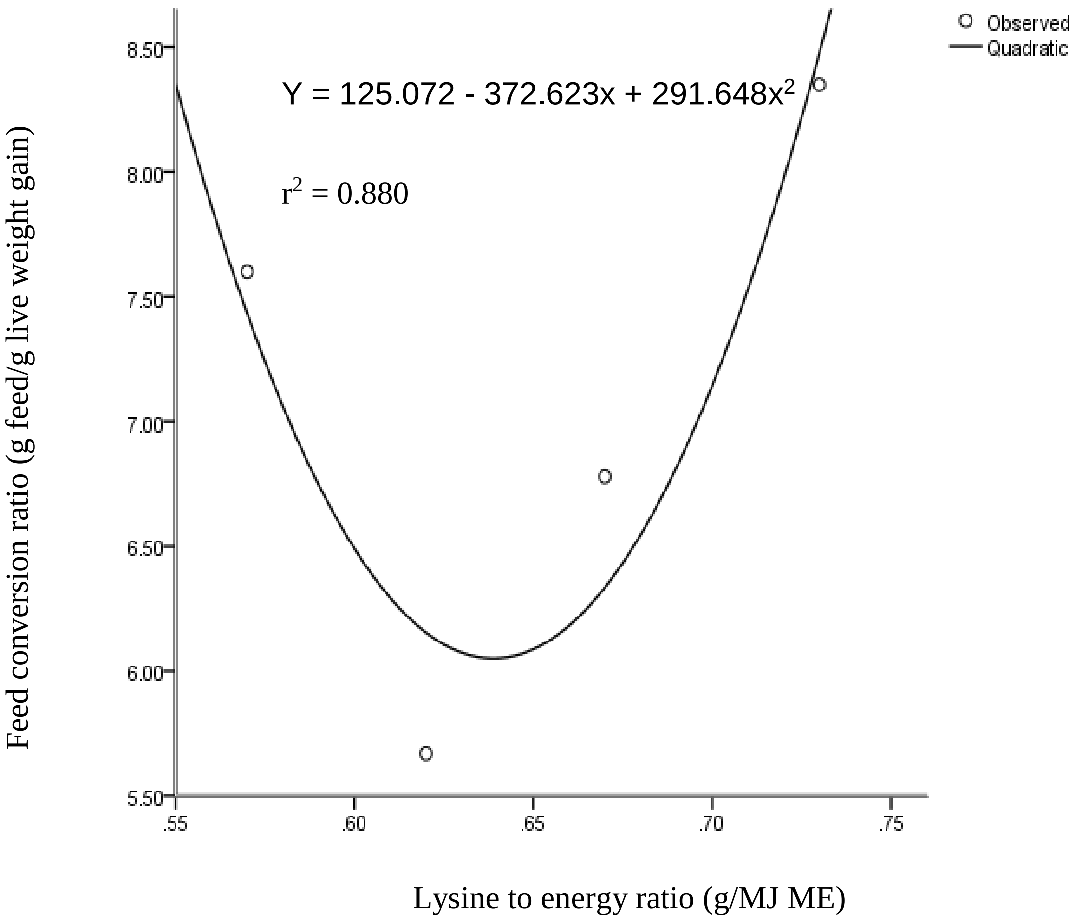


Figure 4.03 Effect of dietary lysine to energy ratio on feed conversion ratio of female Venda chickens aged eight to 13 weeks

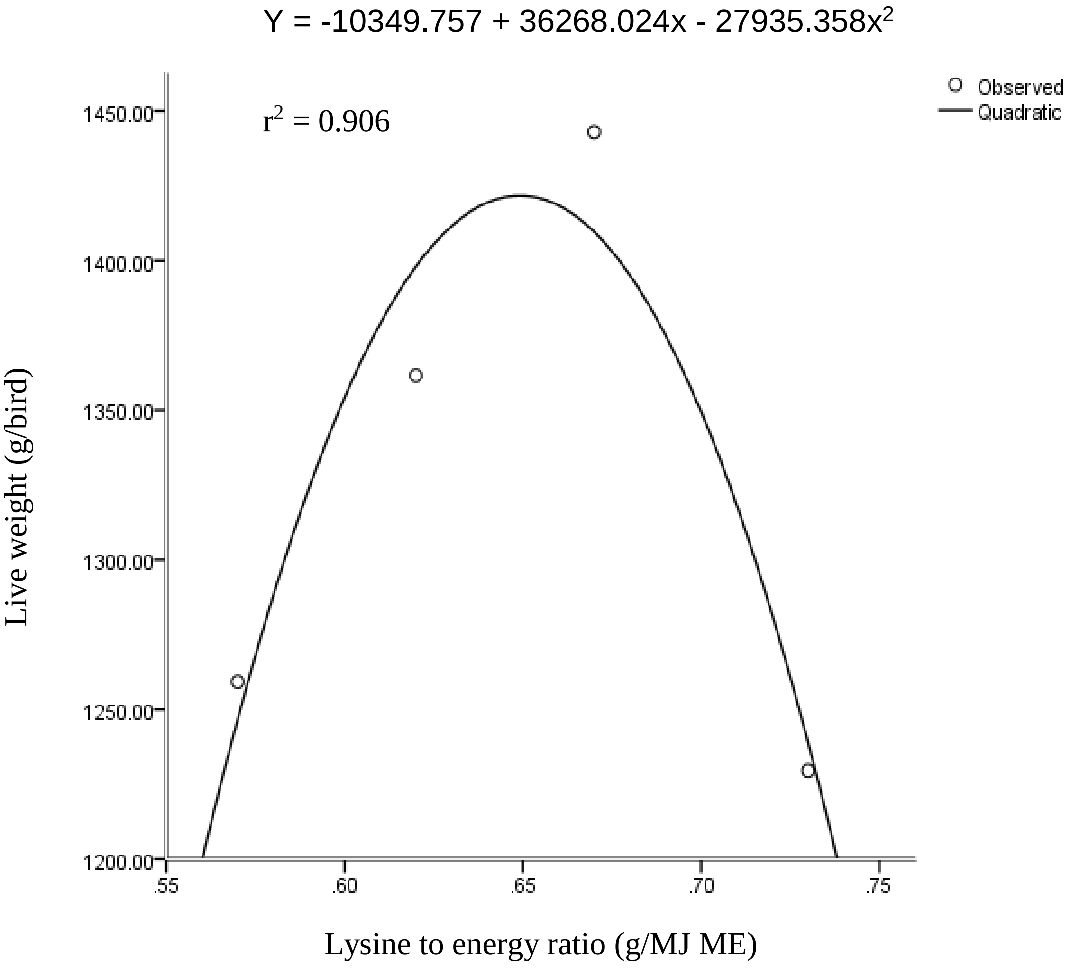


Figure 4.04 Effect of dietary lysine to energy ratio on live weight of female Venda chickens aged 91 days

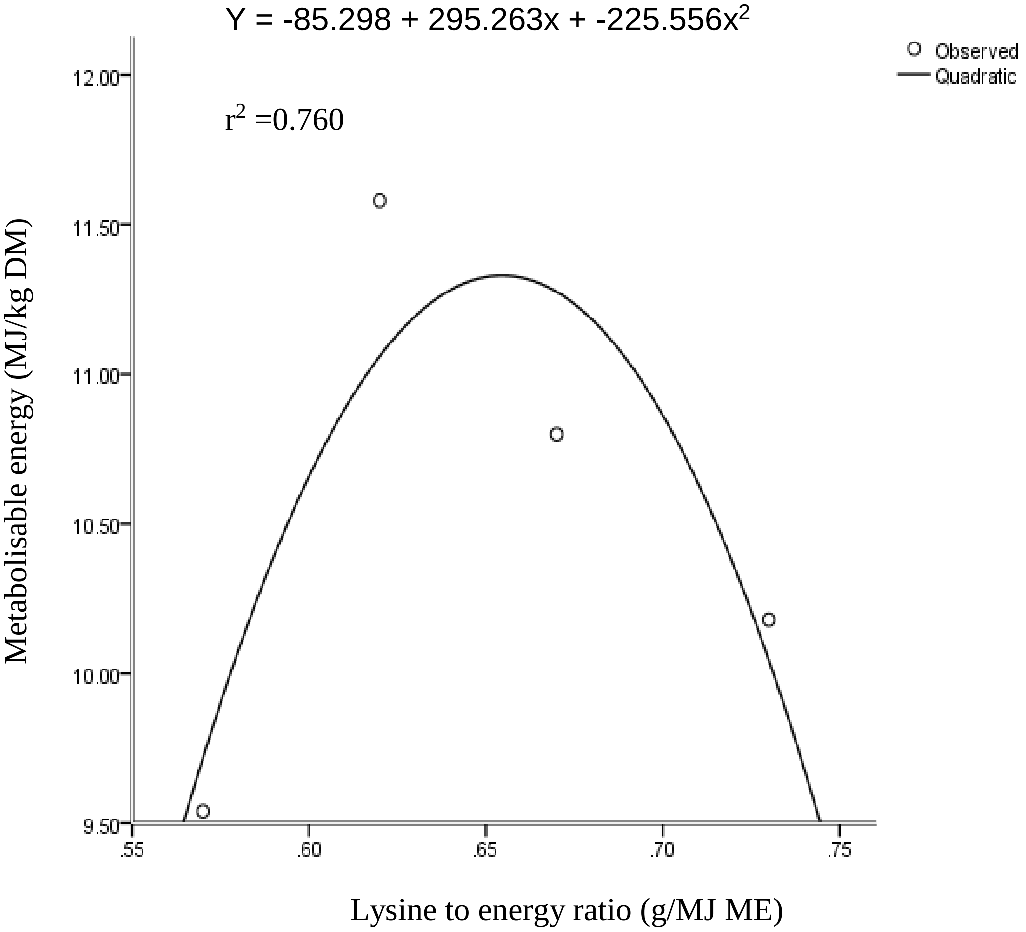


Figure 4.05 Effect of dietary lysine to energy ratio on apparent metabolisable energy of female Venda chickens aged 13 weeks

Table 4.11 Dietary lysine to energy ratios for optimal feed intake (g/bird/day), growth rate (g/bird/day), FCR (g feed/g live weight gain), live weight (g/bird aged 91 days) and apparent metabolisable energy (MJ/kg DM) of female Venda chickens aged eight to thirteen weeks

Trait	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Feed intake	$Y = -402.856 + 1526.121x - 1135.502x^2$	0.575	0.672	109.9
Growth rate	$Y = -309.454 + 1013.112x - 783.877x^2$	0.969	0.646	17.89
FCR	$Y = 125.072 - 372.623x + 291.648x^2$	0.880	0.639	6.05
Live weight	$Y = -10349.76 + 36268.02x - 7935.36x^2$	0.906	0.649	1421.8
ME	$Y = - 85.298 + 295.263x - 225.556x^2$	0.760	0.655	11.33

L:E ratio : Lysine to energy ratio for optimal variables

$r^{2`}$: coefficient of determination

Results of the effect of lysine to energy ratio on carcass characteristics of female indigenous Venda chickens aged 91 days are presented in Table 4.12. Dietary lysine to energy ratio did not have an effect (P>0.05) on thigh, fat pad, gizzard, liver and heart weights. However, carcass weight, dressing percentage, breast meat, drumstick and wing weights were influenced (P<0.05) by dietary lysine to energy ratio. Carcass weight and dressing percentage values of chickens offered diets having lysine to energy ratios of 0.62 or 0.67 were higher (P<0.05) than those of birds on diets having lysine to energy ratios of 0.57 or 0.73. Similarly, chickens on a diet having a lysine to energy ratio of 0.73 had higher (P<0.05) carcass weight and dressing percentage values than those on a diet having a lysine to energy ratio of 0.57. Female chickens offered diets having lysine to energy ratios of 0.62 or 0.67 had similar (P>0.05) carcass weights and dressing percentages.

Female Venda chickens offered diets having lysine to energy ratios of 0.62, 0.67 and 0.73 had similar (P>0.05) breast meat weights; their weights were, however, higher

(P<0.05) than those of birds on a diet having a lysine to energy ratio of 0.57. Chickens offered diets having lysine to energy ratios of 0.62 or 0.67 had similar (P>0.05) drumstick and wing weights. Similarly, chickens offered diets having lysine to energy ratios of 0.62 or 0.73 had the same (P>0.05) drumstick and wing weights. However, chickens offered a diet having a lysine to energy ratio of 0.67 had higher (P<0.05) drumstick and wing weights than those on diets having 0.57 and 0.73 lysine to energy ratios. Similarly, chickens on a diet having a lysine to energy ratio of 0.73 had higher (0<0.05) drumstick and wing weights than those on a diet having a lysine to energy ratio of 0.57.

Carcass weight, dressing percentage, breast meat, drumstick and wing weights were optimized at dietary lysine to energy ratios of 0.656 (r^2 = 0.985), 0.664 (r^2 = 0.989), 0.669 (r^2 = 0.994), 0.665 (r^2 = 0.985) and 0.663 (r^2 = 0.987), respectively (Figures 4.06 to 4.10, respectively and Table 4.13).

Table 4.12 Effect of lysine to energy ratio (g/MJ ME) on carcass characteristics (g) of female Venda chickens aged 91 days

	Dietary lysine to energy ratio (g/MJ ME)				
Variable	0.57	0.62	0.67	0.73	SE
Carcass weight	911.0 ^{c}	1197.3 ^{a}	1203.3 ^{a}	1009.3 ^{b}	33.28
Dressing %	72.4 ^{c}	87.9 ^{a}	89.9 ^{a}	82.1 ^{b}	1.865
Breast meat weight	182.3 ^{b}	204.7 ^{a}	209.3 ^{a}	200.0 ^{a}	3.132
Drumstick weight	110.3 ^{c}	127.1 ^{ab}	129.0 ^{a}	121.3 ^{b}	2.093
Thigh weight	122.7	148.7	143.7	134.3	2.857
Wing weight	97.3 ^{c}	116.7 ^{ab}	118.7 ^{a}	108.7 ^{b}	2.433
Fat pad weight	2.7	2.7	2.6	2.6	0.018
Gizzard weight	52.0	56.7	60.3	55.7	1.496
Liver weight	25.7	29.0	27.7	28.3	0.710
Heart weight	5.0	7.0	5.7	6.3	0.276

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

SE : Standard error

$Y = -16826.595 + 55024.080x - 41916.503x^2$

$r^2 = 0.985$

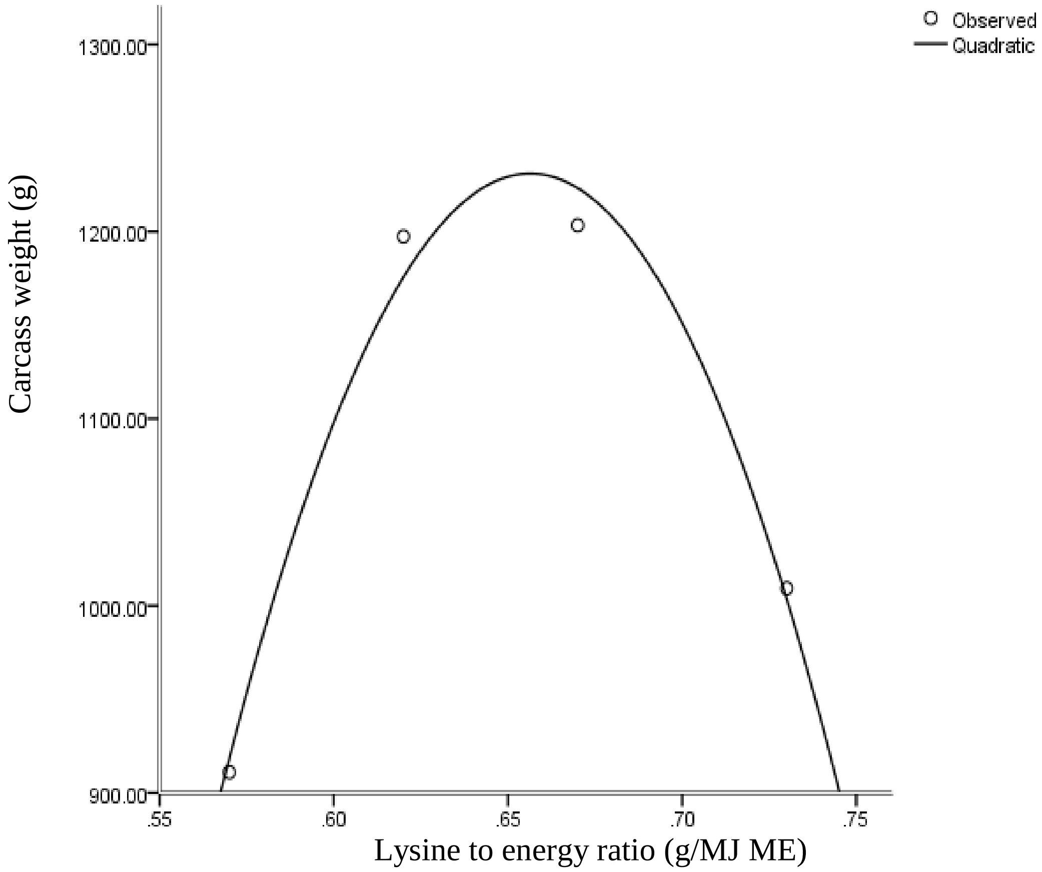


Figure 4.06 Effect of dietary lysine to energy ratio on carcass weight of female Venda chickens aged 91 days

$Y = -819.331 + 2742.357 - 2065.584x^2$

$r^2 = 0.989$

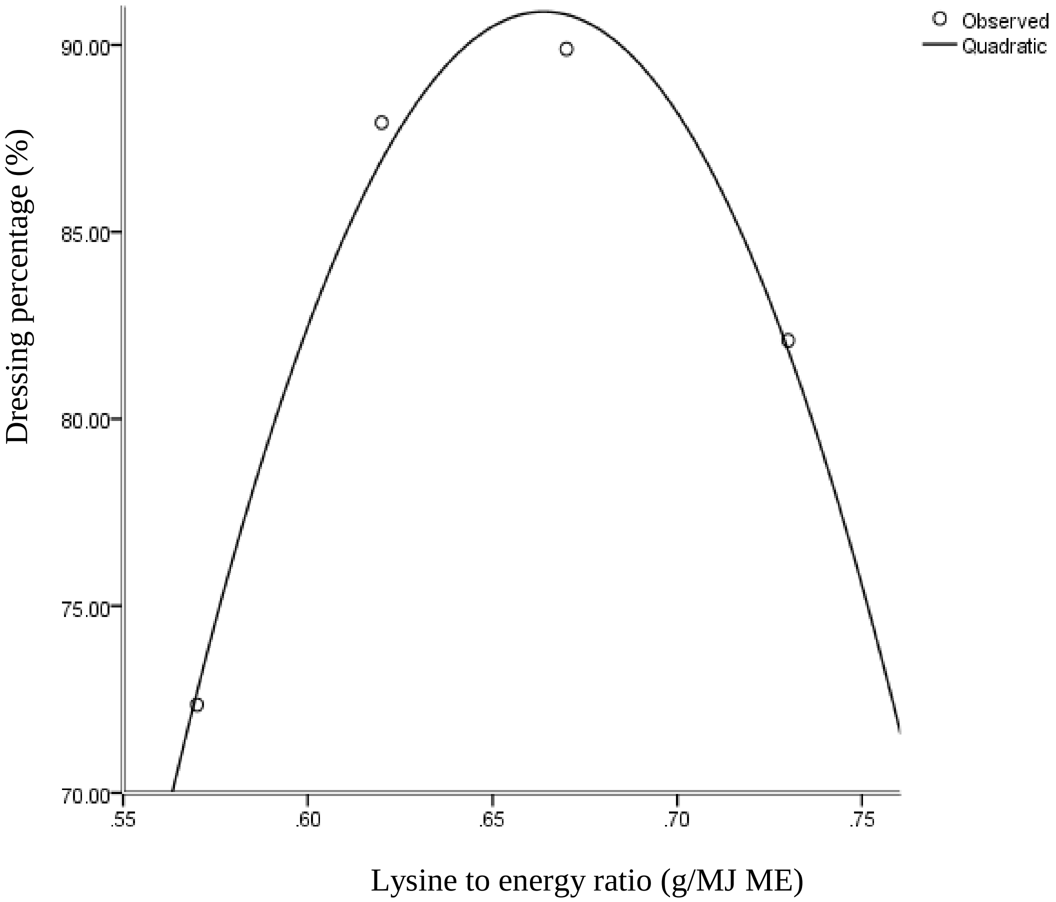
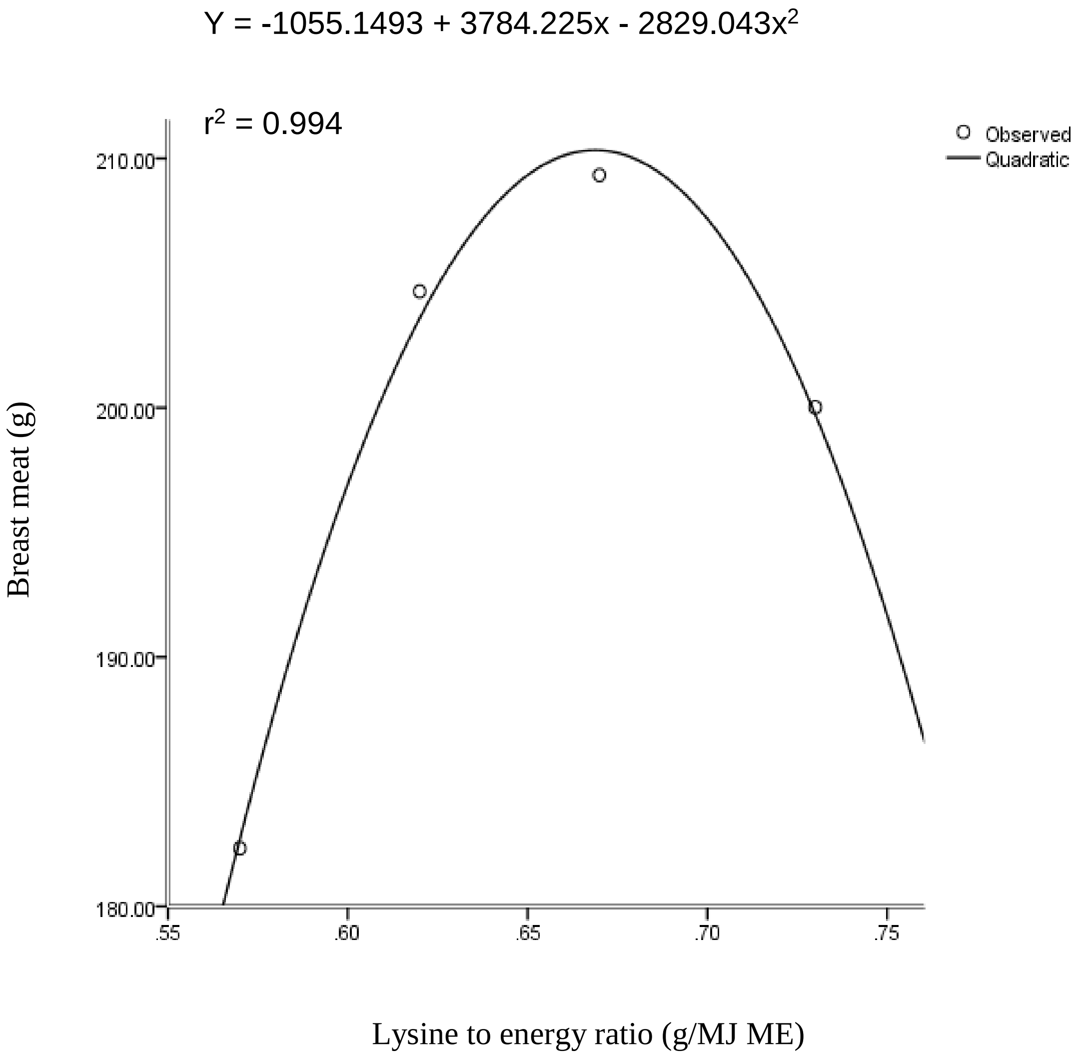


Figure 4.07 Effect of dietary lysine to energy ratio on dressing percentage of female Venda chickens aged 91 days



$Y = -1055.1493 + 3784.225x - 2829.043x^2$

$r^2 = 0.994$

Figure 4.08 Effect of dietary lysine to energy ratio on breast meat of female Venda chickens aged 91 days

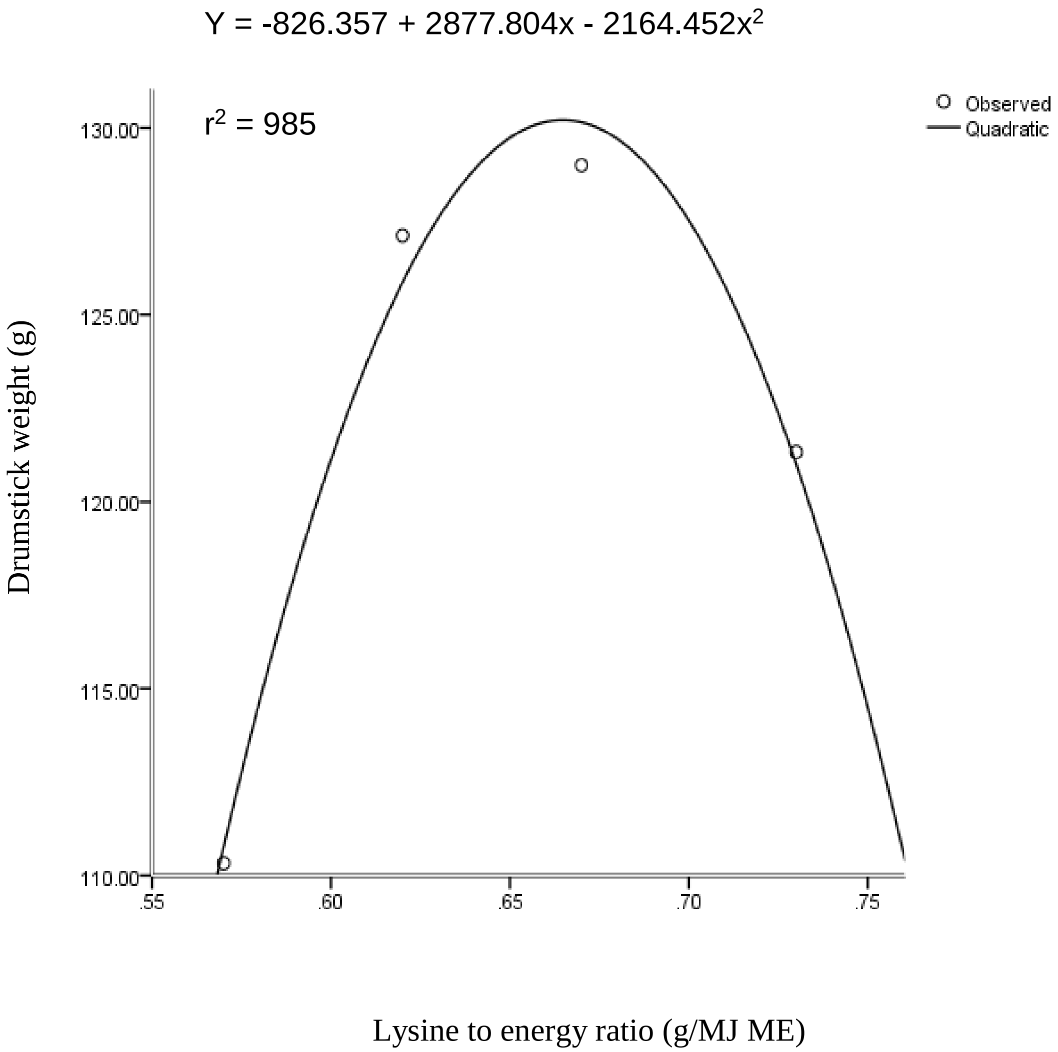
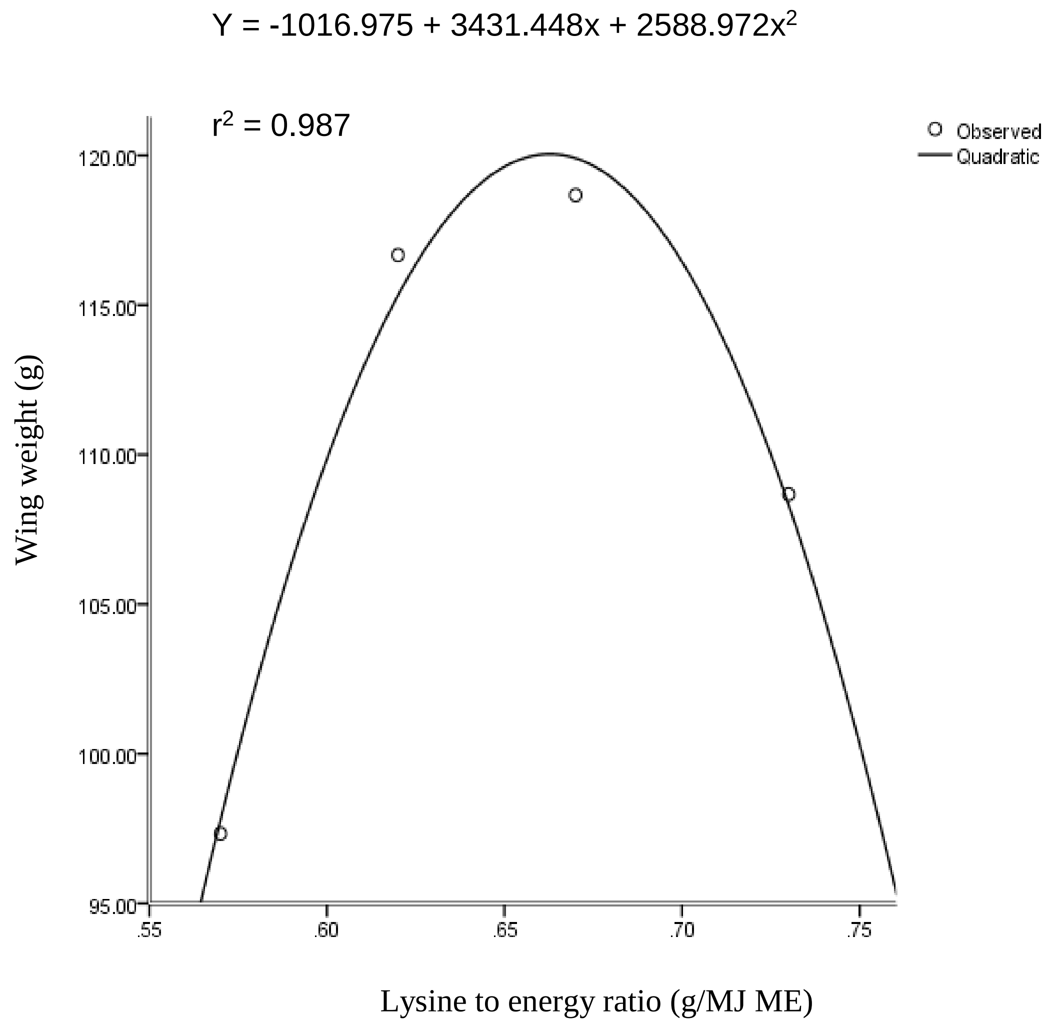


Figure 4.09 Effect of dietary lysine to energy ratio on drumstick weight of female Venda chickens aged 91 days



$Y = -1016.975 + 3431.448x + 2588.972x^2$

$r^2 = 0.987$

Figure 4.10 Effect of dietary lysine to energy ratio on wing weight of female Venda chickens aged 91 days

Table 4.13 Dietary lysine to energy ratios for optimal carcass weight (carcass wt) (g), dressing percentage (%), breast meat (g), drumstick (g) and wing (g) weights of female Venda chickens aged 91 days

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Carcass wt	$Y = -16826.60 + 55024.08x - 41916.50x^2$	0.985	0.656	1231.03
Dressing %	$Y = -819.33 + 2742.36 - 2065.58x^2$	0.989	0.664	90.89
Breast meat	$Y = -1055.15 + 3784.23x - 2829.04x^2$	0.994	0.669	210.33
Drumstick	$Y = -826.36 + 2877.80x - 2164.45x^2$	0.985	0.665	130.21
Wing	$Y = -1016.98 + 3431.45x + 2588.97x^2$	0.987	0.663	120.04

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Results of the effect of lysine to energy ratio on breast meat pH at different times, drip loss after slaughter and tenderness, juiciness and flavour of meat of indigenous female Venda chickens aged 91 days are presented in Table 4.14. Dietary lysine to energy ratio affected ($P<0.05$) breast meat drip loss after slaughter, and meat juiciness and flavour. Chickens offered a diet having a lysine to energy ratio of 0.67 produced meat with a higher ($P<0.05$) drip loss than those of meat from chickens on diets having lysine to energy ratios of 0.57 and 0.73. However, female Venda chickens offered diets having lysine to energy ratios of 0.62 or 0.67 produced meat with similar ($P>0.05$) drip losses. Similarly, chickens offered diets having 0.57, 0.62 or 0.73 lysine to energy ratios produced meat with the same ($P>0.05$) drip losses. Chickens offered a diet having a lysine to energy ratio of 0.67 produced breast meat with higher ($P<0.05$) juiciness scores than those of meat from chickens offered a diet having a lysine to energy ratio of 0.62. However, female Venda chickens offered diets having lysine to energy ratios of 0.57, 0.67 or 0.73 produced breast meat with similar ($P>0.05$) juiciness scores. Similarly, chickens offered diets having lysine to energy ratios of 0.57, 0.62 or 0.73 produced breast meat having the same ($P>0.05$) juiciness scores. Chickens offered diets containing lysine to energy ratios of 0.57, 0.62 or 0.67 produced breast meat with better ($P<0.05$) flavour scores than those offered a diet having a lysine to energy ratio of 0.73. However, female Venda chickens fed diets having lysine to energy ratios of 0.57, 0.62 or 0.67 produced breast meat with similar (P>0.05) flavour.

Venda female chicken breast meat pH and tenderness were not affected (P>0.05) by dietary treatments.

Drip loss at slaughtering, breast meat juiciness and flavour were optimized at dietary lysine to energy ratios of 0.631 ($r^2 = 0.668$), 0.708 ($r^2 = 0.604$) and 0.623 ($r^2 = 1.000$), respectively (Figures 4.11 to 4.13, respectively and Table 4.15).

Results of the effect of dietary lysine to energy ratio on haematological values of female Venda chickens aged 91 days are presented in Table 4.16. Dietary lysine to energy ratio had no effect (P>0.05) on all the haematological parameters measured except haemoglobin (Hb) and pack cell volume (PVC) (P<0.05) values. Female Venda chickens on a diet having a 0.73 lysine to energy ratio had higher (P<0.05) Hb values than those from chickens on diets having 0.57, 0.62 or 0.73 lysine to energy ratios. However, chickens offered diets having lysine to energy ratios of 0.62, 0.57 or 0.73 had similar (P>0.05) Hb values. Venda chickens offered a diet having a lysine to energy ratio of 0.73 had higher (P<0.05) PCV values than those from chickens on diets having lysine to energy ratios of 0.67, 0.62 or 0.57. However, chickens on diets having lysine to energy ratios of 0.67, 0.62 or 0.57 had similar (P>0.05) PVC values.

Table 4.14 Effect of lysine to energy ratio (g/MJ ME) on breast meat pH at different times after slaughtering, drip loss after slaughter (%), tenderness, juiciness and flavour of meat of female Venda chickens aged 91 days

	Dietary lysine to energy ratio (g/MJ ME)				
Variable	0.57	0.62	0.67	0.73	SE
pH at slaughter	5.38	5.48	5.55	5.41	0.041
pH at 30 minutes	5.36	5.46	5.53	5.40	0.032
pH at 2 hours	5.30	5.30	5.42	5.38	0.030
pH at 12 hours	5.20	5.52	5.13	5.10	0.036
pH at 24 hours	5.18	5.10	5.07	5.00	0.035
Drip loss	3.33^{b}	3.45^{ab}	3.53^{a}	3.35^{b}	0.030
Tenderness	3.55	3.40	3.33	3.33	0.042
Juiciness	3.48^{ab}	3.38^{b}	3.58^{a}	3.50^{ab}	0.029
Flavour	4.08^{a}	4.08^{a}	4.10^{a}	3.80^{b}	0.042

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

SE : Standard error

Haemoglobin and pack cell volume values were optimized at dietary lysine to energy ratios of 0.556 (r^2= 0.600) and, 0.609 (r^2= 0.964), respectively (Figures 4.14 and 4.15, respectively and Table 4.17).

$Y = -2.139 + 17.899x - 14.193x^2$

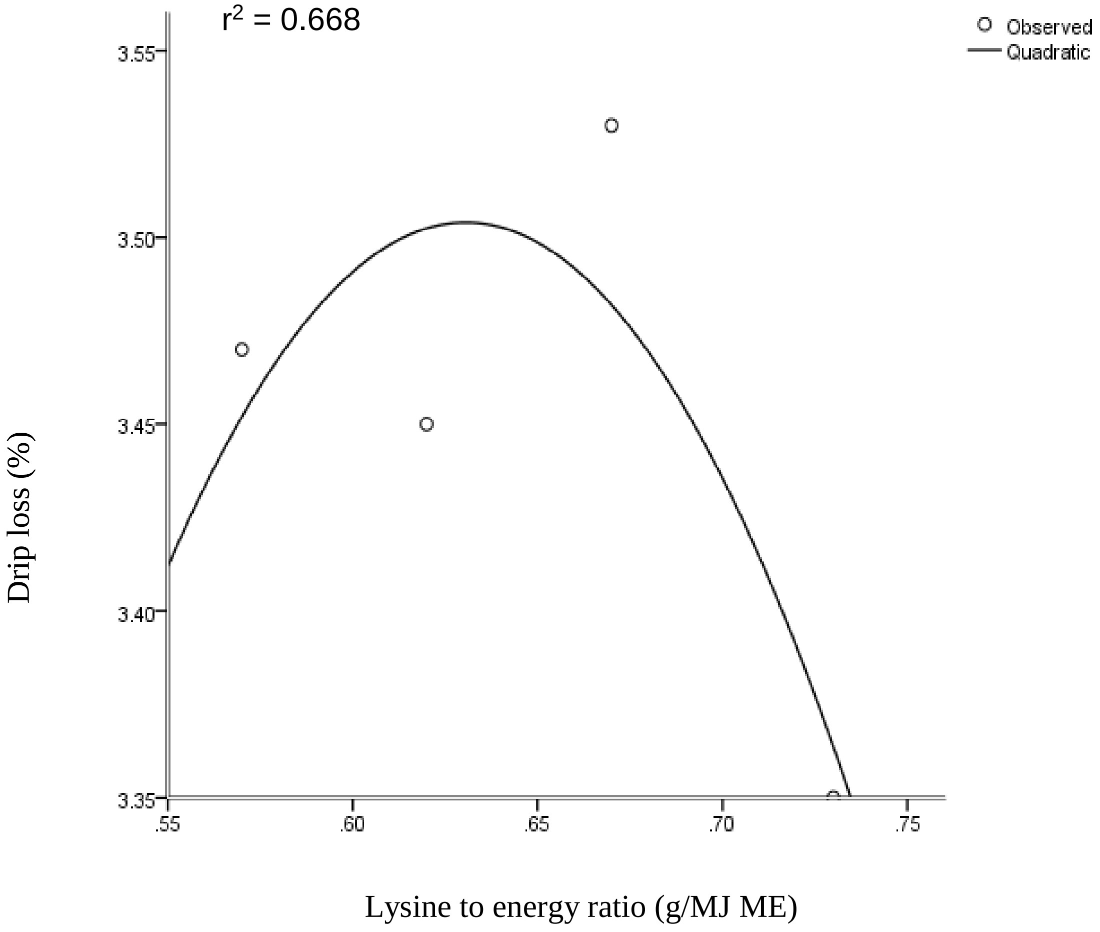


Figure 4.11 Effect of dietary lysine to energy ratio on drip loss of meat of female Venda chickens aged 91 days

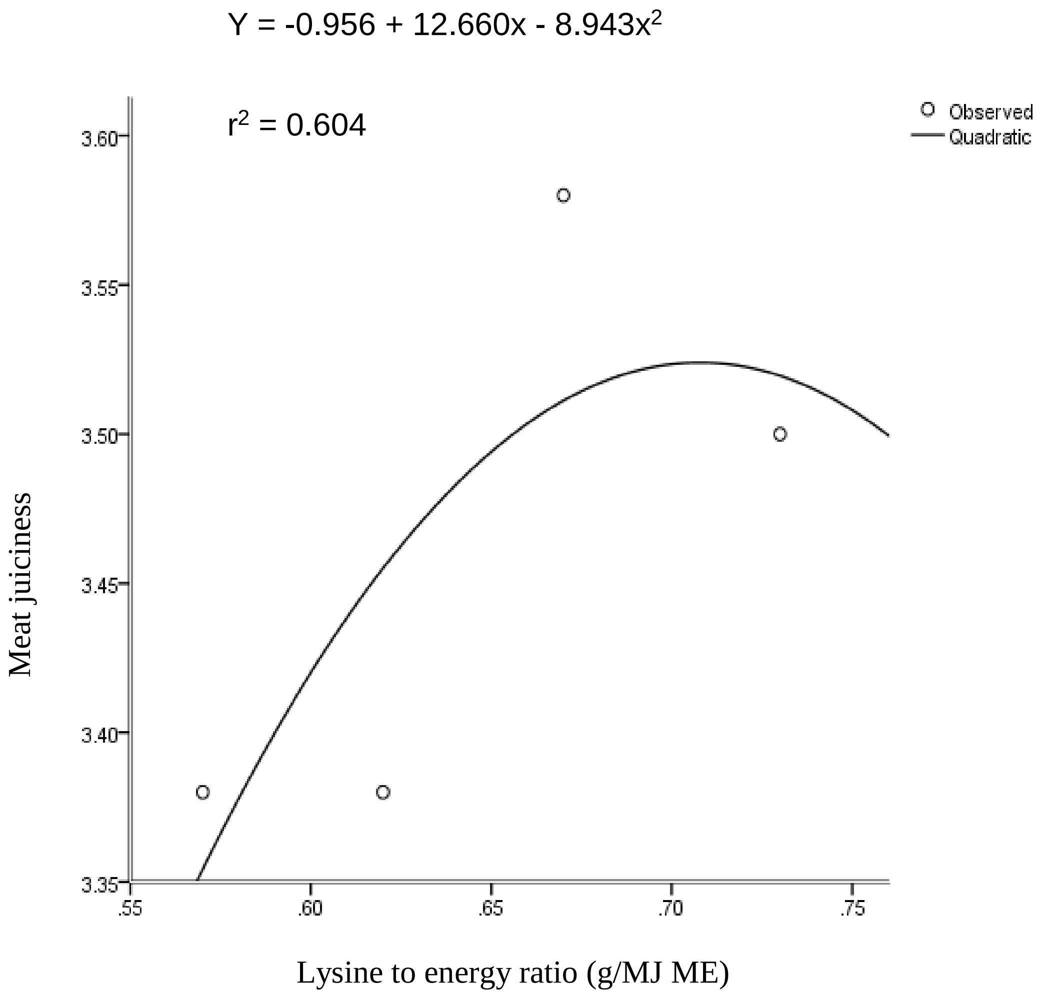


Figure 4.12 Effect of dietary lysine to energy ratio on meat juiciness of female Venda chickens aged 91 days

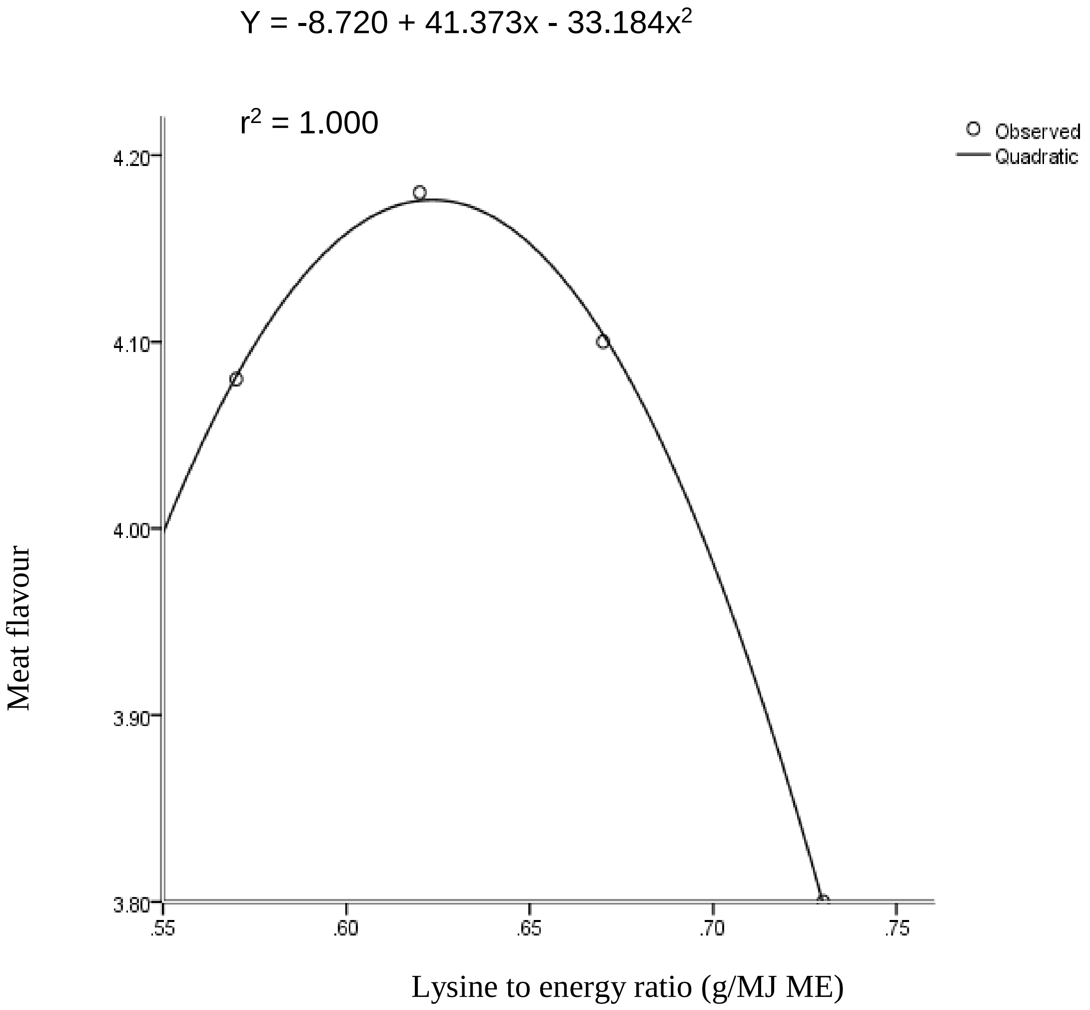


Figure 4.13 Effect of dietary lysine to energy ratio on meat flavour of female Venda chickens aged 91 days

Table 4.14 Dietary lysine to energy ratios for optimal drip loss after slaughtering (%), breast meat juiciness and flavour of meat of female Venda chickens aged 91 days

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Drip loss	$Y = -2.139 + 17.899x - 14.193x^2$	0.668	0.631	3.504
Juiciness	$Y = -0.956 + 12.660x - 8.943x^2$	0.604	0.708	3.524
Flavour	$Y = -8.720 + 41.373x - 33.184x^2$	1.000	0.623	4.176

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Table 4.16 Effect of lysine to energy ratio (g/MJ ME) on white blood cell (WBC), red blood cell (RBC), haemoglobin (Hb), pack cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) in female Venda chickens aged 91 days.

	Dietary lysine to energy ratio(g/MJ ME)				
Variable	0.57	0.62	0.67	0.73	SE
WBC $(10)^3$ µL	23.52	25.63	26.59	26.48	0.430
RBC $(10)^4$ µL	2.62	2.65	2.74	2.67	0.039
Hb (g/dL)	9.62^{b}	9.77^{b}	10.52^{a}	9.58^{b}	0.039
PCV (%)	29.99^{b}	30.16^{b}	30.33^{b}	33.85^{a}	0.495
MCV (fl)	136.17	144.85	145.84	143.51	1.193
MCH (pg)	46.11	48.00	46.57	44.24	0.362
MCHC (g/dL)	24.81	26.77	30.72	31.56	0.741

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

SE : Standard error

$Y = -32.932 + 131.779x - 100.578x^2$

$r^2 = 0.600$

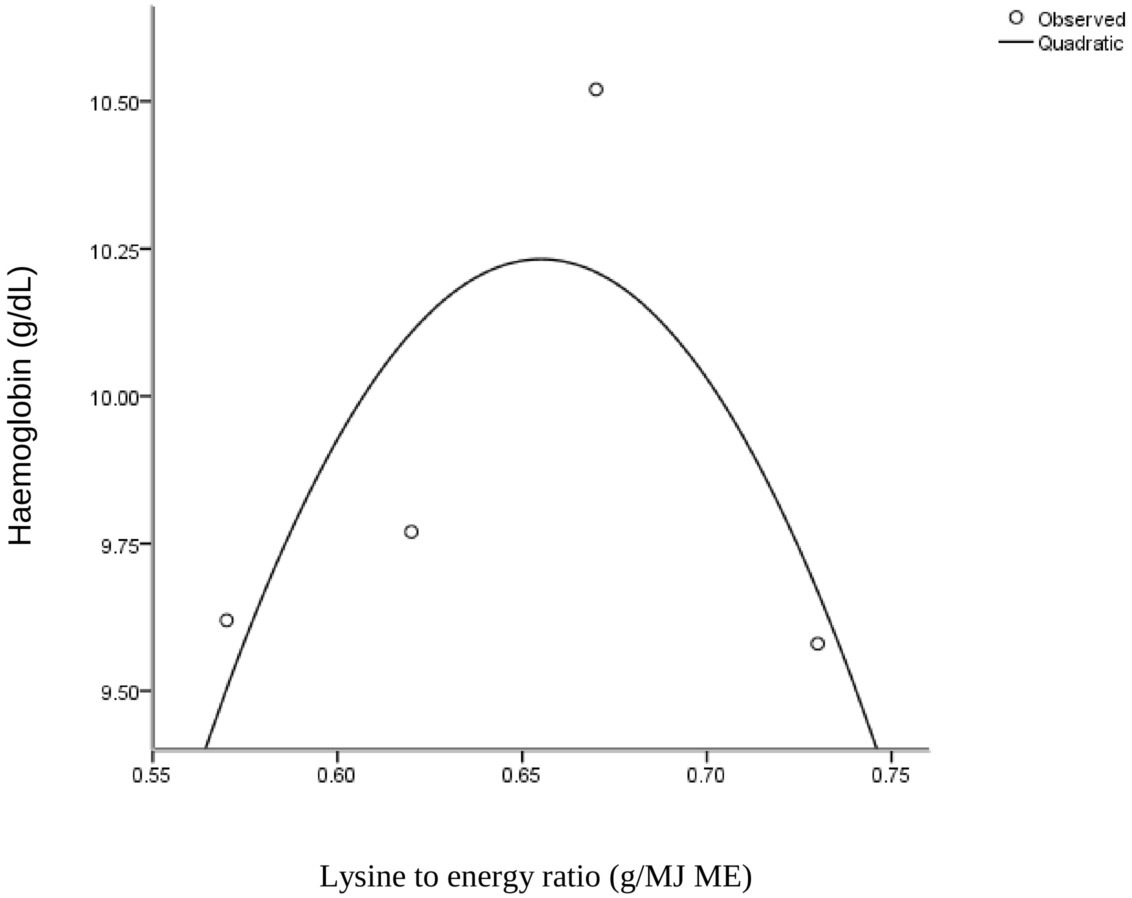


Figure 4.14 Effect of dietary lysine to energy ratio on haemoglobin amount of female Venda chickens aged 91 days

$Y = 132.938 - 338.757x + 277.902x^2$

$r^2 = 0.964$

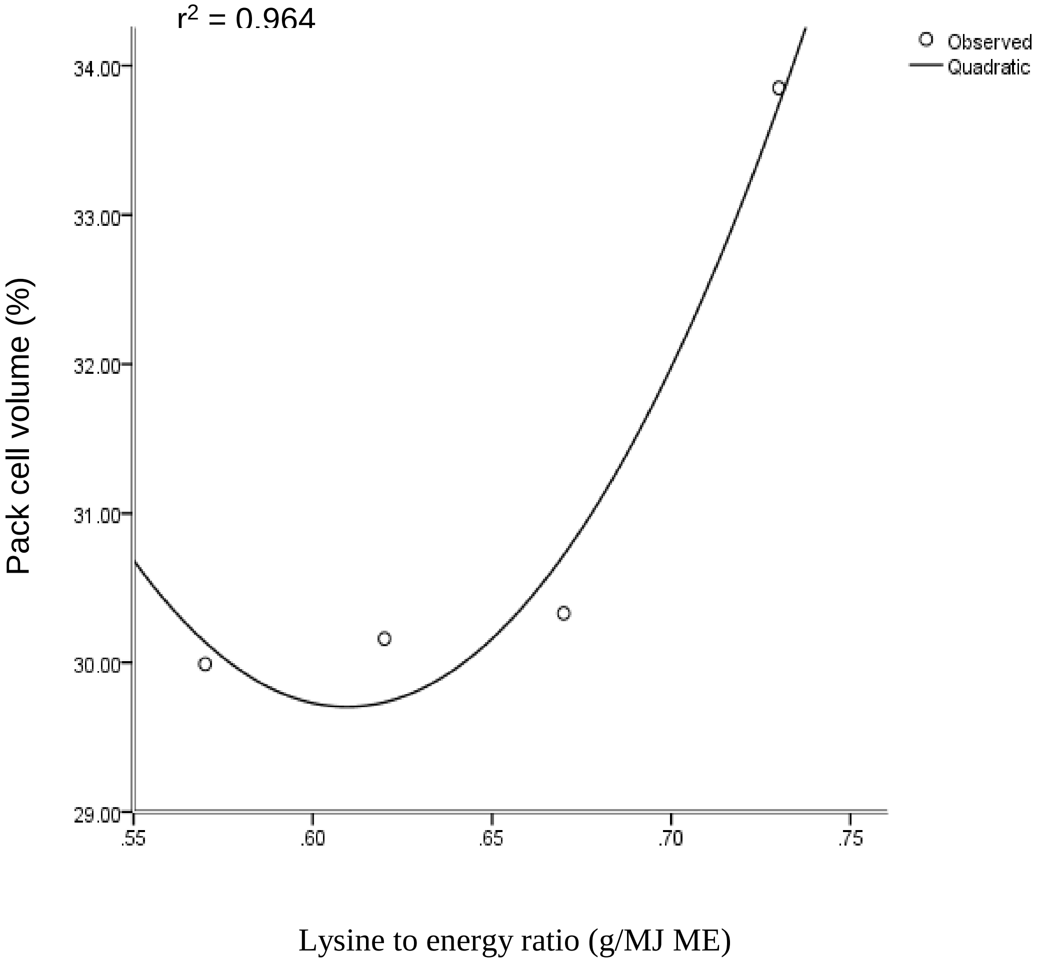


Figure 4.15 Effect of dietary lysine to energy on pack cell volume of female Venda chickens aged 91 days

Table 4.17 Dietary lysine to energy ratios for optimal haemoglobin (Hb) and pack cell volume (PCV) values in female Venda chickens aged 91 days.

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Hb	$Y = 30.328 - 74.588x + 67.034x^2$	0.994	0.556	9.580
PVC	$Y = 132.938 - 338.757x + 277.902x^2$	0.964	0.609	29.703

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Discussion

The dietary treatments used in this experiment are similar to those used in Experiment 1. They were, however, fed to female Venda chickens aged eight to thirteen weeks. The results show that feed intake, growth rate, feed conversion ratio, live weight and ME intake were influenced by dietary lysine to energy ratio. Mbajiorgu *et al.* (2011), also, reported that dietary lysine to energy ratio had effect on growth rate and FCR of male indigenous Venda chickens aged seven to thirteen weeks. Similarly, Hind *et al*. (2012) observed that feeding different lysine and energy diets to broiler chickens influenced their feed intake and FCR.

As the dietary lysine to energy ratio increased, feed intake, growth rate, live weight, ME intake and nitrogen retention of female Venda chicken aged eight to 13 weeks also increased until they were optimized at different dietary lysine to energy ratios. Feed intake was optimized at a dietary lysine to energy ratio of 0.672. This ratio is lower than the dietary lysine to energy ratios of 1.09 and 0.74 reported by Hind *et al*. (2012) and Araujo *et al* (2005), respectively, for broiler chickens aged three to six weeks. The difference might be attributed to different breeds used. Broiler chickens require higher lysine levels as they are bred for fast growth (Nasr and Kheiri, 2012), thus, requiring higher lysine to energy ratio in their diets.

Dietary lysine to energy ratios of 0.646 and 0.649 optimized growth rate and live weight of the chickens, respectively. The optimal ratio of 0.646 for growth rate in the present study is lower than the ratios of 1.05 (Hind *et al.,* 2012), 0.75 (NRC, 1994) and 0.74

(Labadan *et al*., 2001) for broiler chickens aged three to six weeks. Similarly, the ratio of 0.649 for optimal live weight in the present study is lower than a dietary lysine to energy ratio of 0.85 reported by Mbajiorgu *et al*. (2011) for male Venda chickens. It is possible that the difference between the two experiments in dietary lysine to energy ratios for optimal growth rates of Venda chickens may be due to differences in lysine requirements for male and female chickens. Male chickens require higher lysine for their growth (NRC, 1994).

Results of the present study indicate that a dietary lysine to energy ratio of 0.639 optimized FCR. This ratio is lower than 0.89 and 1.84 reported by Sinurat and Balnave (1985) and Araujo *et al*. (2005), respectively, for broiler chickens

Apparent metabolisable energy intake was optimized at a dietary lysine to energy ratio of 0.655. Thereafter, an increase in the dietary lysine to energy ratio resulted in a decrease in ME intake. It can, thus, be noted that in a diet containing 8 g of lysine per kg DM, 12.31 MJ of ME/kg DM and 150 g of CP/kg DM, ME intake of female indigenous Venda chickens aged thirteen weeks was optimized at a dietary lysine to energy ratio of 0.655. This ratio is lower than the lysine to energy ratio of 0.71 observed by Araujo *et al*. (2005) for broiler chickens aged three to six weeks. Thus, broiler chickens seem to require higher lysine to energy ratio in their diets for optimal ME intake than indigenous Venda chicken.

Nitrogen retention, in the present experiment, was not affected by dietary lysine to energy ratio.

It can, therefore, be concluded that in a diet of female Venda chickens aged eight to thirteen weeks, containing a lysine level of 8 g/kg DM and 150 g of CP/kg DM, feed intake, growth rate, FCR, live weight and ME intake were optimized at different dietary lysine to energy ratios of 0.672, 0.646, 0.639, 0.649 and 0.655, respectively. This has a lot of implications in diet formulation for indigenous female Venda chickens.

Results of the effect of dietary lysine to energy ratio on carcass characteristics of female Venda chickens aged 91 days indicated that dietary treatment had an effect on carcass weight, dressing percentage, breast meat, drumstick and wing weights. Ajaujo *et al.* (2005) reported that dietary energy and lysine levels influenced slaughter, carcass, breast meat and leg meat weights, and abdominal fat percentages of broiler chickens aged 44 to 55 days. Tang *et al*. (2007) found that dietary lysine and energy levels influenced live weight, dressing percentage and breast meat, however, the authors reported breast meat was not influenced by dietary lysine and energy levels. Quadratic analysis of the present results indicated that carcass weight, dressing percentage, thigh and wing weights were optimized at an approximately dietary lysine to energy ratio of 0.66. The ratio observed in the present study is lower than ratios of 0.84 for carcass weight, 1.11 for dressing percentage, 0.57 for breast meat weight and 0.80 for leg meat weight observed by Araujo *et al*. (2005) in broiler chickens aged 55 days.

A dietary lysine to energy ratio of approximately 0.67 optimized breast meat, drumstick, gizzard and liver weights. Tang *et al*. (2007) reported a lower dietary lysine to energy ratio of 0.56 for optimal breast meat yield in broiler chickens. However, the NRC (1994) reported a higher lysine to energy ratio of 0.74 for optimal breast meat yield in broiler chickens. Araujo *et al*. (2005) observed that leg weight of broiler chickens was optimized at a dietary lysine to energy ratio of 0.80. The differences observed could be attributed to differences in the breeds used. Broiler chickens require higher dietary lysine for breast meat production than do indigenous chickens (Kerr *et al.,* 1999).

Dietary lysine to energy ratio did not affect the breast meat pHs in the present study. However, breast meat pH values at slaughter, 30 minutes, two hours, 12 hours and 24 hours after slaughter were optimized at different dietary lysine to energy ratios. The present results are contrary to those of Tang *et al*. (2007) which showed that increasing lysine and energy levels in the diets of broiler chickens affected the breast meat pH at 40 minutes and 24 hours after slaughter.

Dietary lysine to energy ratio affected breast meat drip loss, juiciness and flavour. Breast meat drip loss increased until it was optimized at a dietary lysine to energy ratio of 0.631. This is similar to the results obtained by Tang *et al.* (2007). However, these authors did not determine the level for optimal drip loss. Drip loss affects the meat juiciness and flavour. Similar results were reported by Wood *et al*. (2008) and Tang (2007).

Dietary lysine to energy ratio did not have an influence on the haematological parameters measured except the Hb and PCV. Egbunike *et al.* (2009) reported that different dietary protein sources did not influence the haematological parameters. The haematological parameters observed in the present study were within the range reported in literature for indigenous chickens (Elagib and Ahmed, 2011; Islam *et al*., 2004).

Results of the effect of dietary lysine to energy ratio on the haemoglobin showed that as the dietary lysine to energy ratio increased the Hb values increased until it was optimized at a dietary lysine to energy ratio of 0.566. Dairo *et al*. (2010) observed that as the energy levels of the diets of broiler chickens increased, the Hb values, also, increased. The authors did not, however, determine the optimum energy level for the Hb values. Adequate quantities of lysine are essential for normal haemoglobin (Hb) formation in animals. Haemoglobin carries oxygen from lung to tissues. Low amino acid intake may alter the absorption, retention and or utilization of substances which are essential for normal haematopoiesis, thus, affects the iron absorption in intestines (Lönnerdal and Chen, 1990). Thus, low Hb concentration might affect oxygen carrying ability of the blood. Low amino acid-fed animals have subnormal Hb compared to adequately fed animals (Rincker *et* al., 2005). Optimum Hb synthesis increases the availability of oxygen for anabolic activities leading to increased production of energy for muscle mass accretion.

The PCV values, in the present study, increased as the dietary lysine to energy ratio increased and they were optimized at a ratio of 0.609. The results indicate that at low dietary lysine to energy ratio, the PCV values are low. This is in agreement with the results of Edozien and Switzer (1977). The authors stated that PCV are very responsive to amino acid deficiency. Thus, a sufficient amino acid profile is necessary for maintaining optimal concentrations of blood constituents.

It is concluded that in the present study, haematological parameters were within the ranges for indigenous chickens. Dietary lysine to energy ratios of 0.556 and 0.609, optimized Hb and PVC, respectively, in indigenous female Venda chickens fed diets containing 8 g of lysine/kg DM, 150 g of CP/kg DM and 11 MJ of ME/kg DM.

4.3.2 Experiment 6

Results

The nutrient compositions of the diets used in Experiment 6 are the same as those presented in Table 3.12. The diets had a similar dietary lysine content of 9 g/kg DM but different energy levels. The energy levels were 11, 12, 13 and 14 MJ of ME/kg DM (determined in the laboratory using NIRA), thus forming lysine to energy (L:E) ratios of 0.82 (FL_9E_{11}), 0.75 (FL_9E_{12}), 0.69 (FL_9E_{13}) and 0.64 (FL_9E_{14}), respectively.

Results of the effect of dietary lysine to energy ratio on feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen (N) retention and mortality of female Venda chickens aged eight to thirteen weeks are presented in Table 4.18. Female Venda chickens offered a diet having a lysine to energy ratio of 0.75 had a higher ($P<0.05$) feed intake than chickens on diets having lysine to energy ratios of 0.82, 0.69 or 0.64. Similarly, chickens on a diet having a lysine to energy ratio of 0.82 had a higher ($P<0.05$) feed intake than those on diets having 0.69 or 0.64 lysine to energy ratios. However, chickens on diets having lysine to energy ratios of 0.69 or 0.64 had similar ($P>0.05$) feed intakes. Female Venda chickens offered diets having 0.69 or 0.64 lysine to energy ratios had better ($P<0.05$) FCR values than those offered diets having lysine to energy ratios of 0.75 or 0.82. However, chickens offered diets having 0.69 or 0.64 lysine to energy ratios had similar ($P>0.05$) FCR values. Similarly, chickens offered diets having lysine to energy ratios of 0.75 or 0.82 had the same ($P>0.05$) FCR values.

Female Venda chickens offered a diet of a lysine to energy ratio of 0.69 had a higher ($P<0.05$) ME intake than those on diets having lysine to energy ratios of 0.82 or 0.64. Similarly, chickens on a dietary lysine to energy ratio of 0.82 had a higher ($P<0.05$) ME intake than those on a diet having a lysine to energy ratio of 0.64. However, chickens offered diets having lysine to energy ratios of 0.69 or 0.75 had similar ($P>0.05$) ME intakes. Similarly, chickens offered diets having lysine to energy ratios of 0.75 or 0.82 had the same ($P>0.05$) ME intakes.

Growth rate, live weight, N-retention and mortality of female Venda chickens were not affected ($P>0.05$) by the dietary treatments.

Feed intake, feed conversion ratio and apparent metabolisable were optimized at dietary lysine to energy ratios of 0.798 ($r^2 = 0.795$), 0.613 ($r^2 = 0.840$) and 0.750 ($r^2 = 0.865$), respectively (Figures 4.16, 4.17 and 4.18, respectively and Table 4.19).

Table 4.18 Effect of dietary lysine to energy ratio (g/MJ ME) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g feed/g live weigh gain), live weight (g/bird aged 91 days), apparent metabolisable energy (MJ /kg DM), nitrogen retention (g/bird/day) and mortality (%) of female Venda chickens aged eight to thirteen weeks

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.64	0.69	0.75	0.82	SE
Feed intake	82.64^{c}	84.98^{c}	99.82^{a}	95.94^{b}	2.402
Growth rate	20.6	22.1	22.6	20.7	0.60
FCR	4.01^{b}	3.85^{b}	4.41^{a}	4.64^{a}	0.270
Live weight	1147.2	1189.2	1157.6	1127.0	23.95
ME	8.64^{c}	10.65^{a}	10.48^{ab}	10.11^{b}	0.251
N-retention	1.25	1.49	1.69	1.64	0.039
Mortality	0.02	0.01	0.01	0.00	0.001

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

ME :Metabolisable energy

N-retention :Nitrogen retention

SE : Standard error

$Y = -327.466 + 1065.318x - 667.819x^2$

$r^2 = 0.795$

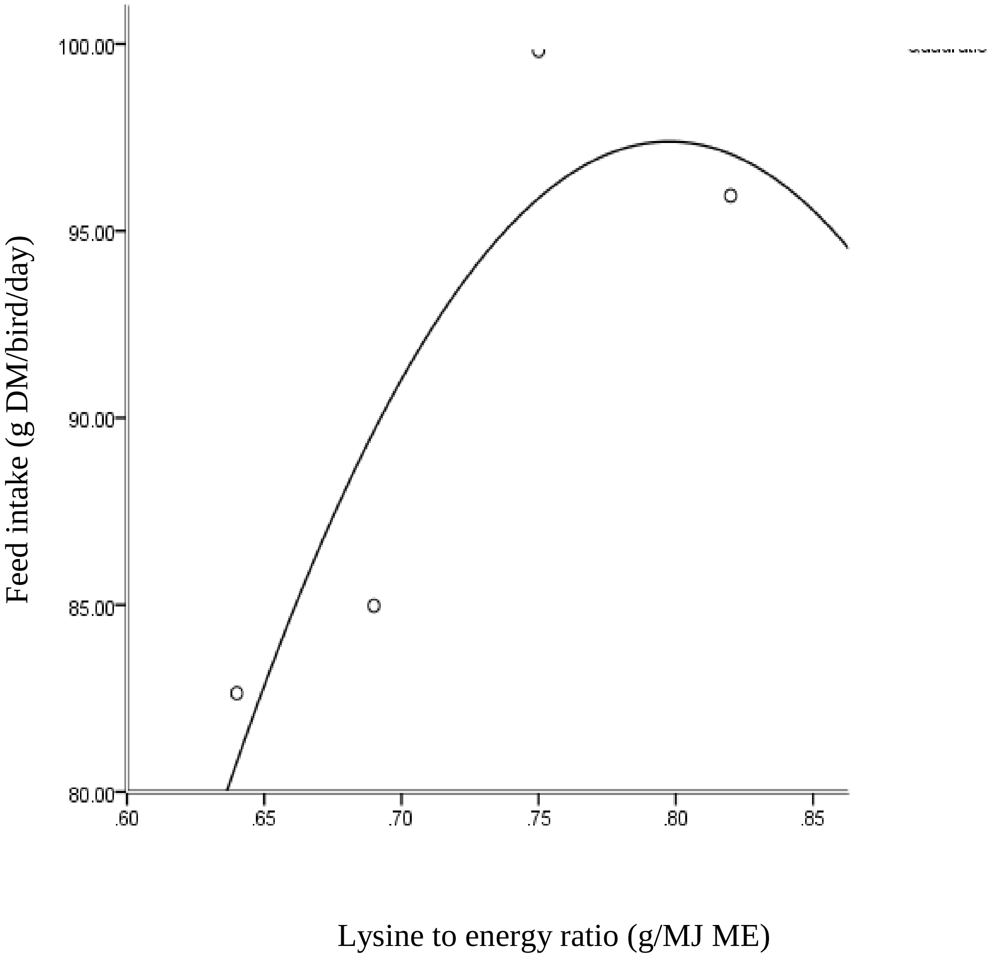


Figure 4.16 Effect of dietary lysine to energy ratio on feed intake of female Venda chickens aged eight to 13 weeks

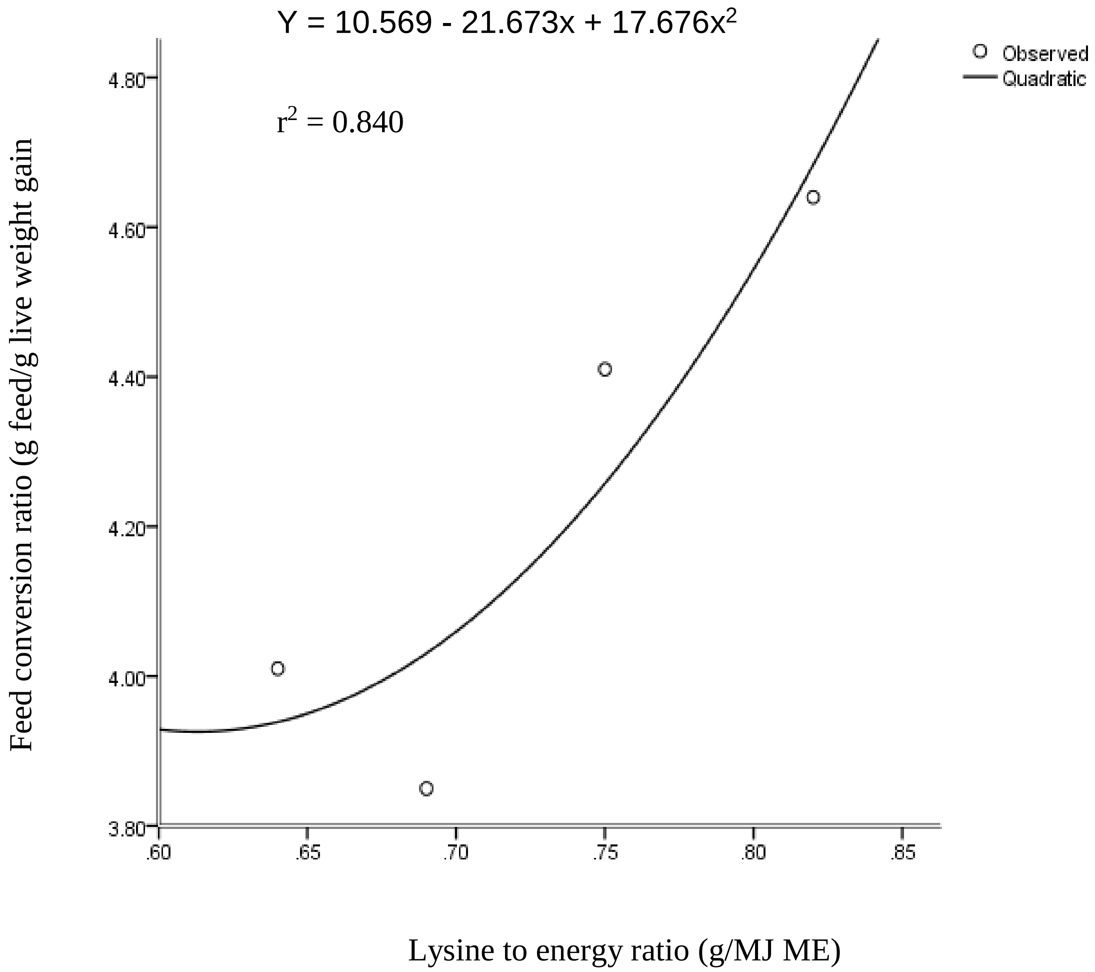


Figure 4.17 Effect of dietary lysine to energy ratio on feed conversion ratio of female Venda chickens aged eight to 13 weeks

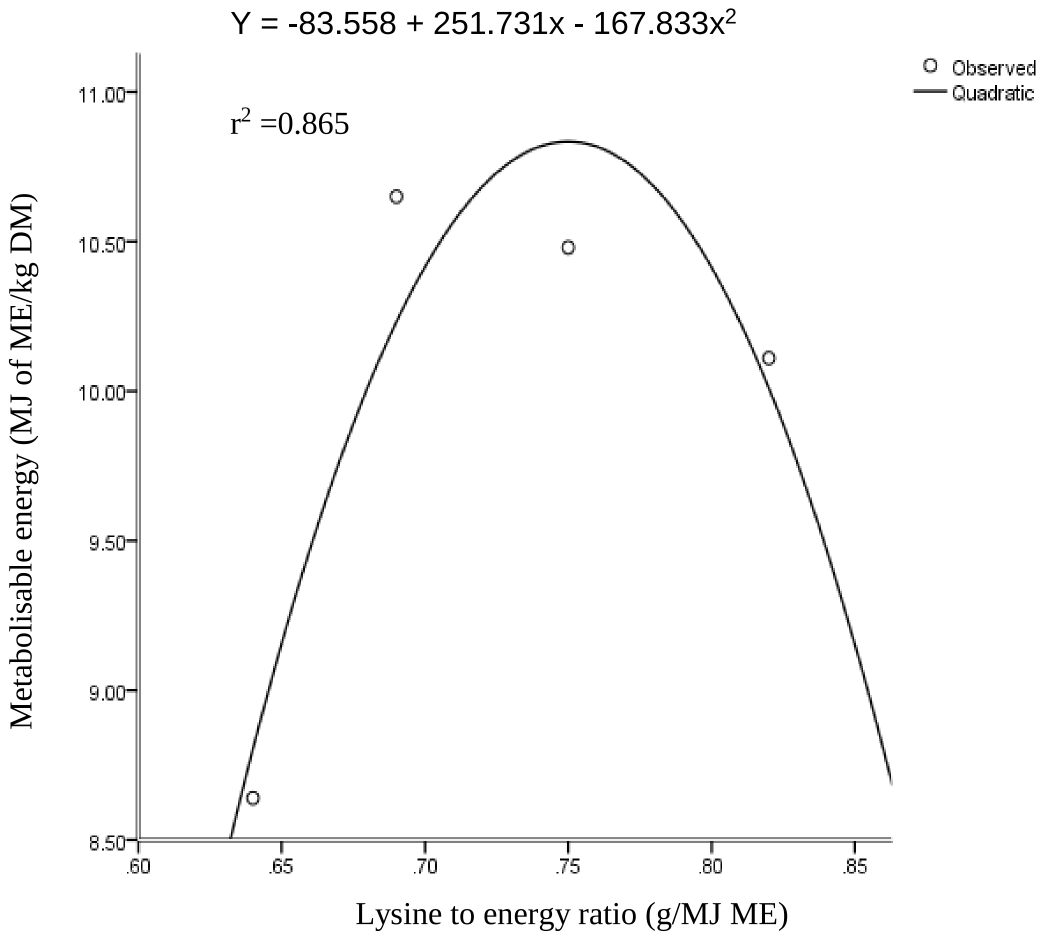


Figure 4.18 Effect of dietary lysine to energy ratio on apparent metabolisable energy of female Venda chickens aged 13 weeks

Table 4.19 Dietary lysine to energy ratios for optimal feed intake (g/bird/day), FCR (g feed/g live weight gain) and apparent metabolisable energy (MJ/kg DM) of female Venda chickens aged eight to thirteen weeks

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Feed intake	$Y = -327.466 + 1065.318x - 667.819x^2$	0.795	0.798	97.388
Growth rate	$Y = -108.395 + 358.090x + 244.705x^2$	0.991	0.732	22.608
FCR	$Y = 10.569 - 21.673x + 17.676x^2$	0.840	0.613	3.923
Live weight	$Y = -1133.366 + 6488.666 - 4556.591x^2$	0.793	0.712	1176.63
ME	$Y = -83.558 + 251.731x - 167.833x^2$	0.865	0.750	10.834
N-retention	$Y = -12.792 + 37.296x - 24.013x^2$	0.995	0.777	1.690

L:E ratio : Lysine to energy ratio for optimal variables

$r^{2`}$: coefficient of determination

Results of the effect of lysine to energy ratio on carcass characteristics of female Venda chickens aged 91 days are presented in Table 4.20. Female Venda chickens offered a diet having a lysine to energy ratio of 0.75 had a higher ($P<0.05$) carcass weight than those of chickens on diets having lysine to energy ratios of 0.69, 0.82 or 0.64. The carcass weights of chickens offered diets having lysine to energy ratios of 0.69 or 0.82 were higher ($P<0.05$) than those of chickens offered a diet having a lysine to energy ratio of 0.64. However, Chickens offered diets having lysine to energy ratios of 0.69 or 0.82 had similar ($P>0.05$) carcass weights. Female Venda chickens offered a diet having a lysine to energy ratio of 0.75 had a higher ($P<0.05$) dressing percentage than those on a diet having a lysine to energy ratio of 0.64. However, the dressing percentages of chickens offered diets having lysine to energy ratios of 0.75, 0.82 or 0.69 were similar ($P>0.05$). Similarly, chickens offered diets having lysine to energy ratios of 0.82, 0.69 or 0.64 had the same ($P>0.05$) dressing percentages.

Female Venda chickens offered a diet having a lysine to energy ratio of 0.75 had higher ($P<0.05$) breast meat weights than those offered diets having lysine to energy ratios of 0.69, 0.64 or 0.82. Similarly, chickens offered a diet having a lysine to energy ratio of 0.69 had a higher ($P<0.05$) breast meat weight than those offered diets having lysine to energy ratios of 0.64 or 0.82. However, chickens offered diets having lysine to energy ratios of 0.64 or 0.82 had similar ($P>0.05$) breast meat weights.

Female Venda chickens offered a diet having a lysine to energy ratio of 0.75 had a higher ($P<0.05$) gizzard weight than those on diets having lysine to energy ratios of 0.69 or 0.64. However, chickens offered diets having lysine to energy ratios of 0.75 and 0.82 had similar ($P>0.05$) gizzard weights. Chickens offered diets having lysine to energy ratios of 0.82, 0.69 or 0.64, also, had similar ($P>0.05$) gizzard weights. However, dietary treatments did not have any effect ($P>0.05$) on drumstick, thigh, wing, fat pad, liver and heart weights of the chickens.

Carcass weight, dressing percentage, breast meat and gizzard weights were optimized at dietary lysine to energy ratios of 0.742 ($r^2 = 0.826$), 0.753 ($r^2 = 0.715$), 0.729 ($r^2 = 0.880$) and 0.758 ($r^2 = 0.624$), respectively (Figures 4.19 to 4.22, respectively and Table 4.21).

Table 4.20 Effect of lysine to energy ratio (g/MJ ME) on carcass characteristics (g) of female Venda chickens aged 91 days

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.64	0.69	0.75	0.82	SE
Carcass weight	865.67 ^{c}	964.67 ^{b}	1141.33 ^{a}	930.33 ^{b}	26.842
Dressing %	81.80 ^{b}	83.38 ^{ab}	89.70 ^{a}	84.78 ^{ab}	1.115
Breast meat	211.33 ^{c}	226.00 ^{b}	244.00 ^{a}	205.33 ^{c}	4.635
Drumstick	139.33	149.00	141.33	139.33	4.247
Thigh	114.67	126.33	132.67	114.00	2.521
Wing	104.69	119.00	110.67	106.67	2.524
Fat pad	2.61	2.69	2.68	2.61	0.024
Gizzard	58.33 ^{b}	60.00 ^{b}	78.67 ^{a}	66.33 ^{ab}	3.28
Liver	26.33	28.00	32.67	30.33	1.729
Heart	8.04	8.00	8.33	7.00	0.307

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

SE : Standard error

$Y = -12116.700 + 35600.901x - 23990.292x^2$

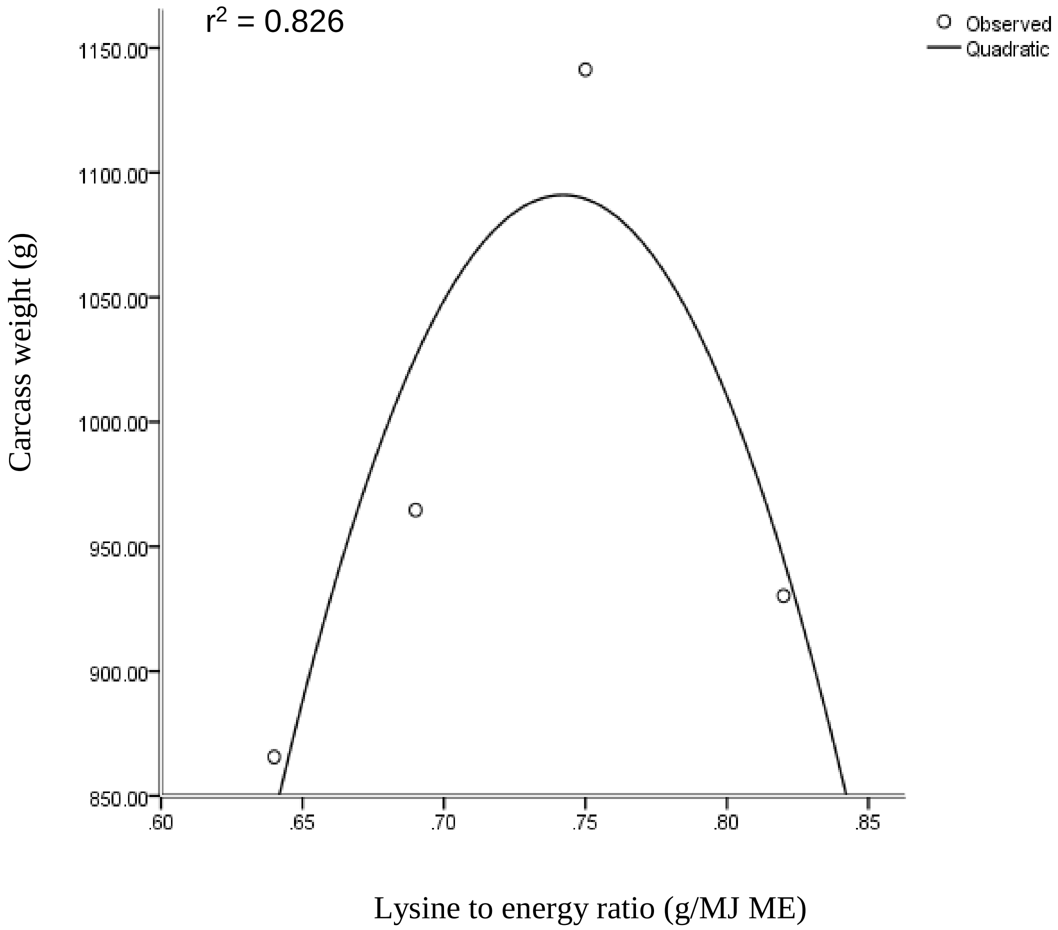


Figure 4.19 Effect of dietary lysine to energy ratio on carcass weight of female Venda chickens aged 91 days

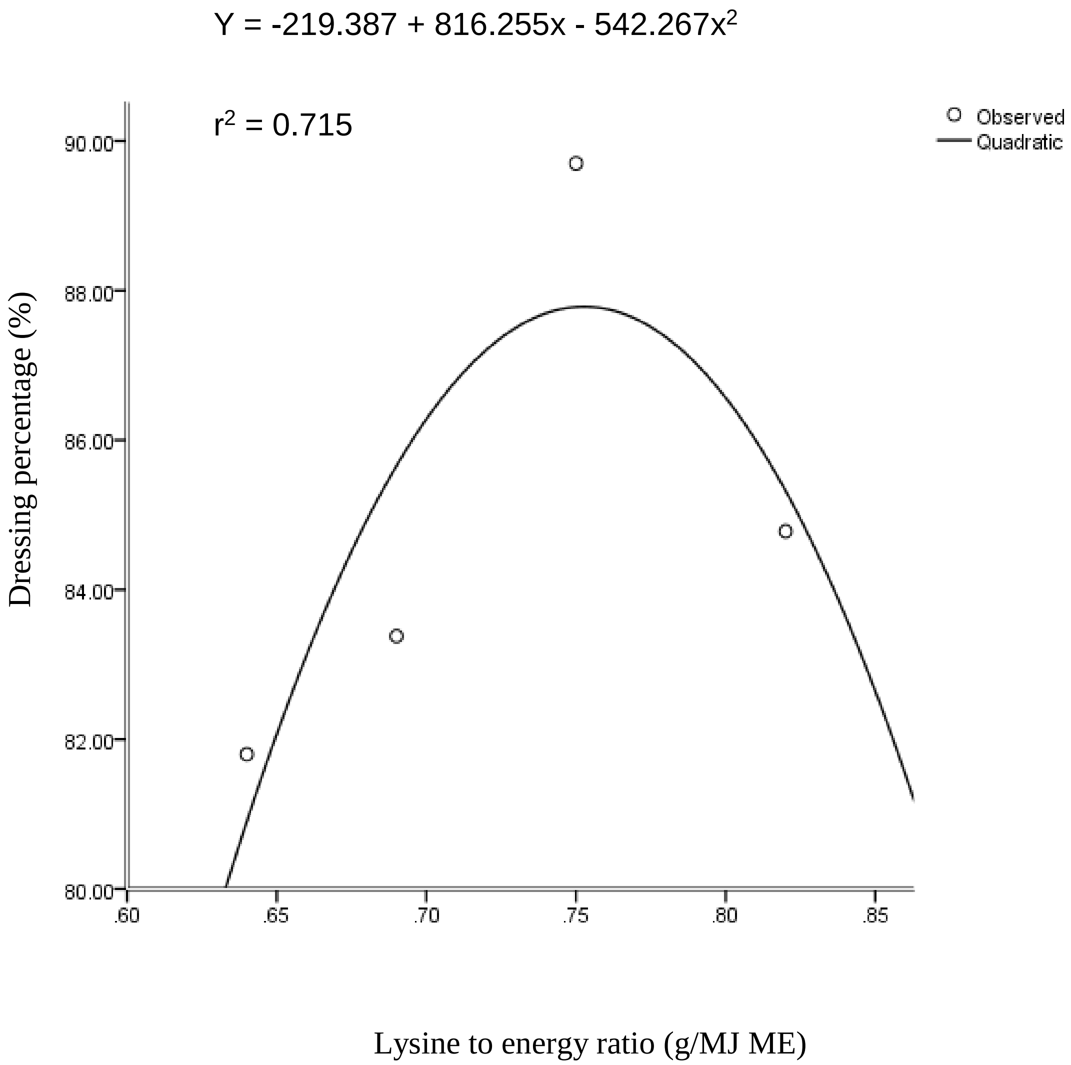


Figure 4.20 Effect of dietary lysine to energy ratio on dressing percentage of female Venda chickens aged 91 days

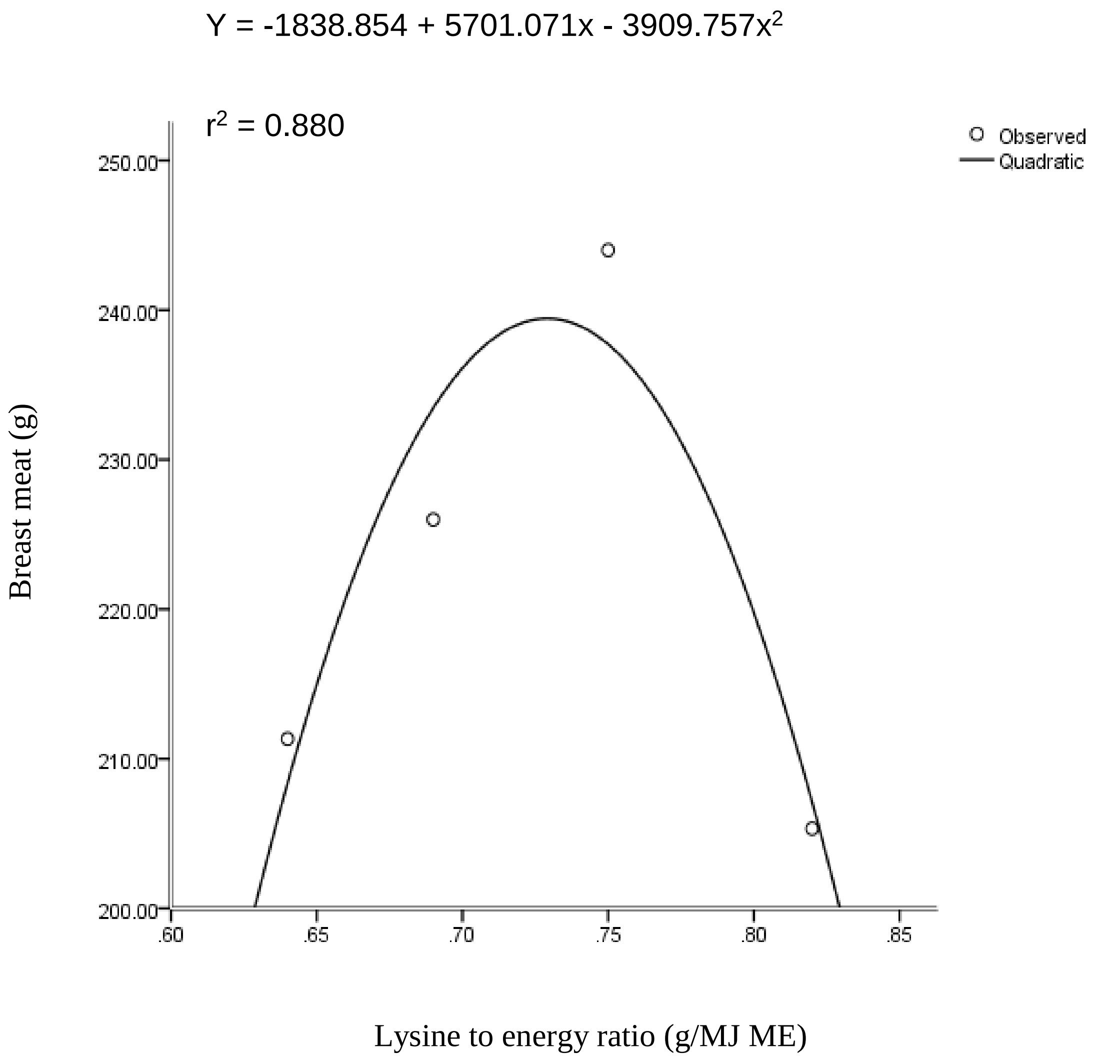
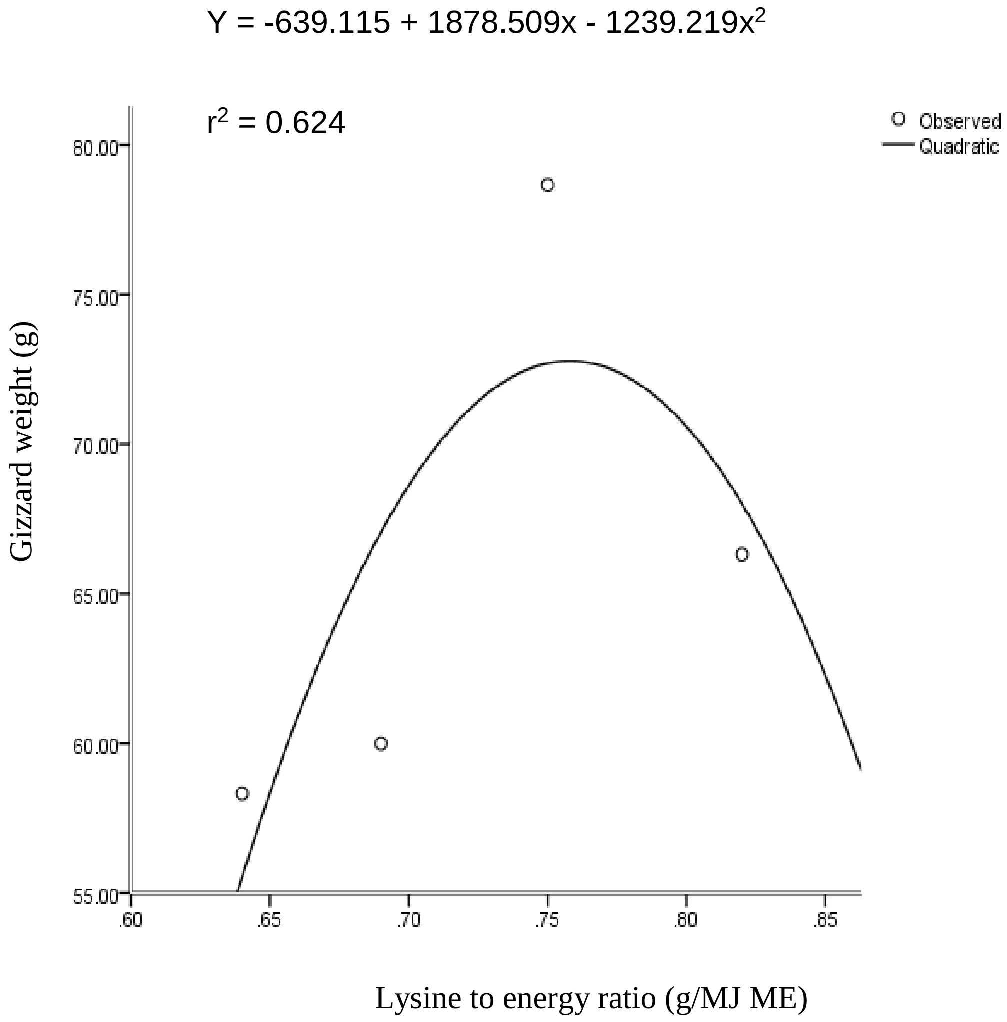


Figure 4.21 Effect of dietary lysine to energy ratio on breast meat of female Venda chickens aged 91 days



$$Y = -639.115 + 1878.509x - 1239.219x^2$$

$$r^2 = 0.624$$

Figure 4.22 Effect of dietary lysine to energy ratio on gizzard weight of female Venda chickens aged 91 days

Table 4.21 Dietary lysine to energy ratios for optimal carcass weight (carcass wt) (g), dressing percentage (%), breast meat (g) and gizzard (g) weights of female Venda chickens aged 91 days

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Carcass wt	$Y = -12116.7 + 35600.90x - 23990.29x^2$	0.826	0.742	1090.977
Dressing %	$Y = -219.387 + 816.255x - 542.267x^2$	0.715	0.753	87.783
Breast meat	$Y = -1838.85 + 5701.071x - 3909.757x^2$	0.880	0.729	239.422
Gizzard	$Y = -639.115 + 1878.509x - 1239.219x^2$	0.624	0.758	72.784

L:E ratio : Lysine to energy ratio for optimal variables

$r^{2`}$: coefficient of determination

Results of the effect of lysine to energy ratio on breast meat pH at different times, drip loss after slaughter, tenderness, juiciness and flavour of meat of female Venda chickens aged 91 days are presented in Table 4.22. Female Venda chickens offered diets having lysine to energy ratios of 0.69, 0.75 or 0.82 had similar ($P>0.05$) meat pH values at 2 hours after slaughter; their meat pH values were, however, higher than those of birds offered a diet having a lysine to energy ratio of 0.64. Chickens offered diets having lysine to energy ratios of 0.75 or 0.82 had similar ($P<0.05$) meat pH values at 12 and 24 hours after slaughtering. Chickens on diets having lysine to energy ratios of 0.69 or 0.64, also, had similar ($P>0.05$) meat pH values at 24 hours after slaughtering. However, chickens offered diets having lysine to energy ratios of 0.75 or 0.82 had higher pH values than those of birds offered diets having lysine to energy ratios of 0.69 or 0.64 at 12 and 24 hours after slaughtering.

Breast meat pH at slaughter and 30 minutes after slaughtering, and meat drip loss, tenderness, juiciness and flavour were not affected ($P>0.05$) by dietary treatments.

Breast meat pH at 2 hours, 12 hours and 24 hour after slaughter, drip loss at slaughtering were optimized at dietary lysine to energy ratios of 0.752 ($r^2 = 0.855$), 0.802 ($r^2 = 0.693$) and 0.797 ($r^2 = 0.897$), respectively (Figures 4.23 to 4.25, respectively and Table 4.23).

Table 4.22 Effect of lysine to energy ratio (g/MJ ME) on breast meat pH at different times, drip loss (%), tenderness, juiciness and flavour of meat of female Venda chickens aged 91 days without post-mortem aging

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.64	0.69	0.75	0.82	SE
pH at slaughter	5.31	5.37	5.43	5.39	0.052
pH at 30 minutes	5.28	5.33	5.42	5.38	0.021
pH at 2 hours	5.17 ^{b}	5.42 ^{a}	5.38 ^{a}	5.36 ^{a}	0.035
pH at 12 hours	4.98 ^{b}	5.04 ^{b}	5.20 ^{a}	5.10 ^{a}	0.027
pH at 24 hours	4.80 ^{b}	4.90 ^{b}	5.23 ^{a}	5.16 ^{a}	0.031
Drip loss	3.58	3.57	3.56	3.63	0.020
Tenderness	3.40	3.36	3.45	3.40	0.028
Juiciness	3.40	3.49	3.36	3.36	0.025
Flavour	4.08	4.14	3.92	4.06	0.024

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

SE : Standard error

$$Y = -5.24 + 28.364x - 18.852x^2$$

$$r^2 = 0.805$$

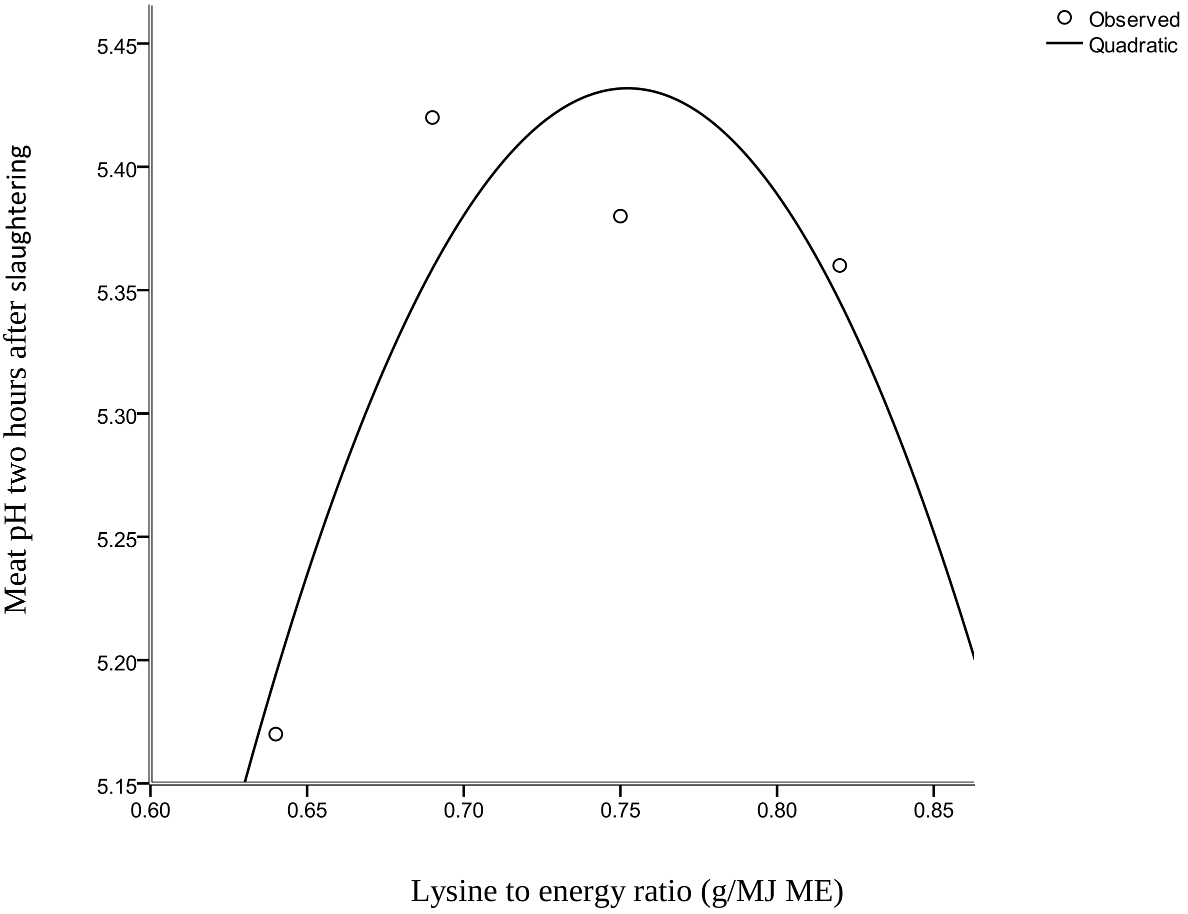


Figure 4.23 Effect of dietary lysine to energy ratio on meat pH two hours after slaughtering of female Venda chickens aged 91 days

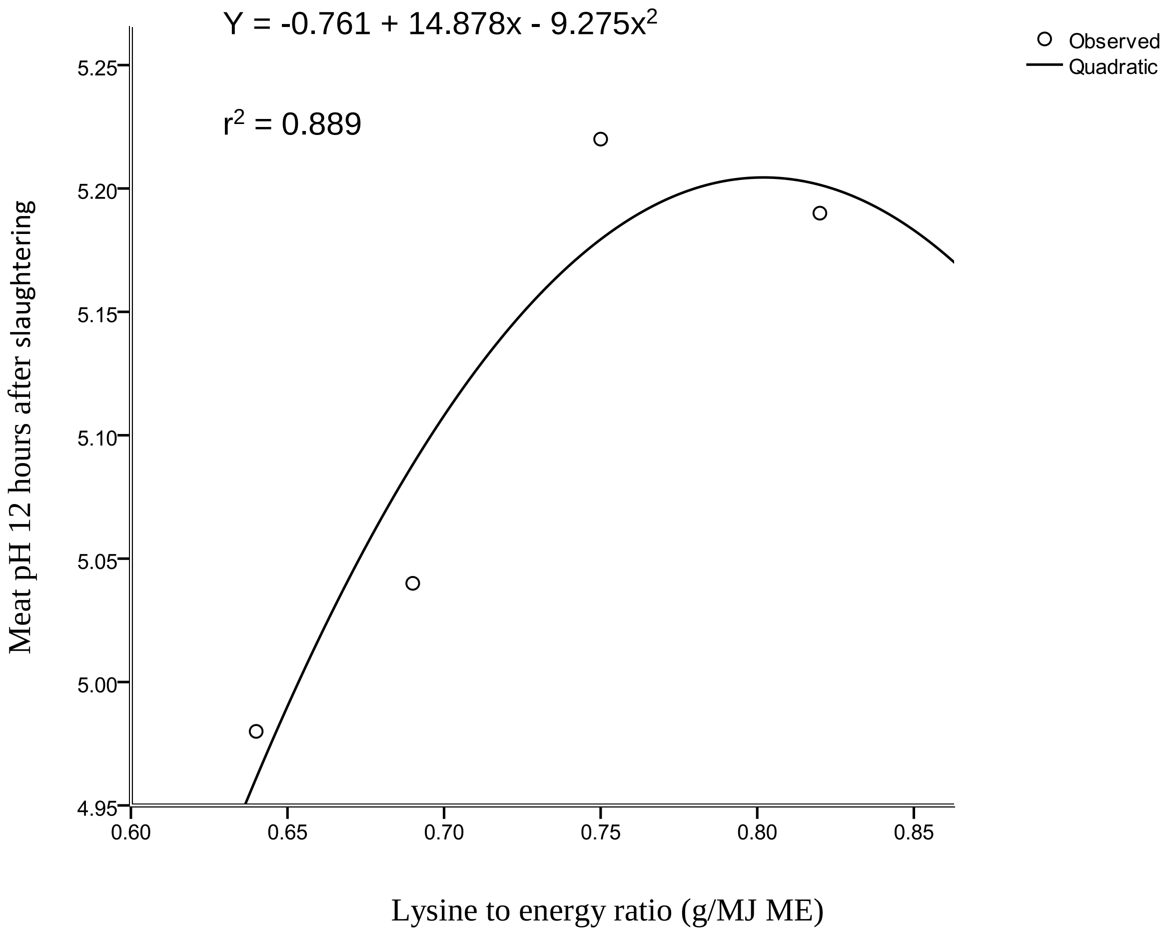


Figure 4.24 Effect of dietary lysine to energy ratio on meat pH 12 hours after slaughtering of female Venda chickens aged 91 days

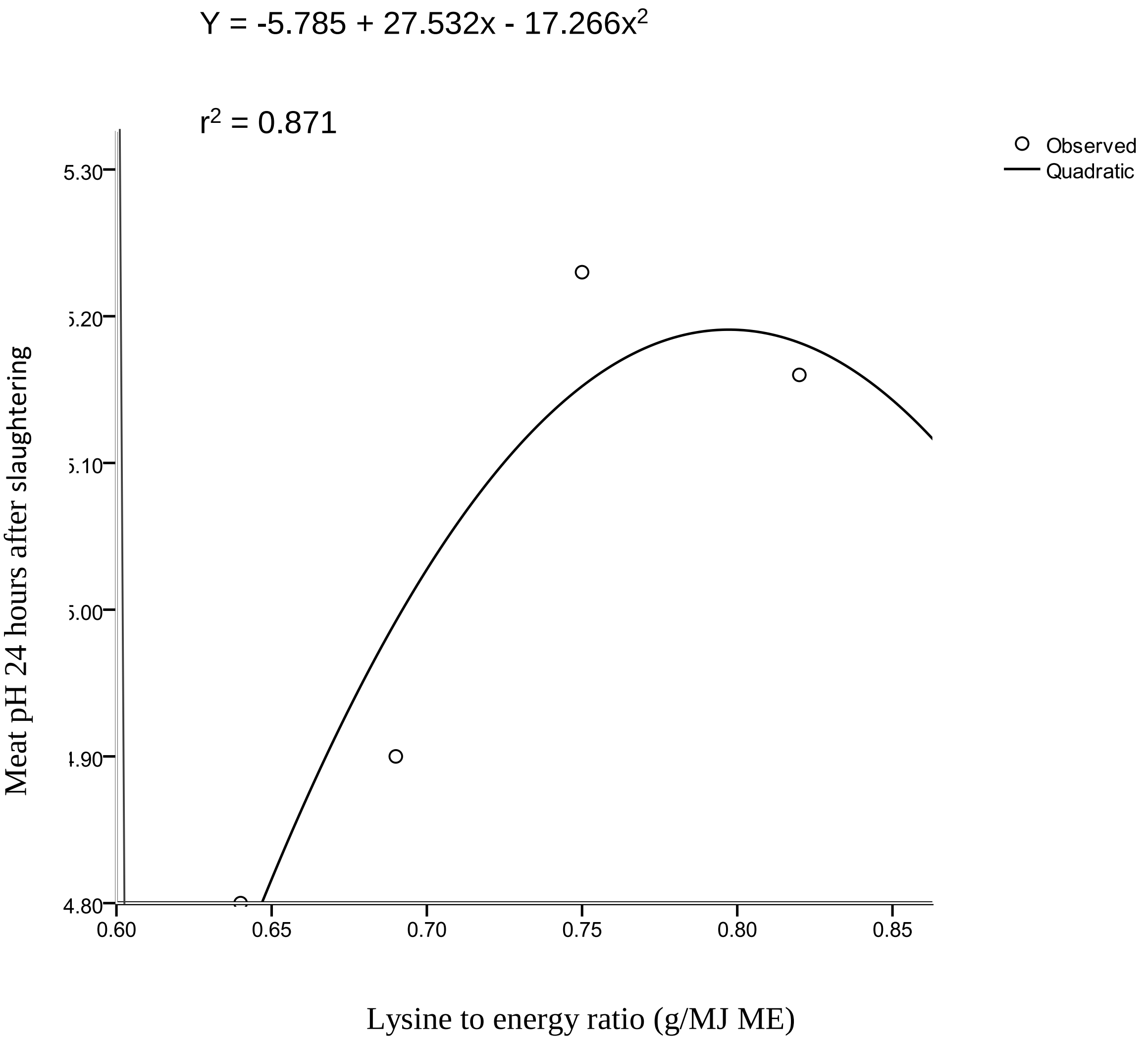


Figure 4.25 Effect of dietary lysine to energy ratio on meat pH 24 hours after slaughtering of female Venda chickens aged 91 days

Table 4.23 Dietary lysine to energy ratio for optimal breast meat pH at two, 12 and 24 hours after slaughter of meat of female Venda chickens aged 91 days

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
pH at two hours	$Y = -5.24 + 28.364x - 18.852x^2$	0.855	0.752	5.429
pH at 12 hours	$Y = -0.761 + 14.878x - 9.275x^2$	0.693	0.802	5.205
pH at 24 hours	$Y = -5.785 + 27.532x - 17.266x^2$	0.897	0.797	5.190

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Results of the effect of dietary lysine to energy ratio on haematological values of female Venda chickens aged 91 days are presented in Table 4.24. Female Venda chickens offered diets having lysine to energy ratios of 0.75 or 0.82 had similar ($P>0.05$) red blood cell (RBC) values. Similarly, Venda chickens offered diets having lysine to energy ratios of 0.82, 0.69 or 0.64 had the same ($P>0.05$) RBC values. However, chickens offered a diet having a lysine to energy ratio of 0.75 had higher ($P<0.05$) RBC values than those offered diets having lysine to energy ratios of 0.69 or 0.64. The haemoglobin (Hb) values of female Venda chickens offered diets having lysine to energy ratios of 0.75 or 0.82 were similar ($P>0.05$). Chickens offered diets having lysine to energy ratios of 0.69 or 0.64 had similar ($P>0.05$) Hb values. However, chickens offered diets having lysine to energy ratios of 0.75 or 0.82 had higher ($P<0.05$) Hb values than those on of diets having lysine to energy ratios of 0.69 or 0.64.

Dietary lysine to energy ratios had no effect ($P>0.05$) on white blood cell (WBC), pack cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) of female Venda chickens aged 91 days.

Red blood cell and haemoglobin values were optimized at dietary lysine to energy ratios of 0.748 ($r^2 = 0.700$), and 0.634 ($r^2 = 0.897$), respectively (Figures 4.26 and 4.27, respectively and Table 4.25).

Table 4.24 Effect of lysine to energy ratio (g/MJ ME) on white blood cell (WBC), red blood cell (RBC), haemoglobin (Hb), pack cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) in female Venda chickens aged 91 days

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.64	0.69	0.75	0.82	SE
WBC $(10)^3$ µL	24.14	24.66	26.17	25.23	0.199
RBC $(10)^4$ µL	2.53^b	2.55^b	2.63^a	2.56^{ab}	0.014
HB (g/dL)	9.94^b	10.11^b	10.90^a	10.72^a	0.261
PCV (%)	20.88	21.59	26.79	28.26	1.387
MCV (fl)	139.70	142.41	140.62	138.51	1.228
MCH (pg)	45.61	47.11	46.80	43.72	0.407
MCHC (g/dL)	25.33	26.77	31.22	30.63	0.694

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

SE : Standard error

$Y = -1.525 + 11.036x - 7.373x^2$

$r^2 = 0.700$

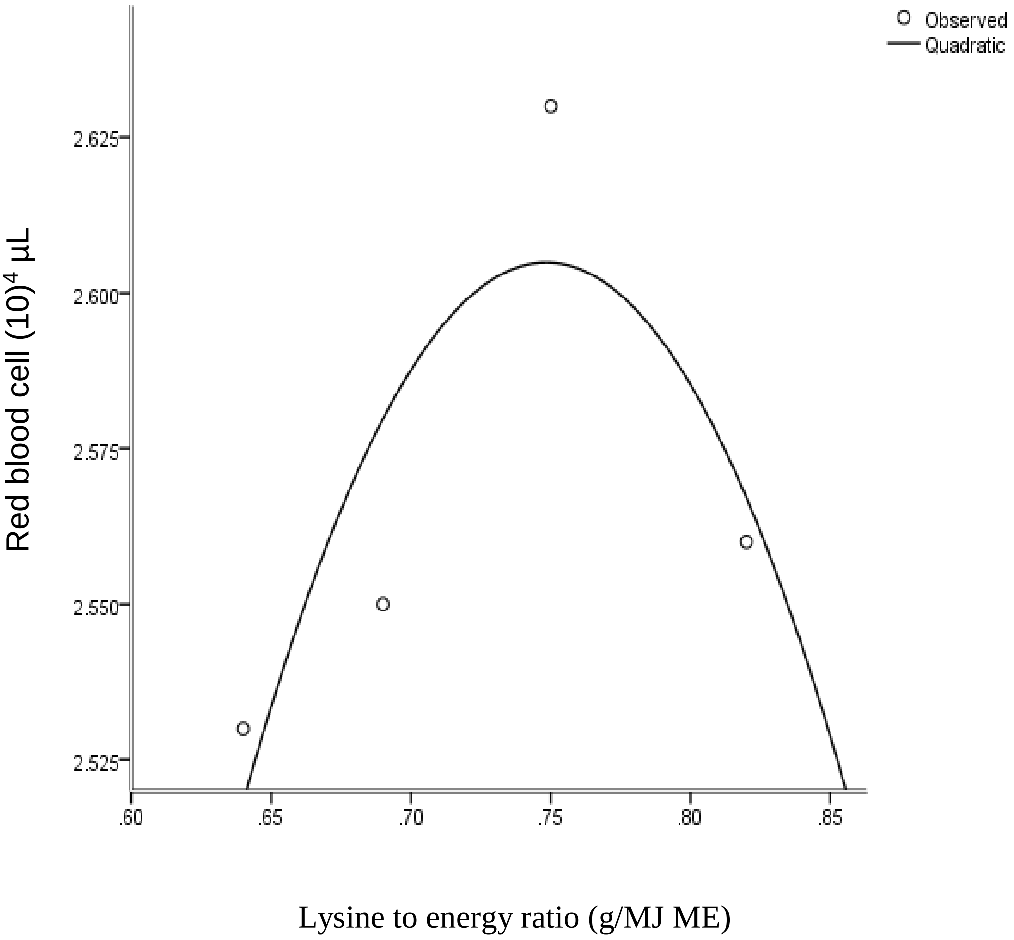


Figure 4.26 Effect of dietary lysine to energy ratio on red blood cell count of female Venda chickens aged 91 days

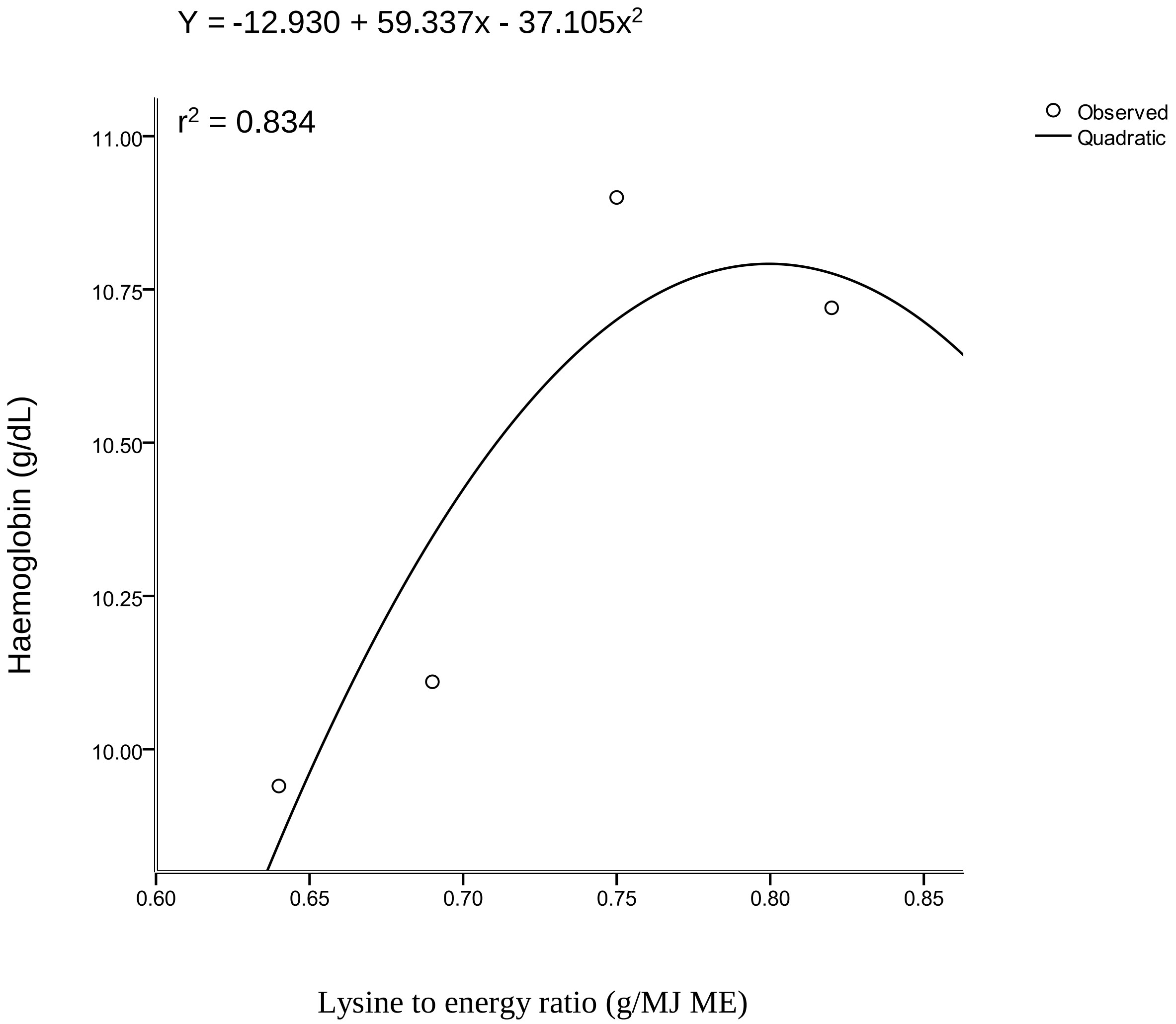


Figure 4.27 Effect of dietary lysine to energy ratio on haemoglobin amount of female Venda chickens aged 91 days

Table 4.25 Dietary lysine to energy ratios for optimal red blood cell (RBC) and haemoglobin (Hb) values in female Venda chickens aged 91 days.

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
RBC	$Y = -1.525 + 11.036x - 7.373x^2$	0.700	0.748	2.605
Hb	$Y = 33.4116 - 74.505x + 58.737x^2$	0.897	0.634	9.785

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Discussion

This experiment was designed to provide higher dietary lysine levels (9 g/kg DM) than those provided in Experiment 5. Thus, dietary lysine to energy ratios ranging from 0.64 to 0.82 (g/MJ ME) were formulated. The diets contained similar levels of other nutrients which met the chicken's requirements as recommended by the NRC (1994).

Results of Experiment 6 indicate that dietary lysine to energy ratio had significant effects on feed intake, FCR and ME intake of female Venda chickens aged eight to 13 weeks. This is in line with the results obtained by Hind *et al*. (2012) in broiler chickens. Araujo *et al*. (2005), also, reported that dietary lysine and energy levels had effect on feed intake and FCR in broiler chickens aged 44 to 55 days. Contrary to the present findings, Abdallah *et al*. (2011) found no differences in feed intake and FCR when Cobb 500 broiler chickens were fed diets differing in digestible lysine and metabolisable energy levels. Similarly, Mbajiorgu *et al*. (2011) reported that dietary lysine to energy ratio had no effect on ME intakes of male Venda chickens aged seven to 13 weeks. However, Mbajiorgu *et al*. (2011) reported better FCR for diets with higher lysine to energy ratios. The quadratic analysis of the data showed that dietary lysine to energy ratio of 0.798 optimized feed intake in the present study. This is lower than the ratio of 1.07 reported by Hind *et al.* (2012) for broiler chickens aged six weeks. The ratio of 0.798 for feed intake observed in the present study was higher than those of 0.74 for broiler chickens (Araujo, 2005) and 0.71 for male Venda chickens aged seven to 13 weeks (Mbajiorgu *et al*., 2011). The present results indicate that dietary lysine to energy ratio of 0.613 optimized FCR for female Venda chickens. This implies that a lower dietary lysine to energy ratio is required for optimal FCR when compared with that of feed intake in female Venda chickens aged eight to 13 weeks. Hind *et al*. (2012) observed similar results. However, the dietary lysine to energy ratio of 1.04 for optimal FCR in broiler chickens reported by these authors is higher than those obtained in the present study. This is understandable because broiler chickens require higher lysine for their fast growth (NRC, 1994).

The ME intakes of female Venda chickens increased as the dietary lysine to energy ratio increased. Mbajiorgu *et al.* (2011) reported a similar trend in male Venda chickens aged seven to 13 weeks. However, the lysine to energy ratio of 0.750 for optimal ME intake observed in the present study is higher than the ratio of 0.61 reported by Mbajiorgu *et al.* (2011) for male Venda chickens. The difference may be due to differences in the sex of the chickens used (NRC, 1994). Araujo *et al*. (2005) reported a lower dietary lysine to energy ratio of 0.71 for optimal ME intake of broiler chickens than the 0.75 reported for female Venda chickens in the present study. This might be due to breed differences and diets used (Shahin and Elazeem, 2005). This indicates that different production parameters were optimized at different dietary lysine to energy ratios. This is in line with the results of Labadan *et al.* (2001), Araujo *et al*. (2005) and Hind *et al.* (2012) in broiler chickens. Similar conclusions were reported by Mbajiorgu *et al*. (2011) in male Venda chickens aged seven to 13 weeks.

The growth rate, live weight, nitrogen retention and mortality of female Venda chickens in the present study were not influenced by dietary lysine to energy ratio. This is in line with the results obtained by Hind *et al*. (2012) in Ross broiler chickens aged one to six weeks. Similarly, Mbajiorgu *et al*. (2011) reported that dietary lysine to energy ratio had no influence on the live weight of male Venda chickens aged seven to 13 weeks. However, Araujo *et al.* (2005) reported that dietary lysine to energy ratio had significant effects on weight gain of broiler chickens aged 44 to 55 days.

It is concluded that dietary lysine to energy ratio influenced feed intake, FCR and ME intakes but not growth rate, nitrogen retention and live weight of female Venda chickens aged eight to 13 weeks. Dietary lysine to energy ratios of 0.798, 0.613 and 0.750 optimized feed intake, FCR and ME intake of female Venda chickens aged eight to 13 weeks, respectively.

The present study showed that carcass weight, dressing percentage, breast meat and gizzard weights were influenced by dietary lysine to energy ratio. Araujo *et al*. (2005) reported that carcass weight, dressing percentage, breast meat weight and leg weight of broiler chickens aged 44 to 55 days were influenced by dietary lysine to energy ratio. Mbajiorgu *et al*. (2011), also, observed that dietary lysine to energy ratio had effect on breast meat yield of male Venda chickens aged 91 days. However, Mbajiorgu *et al.* (2011) observed that dietary lysine to energy ratio had no effect on carcass weight, dressing percentage and gizzard weight of male Venda chickens aged 91 days.

A dietary lysine to energy ratio of 0.742 optimized carcass weights of female Venda chickens aged 91 days. This ratio is lower than the ratios of 0.84 for broiler chickens (Araujo *et al*., 2005) and 1.36 for male Venda chickens aged 91 days (Mbajiorgu *et al*. 2011) These differences can be attributed to breeds (broiler versus indigenous) and sex (male versus female) of the chickens used. Quadratic analysis of the present study showed that a dietary lysine to energy ratio of 0.753 optimized dressing percentage of female Venda chickens aged 91 days. A dietary lysine to energy ratio of 0.753 for optimal dressing percentage observed in this study is higher than the ratio of 0.70 reported by Tang *et al*. (2007) but lower than the 1.11 reported by Araujo *et al*. (2005) for broiler chickens. A dietary lysine to energy ratio of 0.729 optimized breast meat yield of female Venda chickens in the present study. This ratio is similar to that reported by Kerr *et al*. (1999) for male broiler chickens aged 48 days. However, the ratio of 0.729 for optimal breast meat yield in the present study is lower than the 0.74 reported by Labadan *et al*. (2001) for broiler chickens aged six weeks. Gizzard weights in the present study were optimized at a dietary lysine to energy ratio of 0.758. No study was found on the optimal lysine to energy ratio for gizzard weight.

Dietary lysine to energy ratio did not have any significant effect on breast meat pH at slaughter and 30 minutes after slaughter of female Venda chickens aged 91 days. However, dietary lysine to energy ratio had an effect on breast meat pH values at 2, 12 and 24 hours after slaughter of the chickens. Breast meat pH at 2, 12 and 24 hours after slaughter increased until they were optimized at dietary lysine to energy ratios of 0.768, 0.592 and 0.688, respectively. Thereafter, additional increase in dietary lysine to energy ratio led to a decrease in meat pH values. Meat pH is determined by muscle glycogen content and its degradation rate (Battula *et al.,* 2008). However, it is not clear how dietary lysine to energy ratio affects the metabolism of glycogen in the muscles. Tang *et al*. (2007) reported that dietary lysine to energy concentration had no effect on breast meat pH values 45 minutes and 24 hours after slaughter of broiler chickens aged six weeks. Similarly, Apple *et al*. (2004) found that dietary lysine to energy ratio had no effect on the pH values of pig meat. Dietary lysine to energy ratio had no effect on meat drip loss, tenderness and flavour of female Venda chickens aged 91 days. However, Tang *et al*. (2007) observed that an increase in dietary lysine content significantly decreased water-holding capacity in the breast meat muscles of broiler chickens.

All the haematological values observed in the present study were within the ranges for indigenous chickens (Elagib and Ahmed, 2011) possibly indicating that dietary lysine to energy ratio had no negative effects on haematological parameters and or health of the chickens. No study was found on the effect of dietary lysine to energy ratio on white blood cell, pack cell volume, mean corpuscular volume, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration in female Venda chickens. Red blood cell and haemoglobin values were optimized at dietary lysine to energy ratios of 0.748 and 0.634, respectively.

4.3.3 Experiment 7

Results

The diets used in Experiment 7 are similar to those used in Experiment 3. Thus, results of the nutrient composition of the diets used in Experiment 7 are the same as those presented in Table 3.15 (Experiment 3). The diets had a similar lysine content of 11 g/kg DM but different energy levels. The energy levels were 11, 12, 13 and 14 MJ ME/kg DM (determined in the laboratory using NIRA), thus forming lysine to energy (L:E) ratios of 1.00 ($FL_{11}E_{11}$), 0.92 ($FL_{11}E_{12}$), 0.85 ($FL_{11}E_{13}$) and 0.79 ($FL_{11}E_{14}$), respectively.

Results of the effect of dietary lysine to energy ratio on feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen (N) retention and mortality of female Venda chickens aged eight to thirteen weeks are presented in

Table 4.26. Dietary lysine to energy ratio had no effect (P>0.05) on all parameters measured except on feed intake and apparent metabolisable energy values. Female chickens offered diets having lysine to energy ratios of 0.92 or 1.00 had higher (P<0.05) feed intakes than those offered diets having lysine to energy ratios of 0.79 or 0.85. However, female Venda chickens offered diets having lysine to energy ratios of 0.92 or 1.00 had similar (P>0.05) feed intakes. Chickens offered diets having lysine to energy ratios of 0.79 or 0.85, also, had similar (P>0.05) feed intakes. Female Venda chickens offered a diet having a lysine to energy ratio of 0.85 had a higher (P<0.05) ME value than those of chickens offered diets having lysine to energy ratios of 0.79 or 1.00. Similarly, chickens offered a diet containing a lysine to energy ratio of 1.00 had a higher (P<0.05) ME value than those offered a diet having lysine to energy ratio of 0.79. However, female Venda chickens offered diets having lysine to energy ratios of 0.85 or 0.92 had similar (P>0.05) ME values. Venda chickens offered diets having lysine to energy ratios of 0.92 or 1.00 had the same (P>0.05) ME values.

Feed intake and apparent metabolisable energy in female Venda chickens were optimized at dietary lysine to energy ratios of 0.964 ($r^2 = 0.972$) and 0.743 ($r^2 = 0.765$), respectively (Figures 4.38 and 4.39, respectively and Table 4.18).

Results of the effect of lysine to energy ratio on carcass characteristics of female Venda chickens aged 91 days are presented in Table 4.28. Female Venda chickens offered a diet having a lysine to energy ratio of 0.85 had a higher (P<0.05) carcass weight than those on diets having 0.79 or 1.00 lysine to energy ratios. Similarly, chickens offered a diet having a lysine to energy ratio of 0.92 had a higher (P<0.05) carcass weight than those on a diet having 0.79 lysine to energy ratio. Female Venda chickens offered diets having lysine to energy ratios of 0.85 or 0.92 had similar (P>0.05) carcass weights. Similarly, chickens offered diets having lysine to energy ratios of 0.92 or 1.00 had the same (P>0.05) carcass weights. Chickens offered diets having lysine to energy ratios of 0.79 or 1.00 had similar (P>0.05) carcass weights.

Table 4.26 Effect of dietary lysine to energy ratio (g/MJ ME) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g feed/g live weigh gain), live weight (g/bird aged 91 days), apparent metabolisable energy (MJ /kg DM), nitrogen retention (g/bird/day) and mortality (%) of female Venda chickens aged eight to thirteen weeks

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.79	0.85	0.92	1.00	SE
Feed intake	64.72 ^{c}	68.83 ^{b}	73.55 ^{a}	72.36 ^{a}	2.459
Growth rate	12.0	13.3	13.0	12.2	0.50
FCR	5.53	5.19	5.81	5.95	0.288
Live weight	997.3	1091.9	1036.9	993.1	23.95
ME	9.09 ^{c}	10.66 ^{a}	10.32 ^{ab}	9.77 ^{b}	0.221
N-retention	2.03	2.04	2.05	2.05	0.003
Mortality	0.02	0.02	0.02	0.03	0.001

^{a,b,c,d}	:Means in the row not sharing a common superscript are significantly different (P<0.05)
ME	:Metabolisable energy
N-retention	:Nitrogen retention
SE	: Standard error

Breast meat weights of chickens offered a diet having a lysine to energy ratio of 0.85 were higher (P<0.05) than those of chickens offered diets having lysine to energy ratios of 0.79, 0.92 or 1.00. However, chickens offered diets containing 0.79, 0.92 or 1.00 lysine to energy ratios had similar (P>0.05) breast meat weights. Female Venda chickens offered diets having lysine to energy ratios of 0.85 or 0.92 had similar (P>0.05) drumstick weights. However, drumstick weights of chickens on diets having lysine to energy ratios of 0.85 or 0.92 were higher (P<0.05) than those of chickens on diets having 0.79 or 1.00 lysine to energy ratios. Similarly, chickens offered a diet having a lysine to energy ratio of 1.00 had a higher (P<0.05) drumstick weight than those on a diet having a lysine to energy ratio of 0.79.

Dietary lysine to energy ratio had no effect (P>0.05) on dressing percentage, thigh, wing, fat pad, gizzard, liver and heart weights of female Venda chickens aged 91 days.

Carcass weight, breast meat and drumstick weights were optimized at dietary lysine to energy ratios of 0.900 (r^2 = 0.910), 0.890 (r^2 = 0.485) and 0.910, respectively (Figures 4.40 to 4.41, respectively and Table 4.29).

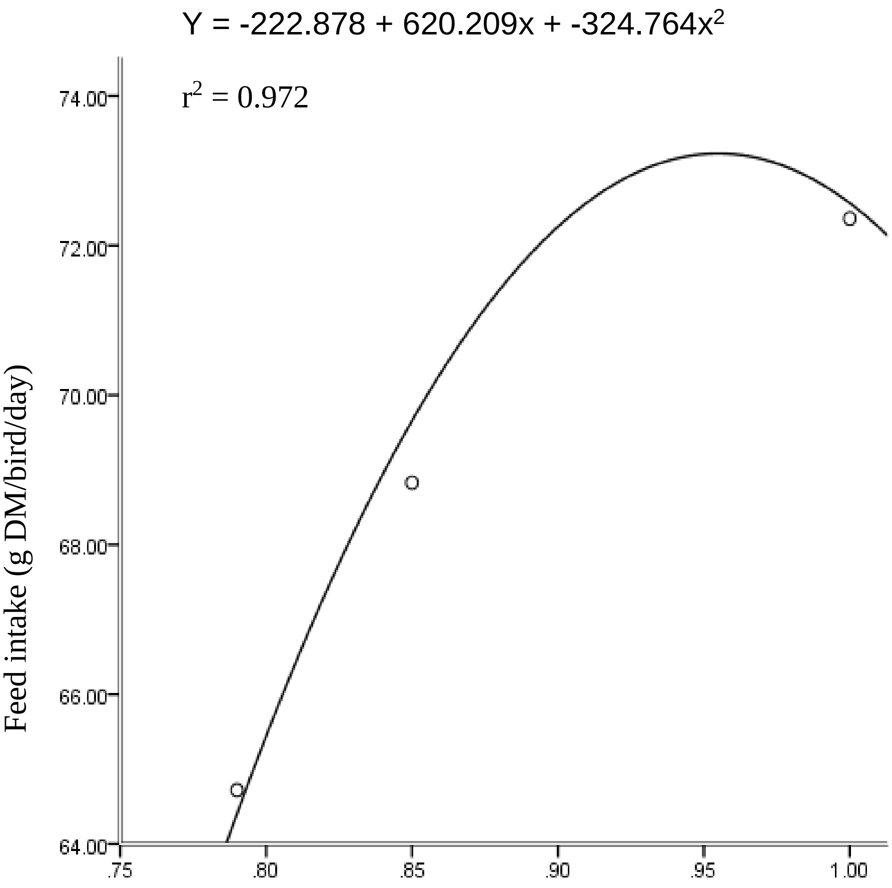


Figure 4.28 Effect of dietary lysine to energy ratio on feed intake of female Venda chickens aged eight to 13

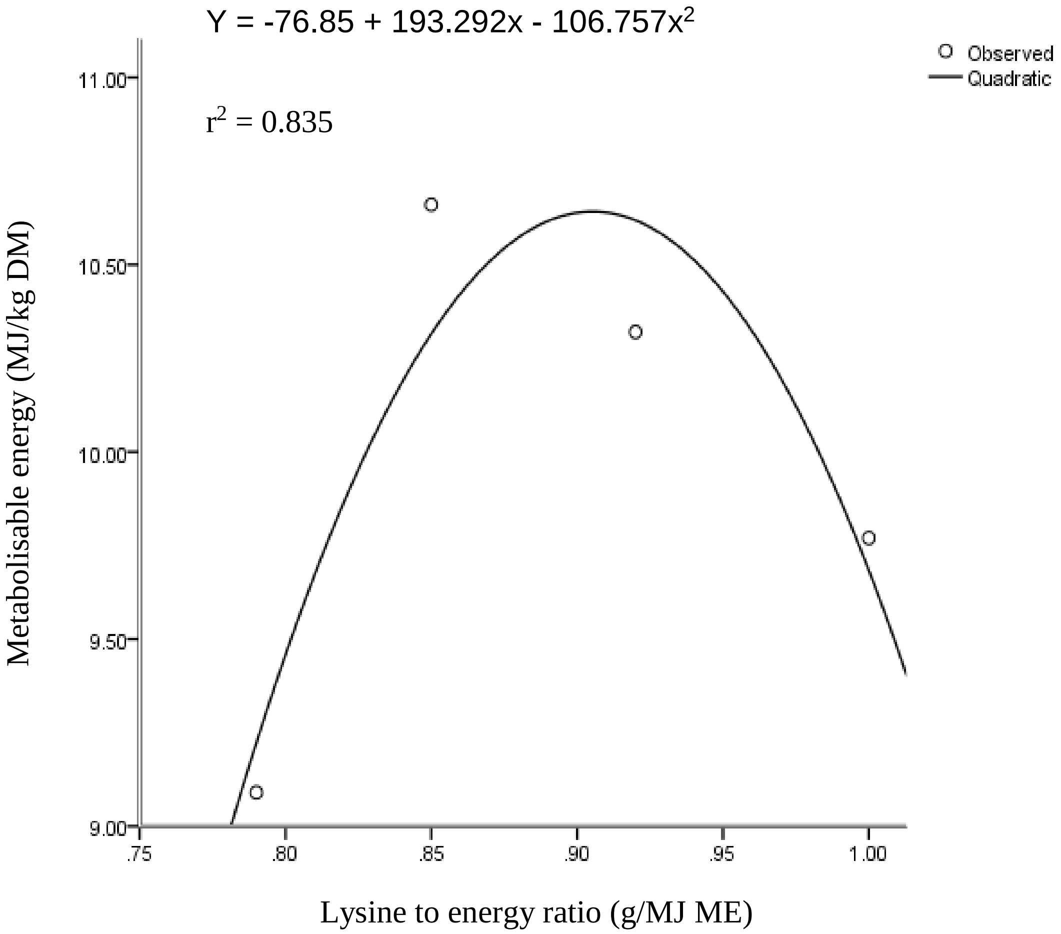


Figure 4.29 Effect of dietary lysine to energy ratio on apparent metabolisable energy of female Venda chickens aged 13 weeks

Table 4.27 Dietary lysine to energy ratios for optimal feed intake (g/bird/day) and metabolisable energy (ME) (MJ/kg DM) of female Venda chickens aged eight to thirteen weeks

Trait	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Feed intake	$Y = -222.878 + 620.209x - 324.764x^2$	0.972	0.964	73.229
ME	$Y = -76.85 + 193.292x - 106.757x^2$	0.835	0.912	10.643
N-retention	$Y = 1.451 + 1.233x - 0.634x^2$	0.990	0.970	2.050

L:E ratio : Lysine to energy ratio for optimal variables

$r^{2`}$: coefficient of determination

Table 4.28 Effect of lysine to energy ratio (g/MJ ME) on carcass characteristics (g) of female indigenous Venda chickens aged 91 days

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.79	0.85	0.92	1.00	SE
Carcass weight	778.1^{c}	1048.7^{a}	1005.7^{ab}	853.4^{bc}	33.914
Dressing %	84.64	89.86	90.85	87.90	1.489
Breast meat weight	119.17^{b}	133.32^{a}	123.00^{b}	120.48^{b}	1.952
Drumstick weight	98.55^{c}	117.66^{a}	116.71^{a}	107.95^{b}	2.373
Thigh weight	108.01	125.23	120.94	115.00	1.947
Wing weight	106.30	112.10	110.13	100.27	2.697
Fat pad weight	2.71	2.69	2.70	2.64	0.028
Gizzard	55.88	56.38	53.39	46.50	1.162
Liver weight	21.07	22.14	23.34	19.12	0.434
Heart weight	5.51	5.83	5.41	5.17	0.182

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

SE : Standard error

$Y = -16249.627 + 38452.274x - 21360.999x^2$

$r^2 = 0.910$

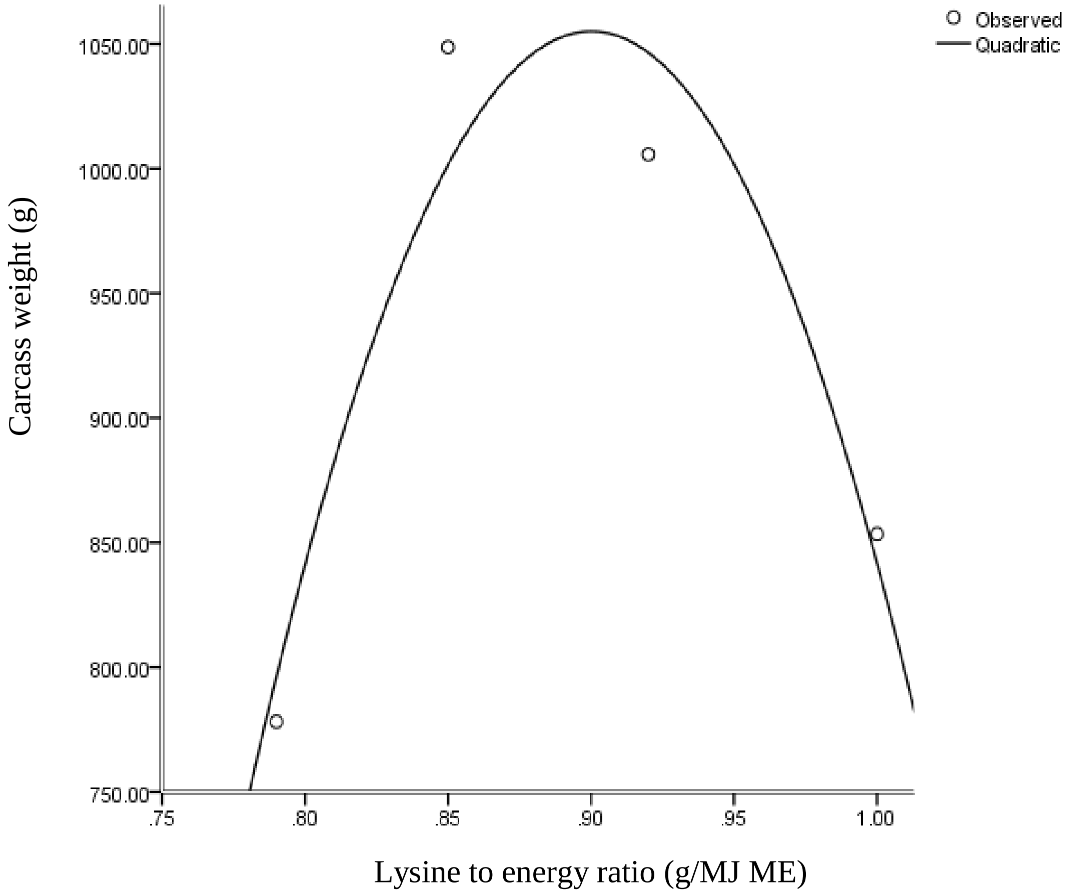


Figure 4.30 Effect of dietary lysine to energy ratio on carcass weight of female Venda chickens aged 91 days

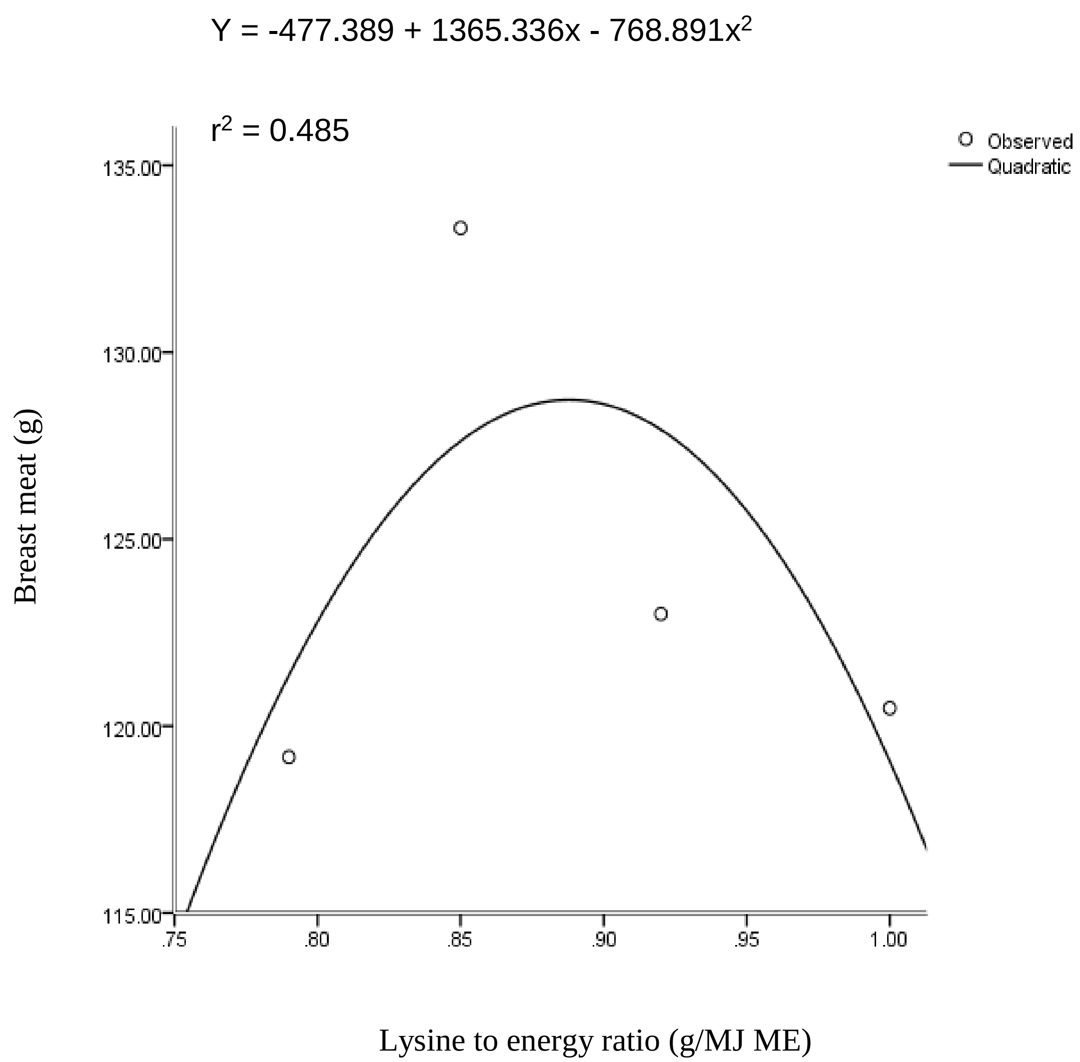


Figure 4.31 Effect of dietary lysine to energy ratio on DM dressing percentage of female Venda chickens aged 91 days

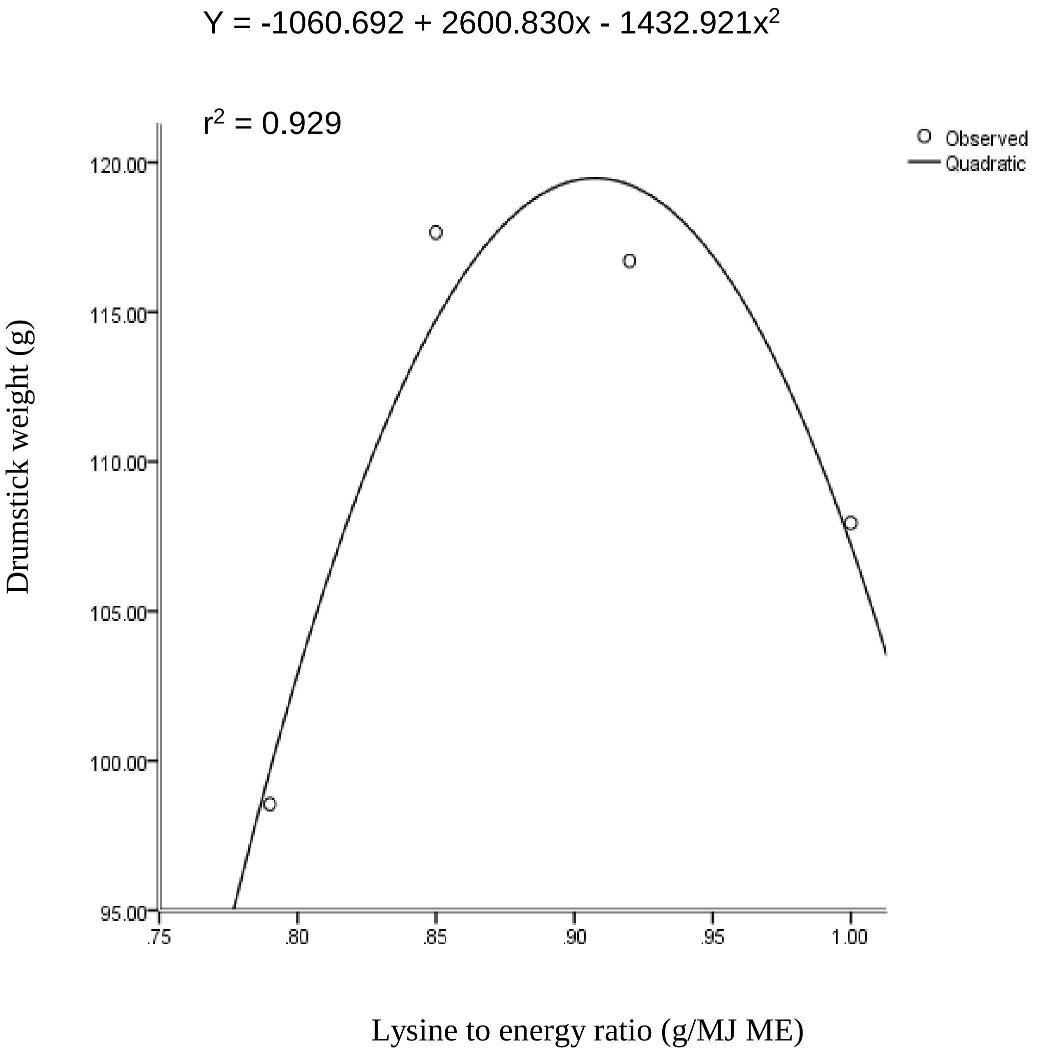


Figure 4.32 Effect of dietary lysine to energy ratio on drumstick weight of female Venda chickens aged 91 days

Table 4.29 Dietary lysine to energy ratios for optimal carcass weight (carcass wt) (g), breast meat (g) and drumstick (g) weights in female Venda chickens aged 91 days

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Carcass wt	$Y= -16249.64+38452.27x -21360.999x^2$	0.910	0.900	1055.010
Breast meat	$Y = -477.389 + 1365.336x - 768.891x^2$	0.485	0.890	128.725
Drumstick	$Y = -1060.69 + 2600.830x - 1432.921x^2$	0.929	0.910	119.470

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

The effects of lysine to energy ratio on breast meat pH at different times after slaughter, drip loss after slaughter, tenderness, juiciness and flavour of meat of female Venda chickens aged 91 days are presented in Table 4.30. Dietary lysine to energy ratio had no effect ($P>0.05$) on the pH of breast meat at different times after slaughter and meat tenderness.

Drip losses of meat of female Venda chickens offered diets having lysine to energy ratios of 0.85, 0.92 or 1.00 were similar ($P>0.05$). Similarly, chickens offered diets having lysine to energy ratios of 0.79, 0.85 or 0.92 had the same ($P>0.05$) meat drip loss percentages. However, chickens offered a diet containing a lysine to energy ratio of 1.00 had a higher ($P<0.05$) meat drip loss than those of meat from chicken son a diet having a lysine to energy ratio of 0.79.

Female Venda chickens offered a diet containing a lysine to energy ratio of 0.92 produced breast meat with higher ($P<0.05$) juiciness values than those of chickens on diets having lysine to energy ratios of 0.79, 0.82 or 1.00. Chickens on diets having lysine to energy ratios of 0.82 or 1.00 produced breast meat with similar ($P>0.05$) juiciness values; however, their values were higher ($P<0.05$) than those of meat from chickens offered a diet containing a lysine to energy ratio of 0.79. Flavour of the meat from chickens on diets having lysine to energy ratios of 0.85 or 1.00 were similar ($P>0.05$). Similarly, chickens on diets having lysine to energy ratios of 0.79 or 0.92 produced breast meat with the same ($P>0.05$) tenderness values. However, chickens on diets containing lysine to energy ratios of 0.85 or 1.00 produced breast meat with better (P<0.05) flavour values than the meat from chickens offered diets having lysine to energy ratios of 0.79 or 092.

Meat drip loss at slaughtering and breast meat juiciness and flavour were optimized at dietary lysine to energy ratios of 1.090 ($r^2 = 0.489$), 0.934 ($r^2 = 0.893$) and 0.895 ($r^2 = 0.742$), respectively (Figures 4.43 to 4.45, respectively and Table 4.31) .

Results of the effect of dietary lysine to energy ratio on haematological values of female indigenous Venda chickens aged 91 days are presented in Table 4.32. Female Venda chickens offered diets having lysine to energy ratios of 0.85, 0.92 or 1.00 had similar (P>0.05) WBC values; their values were, however, higher (P<0.05) than those of chickens on a diet having a lysine to energy ratio of 0.79. Chickens offered diets having lysine to energy ratios of 0.92 or 1.00 had similar (P>0.05) Haemoglobin (Hb) values. Similarly, chickens offered diets having lysine to energy ratios of 0.79 or 0.85 had the same (P>0.05) Hb values. However, chickens offered diets having lysine to energy ratios of 0.92 or 1.00 had higher (P<0.05) Hb values than those of birds offered diets having lysine to energy ratios of 0.85 or 0.79.

Table 4.30 Effect of lysine to energy ratio (g/MJ ME) on breast meat pH at different times, drip loss (%), tenderness, juiciness and flavour of meat of female Venda chickens aged 91 days

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.79	0.85	0.92	1.00	SE
pH at slaughtering	5.56	5.59	5.58	5.57	0.092
pH at 30 minutes	5.52	5.56	5.55	5.54	0.112
pH at 2 hours	5.50	5.52	5.52	5.50	0.022
pH at 12 hours	5.57	5.48	5.61	5.42	0.030
pH at 24 hours	5.54	5.59	5.52	5.64	0.355
Drip loss	3.53^{b}	3.65^{ab}	3.58^{ab}	3.67^{a}	0.026
Tenderness	3.31	3.33	3.42	3.41	0.023
Juiciness	3.39^{c}	3.48^{b}	3.63^{a}	3.54^{b}	0.025
Flavour	3.76^{b}	4.09^{a}	3.95^{b}	4.10^{a}	0.045

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

SE : Standard error

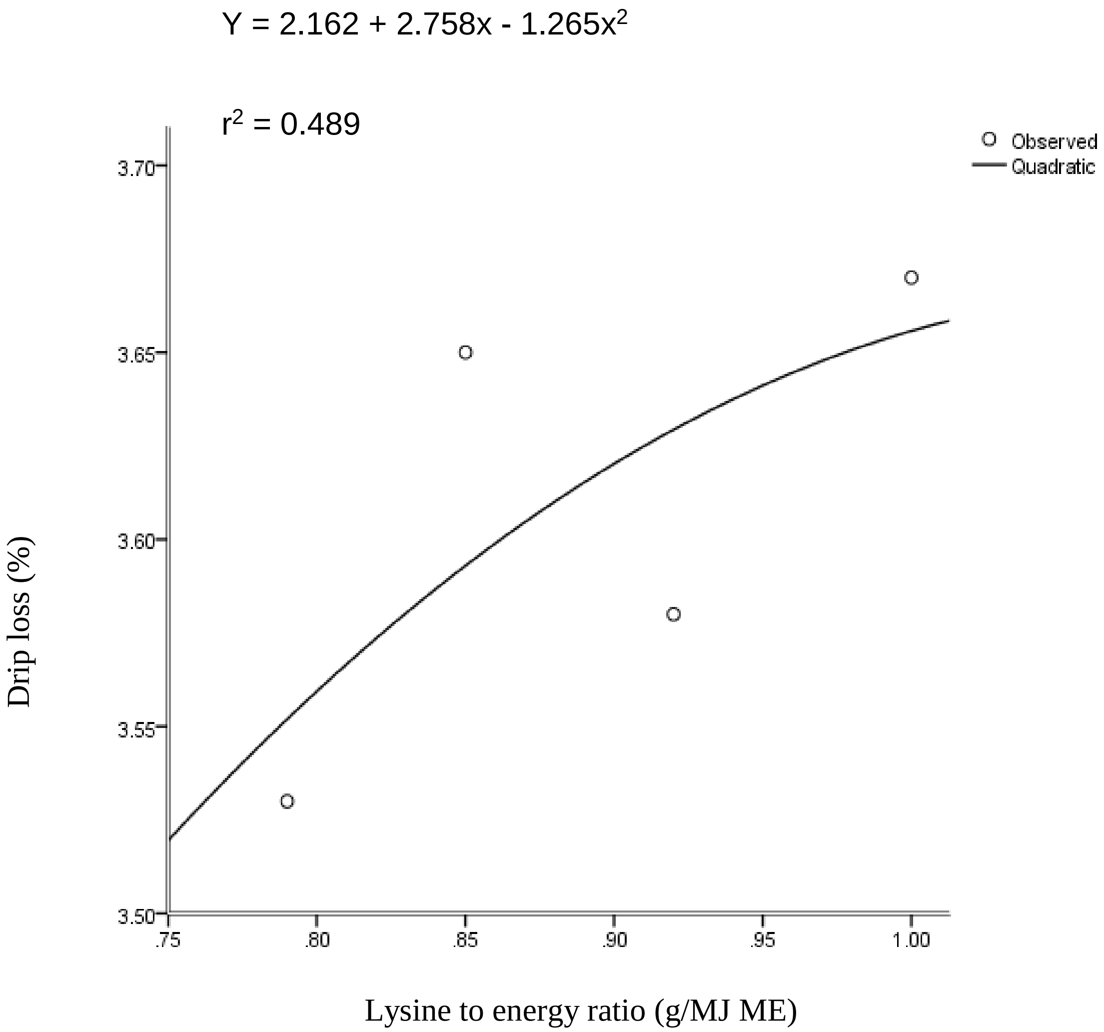


Figure 4.33 Effect of dietary lysine to energy ratio on drip loss in meat of female Venda chickens aged 91 days

$Y = -5.749 + 20.009x - 10.710x^2$

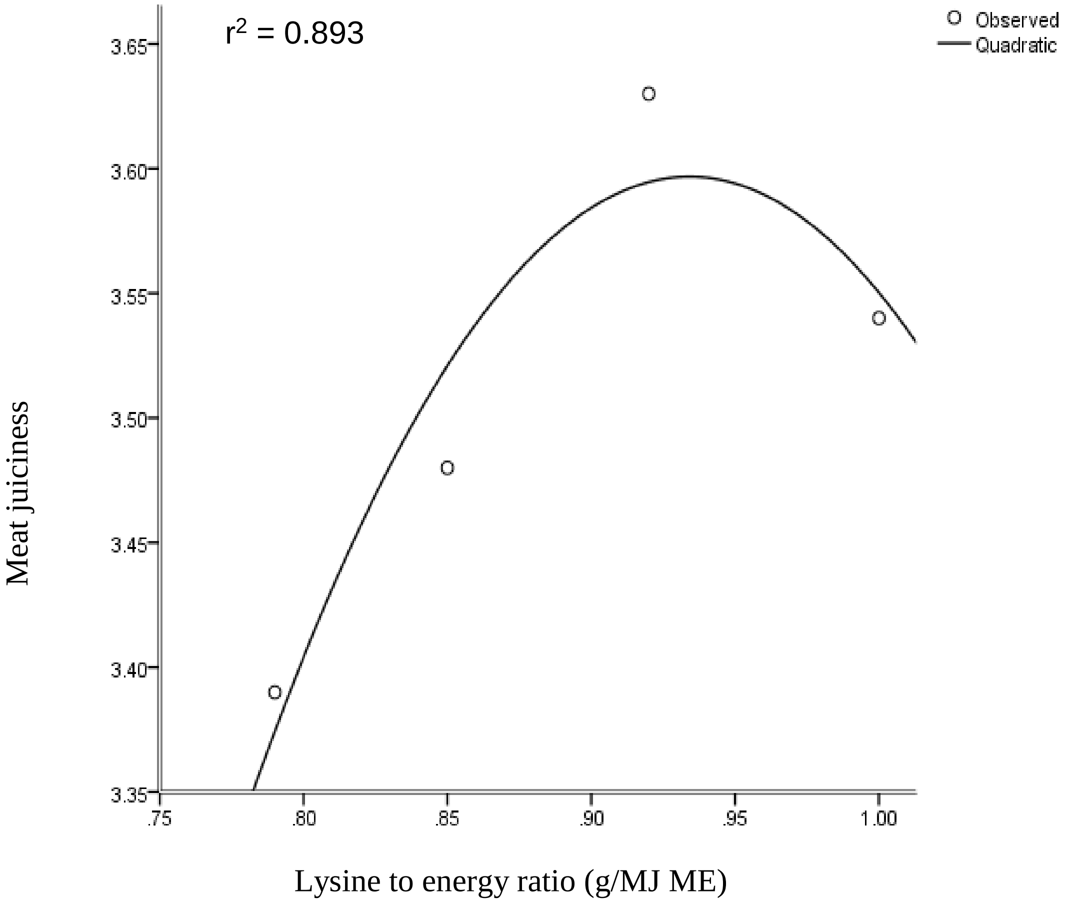


Figure 4.34 Effect of dietary lysine to energy ratio on meat juiciness of female Venda chickens aged 91 days

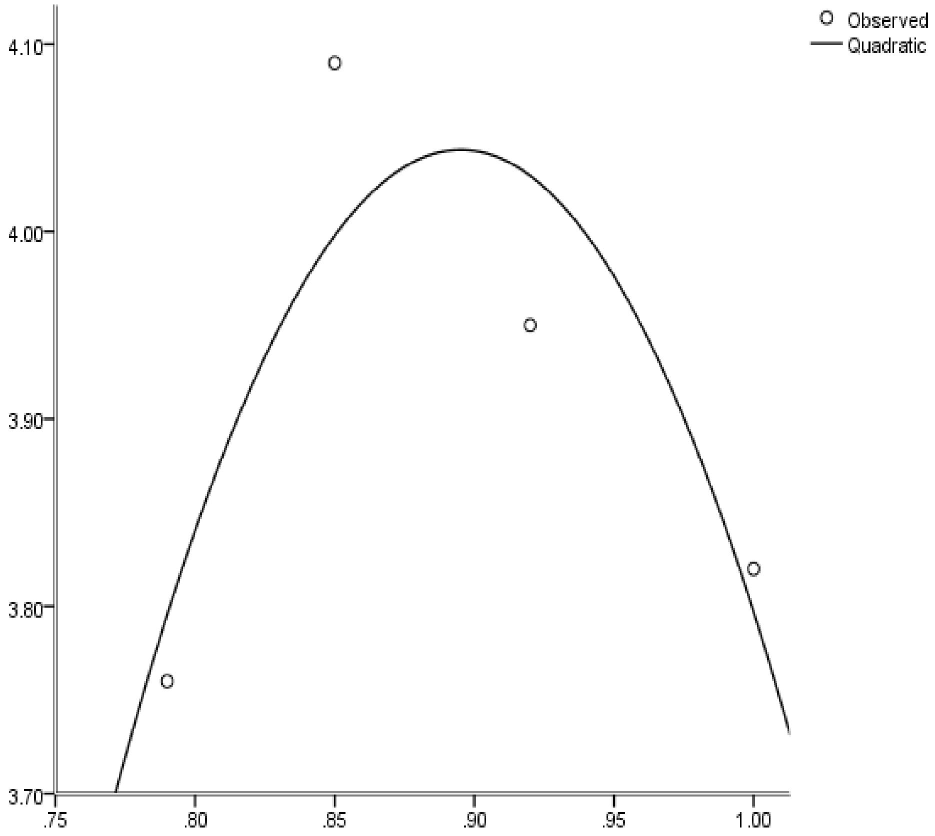


Figure 4.35 Effect of dietary lysine to energy ratio on meat flavour of female Venda chickens aged 91 days

Table 4.31 Dietary lysine to energy ratios for optimal drip loss after slaughtering (%), juiciness and flavour of meat of female Venda chickens aged 91 days

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Drip loss	$Y = 2.162 + 2.758x + -1.265x^2$	0.489	1.090	3.665
Juiciness	$Y = -5.749 + 20.009x + -10.710x^2$	0.893	0.934	3.596
Flavour	$Y = -13.938 + 40.174x + -22.440x^2$	0.742	0.895	4.043

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Dietary lysine to energy ratio had no effect ($P>0.05$) on red blood cell (RBC), pack cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) values of female Venda chickens aged 91 days (Table 4.32).

White blood cell and haemoglobin values were optimized at dietary lysine to energy ratios of 0.927 ($r^2 = 0.959$) and 0.996 ($r^2 = 0.957$), respectively (Figures 4.46 and 4.47, respectively and Table 4.33).

Table 4.32 Effect of lysine to energy ratio (g/MJ ME) on white blood cell (WBC), red blood cell (RBC), haemoglobin (Hb), pack cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) in female Venda chickens aged 91 days.

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.79	0.85	0.92	1.00	SE
WBC $(10)^3$ µL	23.26^b	25.36^a	25.64^a	25.23^a	0.246
RBC $(10)^4$ µL	2.44	2.46	2.62	2.48	0.022
Hb (g/dL)	11.76^b	11.95^b	12.10^a	12.08^a	0.144
PCV (%)	32.48	33.45	34.48	35.56	0.639
MCV (fl)	142.45	144.06	143.00	135.05	1.309
MCH (pg)	45.48	47.05	46.47	43.67	0.551
MCHC (g/dL)	25.49	27.27	28.97	29.87	0.784

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

SE : Standard error

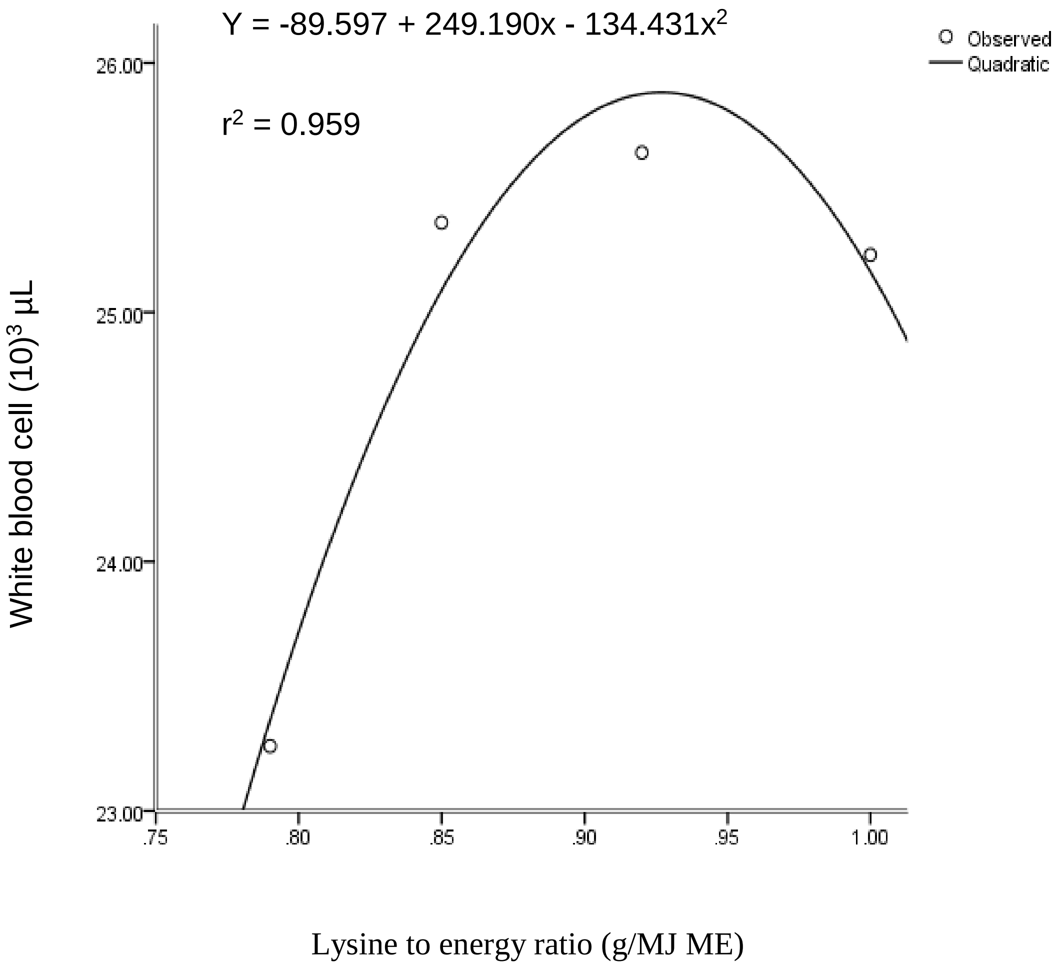


Figure 4.36 Effect of dietary lysine to energy ratio on white blood cell count of female Venda chickens aged 91 days

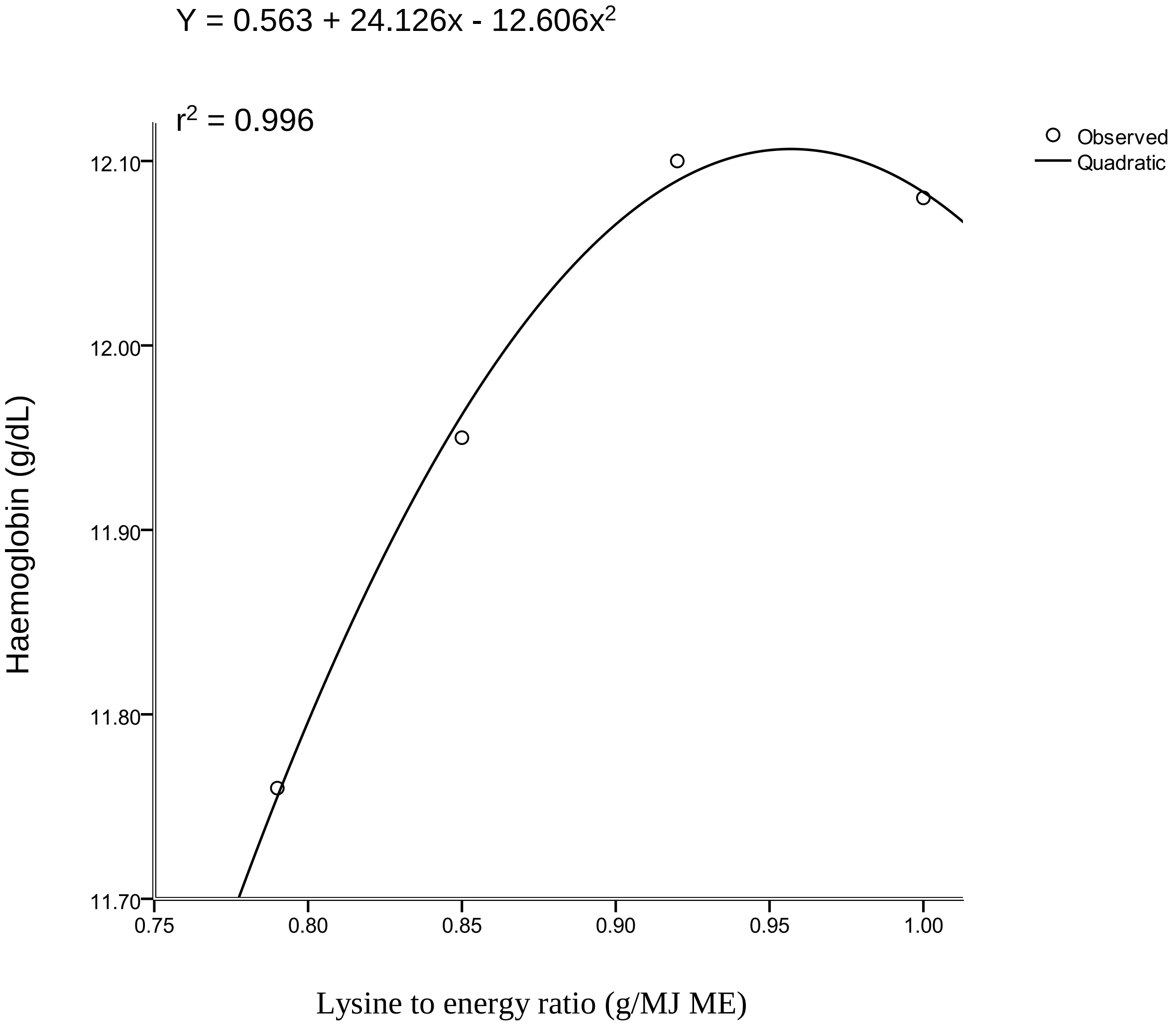


Figure 4.37 Effect of dietary lysine to energy ratio on haemoglobin amount of female Venda chickens aged 91 days

Table 4.33 Dietary lysine to energy ratios for optimal on white blood cell (WBC) and haemoglobin (Hb) values) in female Venda chickens aged 91 days.

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
WBC	$Y = -89.597 + 249.190x - 134.431x^2$	0.959	0.927	25.882
Hb	$Y = 0.563 + 24.126x - 12.606x^2$	0.957	0.996	12.106

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Discussion

Diets used in this experiment contained a similar lysine value of 11 g/kg DM but different dietary energy values of 11, 12, 13 and 14, thus forming dietary lysine to energy ratios of 0.79, 0.85, 0.92 and 1.00, respectively. Dietary lysine to energy ratio had significant effects on feed and ME intakes. Similar results have been reported by Araujo *et al. (*2005) for broiler chickens aged 44 to 55 days. Similarly, Abdallah *et al*. (2011) and Hind *et al*. (2012) reported that feeding different levels of lysine and energy to broiler chickens significantly influenced their feed intake. However, these authors did not measure the metabolisable energy intake. Contrary to the results observed in the present study, Mbajiorgu *et al*. (2011) did not observe differences in feed and ME intakes when male Venda chickens aged seven to 13 weeks were fed varying lysine to energy diets. This difference could be purely attributed to differences in sex of the chickens used in each study (Shahin and Elazeem, 2005).

The optimum dietary lysine to energy ratio of 0.964 optimized feed intake in female Venda chickens aged eight to 13 weeks. The ratio observed in the present study is lower than the ratio of 1.07 reported by Hind *et al.* (2012) for broiler chickens. However, the ratio of 0.964 in this study is higher than ratios of 0.71 reported by Mbajiorgu *et al.* (2011) for male Venda chickens aged seven to 13 weeks and 0.872 reported by Berri *et al.* (2008) for broiler chickens aged 21 to 42 days. Differences between the studies in dietary contents may account for the major differences in lysine to energy ratios for optimal intake (Hind *et al.,* 2012)

A lysine to energy ratio of 0.912 optimized metabolisable energy intakes of female Venda chickens aged eight to 13 weeks. Araujo *et al.* (2005) observed that a lysine to energy ratio of 0.71 optimized ME intake in broiler chickens aged 44 to 55 days. The differences in the results could be attributed to the breeds used and dietary treatments.

Results of the present study indicate that dietary lysine to energy ratio had significant effect on carcass weight, breast and drumstick meat weights. These results are in line with the findings of Araujo *et al.* (2005) in broiler chickens aged 44 to 55 days. Mbajiorgu *et al.* (2011), also, observed differences in the breast meat yield of male Venda chickens aged 49 days fed diets varying in lysine to energy ratios. Similarly, Tang *et al*. (2007) observed differences in live body weights and dressing percentages of Arbor Acre broiler chickens fed diets containing varying ME and lysine levels.

Quadratic analysis of the present results indicated that carcass weight was optimized at a dietary lysine to energy ratio of 0.90. Berri *et al*. (2008) observed a similar ratio in broiler chickens. However, the ratio of 0.90 observed in the present study is lower than the 1.36 observed by Mbajiorgu *et al*. (2011) in male Venda chickens aged 91 days. The differences in the results of optimal carcass weights might be attributed to the different sexes of the chickens used. Dietary lysine to energy ratio of 0.89 optimized breast meat in the present study. This ratio is higher than the ratios of 0.81 (Mbajiorgu *et al*., 2011) and 0.718 (Kerr *et al*., 1999) for male Venda chickens aged 91 days and broiler chickens aged 42 days, respectively. As the dietary lysine to energy ratio increased the drumstick weights of the female Venda chickens increased until they were optimized at a ratio of 0.91.

The effects of dietary lysine to energy ratio on breast meat pH and sensory evaluation, in the present experiment, indicate that only breast meat drip loss, juiciness and flavour were influenced by dietary treatments. Tang *et al.* (2007) showed that water loss rate in broiler chickens were influenced by dietary ME and lysine. Contrary to the results of the present study these authors also reported significant differences in the breast meat pH at 24 hours after slaughter.

Results indicate that breast meat drip loss was optimized at a dietary lysine to energy ratio of 1.09. This ratio is lower than the 0.888 reported by Berri *et al*. (2008) for broiler chickens aged 42 days. Breast meat juiciness and flavour were influenced by dietary lysine to energy ratio. The breast meat juiciness in the present study was optimized at dietary lysine to energy ratio of 0.934. Madruga *et al.* (2010) reported that a diet with the highest energy content produced higher juiciness in lamb meat. Breast meat flavour in the present study was influenced by dietary lysine to energy ratio in the present study and was optimized at a dietary lysine to energy ratio of 0.895. This results is in line to those of Spanier and Miller (1993) who reported that proteins (lysine), carbohydrates (energy) and lipids play primary roles in flavour development because they include numerous compounds which are capable of developing into important flavour precursors when heated.

Results of the effect of dietary lysine to energy ratio on the haematological values of female Venda chickens aged 91 days showed that increasing dietary lysine to energy ratio increased WBC values. However, the WBC values in the present study were within the range for indigenous chickens (Islam *et al*., 2004). White blood cells play an important role in the body's immune system, searching the blood for invading viruses, bacteria and fungi. When a foreign virus or bacteria enters blood, the white blood cells or leukocytes, recognize and destroy the invading particle before they can cause diseases (Schmid-Hempel, 2009). The present results indicate that increasing dietary lysine to energy ratio improved white blood cells and hence the ability of the chickens to fight disease invasion. Dietary lysine to energy ratio of 0.927 optimized WBC. Haemoglobin values in the present study were significantly influenced by dietary treatments. Haemoglobin values increased with increase in dietary lysine to energy ratio and they were optimized at a dietary lysine to energy ratio of 0.996. Low haemoglobin levels indicate anaemia (Adeyemo and Longe, 2007). Optimum Hb synthesis increases the availability of oxygen for anabolic activity leading to increased production of energy for muscle accretion. Although the RBC, PCV, MCV, MCH and MCHC values were not influenced by dietary lysine to energy ratio, their values were within the ranges for indigenous chickens (Elagib and Ahmed, 2011; Islam *et al*., 2004).

4.3.4 Experiment 8

Results

The nutrient compositions of the diets used in Experiment 8 are the same as those presented in Table 3.18 (Experiment 4). The diets had a similar lysine content of 12 g/kg DM but different energy levels. The energy levels were 11, 12, 13 and 14 MJ of ME/kg DM (determined in the laboratory using NIRA), thus forming lysine to energy (L:E) ratios of 1.09 ($FL_{12}E_{11}$), 1.00 ($FL_{12}E_{12}$), 0.92 ($FL_{12}E_{13}$) and 0.86 ($FL_{12}E_{14}$), respectively.

Results of the effect of dietary lysine to energy ratio on feed intake, growth rate, feed conversion ratio (FCR), live weight, apparent metabolisable energy, nitrogen (N) retention and mortality of female Venda chickens aged eight to thirteen weeks are presented in Table 4.34. Dietary lysine to energy ratio had effect ($P<0.05$) on all the parameters measured except mortality ($P>0.05$) of the chickens. Female Venda chickens offered a diet having a lysine to energy ratio of 0.92 had higher ($P<0.05$) feed intake and N-retention than those on diets having 0.86, 1.00 or 1.09 lysine to energy ratios. Chickens offered a diet having a lysine to energy ratio of 1.00 had higher ($P<0.05$) feed intake and N-retention than those on diets having 0.86 or 1.09 lysine to energy ratios. Similarly, chickens offered a diet having a lysine to energy ratio of 1.09 had higher ($P<0.05$) feed intake and N-retention than those on a diet having a lysine to energy ratio of 0.86. Growth rates of chickens offered diets having lysine to energy ratios of 0.92 or 1.00 were similar ($P>0.05$); their growth rates were, however, higher ($P<0.05$) than those of chickens offered diets having lysine to energy ratios of 0.86 or 1.09. Similarly, chickens offered a diet having a lysine to energy ratio of 1.09 had higher ($P<0.05$) growth rates than chickens on a diet having a lysine to energy ratio of 0.86.

Female Venda chickens offered a diet having a lysine to energy ratio of 1.00 had a better ($P<0.05$) FCR value than those of chickens offered diets having lysine to energy ratios of 0.82, 0.86 or 1.09. Chickens offered a diet having a lysine to energy ratio of 0.82, also, had a better ($P<0.05$) FCR than those birds offered diets having lysine to energy ratios of 0.86 or 1.09. Similarly, chickens on a dietary treatment of a 1.09 lysine to energy ratio had a better ($P<0.05$) FCR than those offered a diet having a lysine to energy ratio of 0.86. Live weights of Venda chickens offered a diet having a lysine to energy ratio of 1.00 were higher ($P<0.05$) than those of chickens offered diets having lysine to energy ratios of 0.86, 0.92 or 1.09. Female Venda chickens on a diet having a lysine to energy ratio of 0.92 had higher ($P<0.05$) live weights than those offered diets having lysine to energy ratios of 0.86 or 0.92. Chickens on a diet having a lysine to energy ratio of 0.92 had higher ($P<0.05$) live weights than those offered a diet having a lysine to energy ratio of 0.86.

Female Venda chickens offered a diet having a lysine to energy ratio of 0.92 had a higher ($P<0.05$) ME value than those of birds on diets having lysine to energy ratios of 0.86, 1.00 or 1.09. Chickens offered a diet having a lysine to energy ratio of 1.00 had a higher ($P<0.05$) ME value than those of chickens on diets having lysine to energy ratios of 0.86 or 1.09. Similarly, chickens offered a diet having a lysine to energy ratio of 1.09 had a higher ($P<0.05$) ME value than those of chickens on a diet having a lysine to energy ratio of 0.86.

Results of the effect of dietary lysine to energy ratio on optimal feed intake, growth rate, FCR, live weight, apparent metabolisable energy and nitrogen retention of Venda chickens aged eight to thirteen weeks are presented in Figures 4.97 to 4.102, respectively and Table 4.35. Feed intake, growth rate, FCR, live weight, apparent metabolisable energy and nitrogen retention in female Venda chickens were optimized at dietary lysine to energy ratios of 0.996 ($r^2 = 0.667$), 0.980 ($r^2 = 0.932$), 0.991 ($r^2 = 0.940$), 1.010 ($r^2 = 0.878$), 0.957 ($r^2 = 0.976$) and 0.993 ($r^2 = 0.690$), respectively.

Table 4.34 Effect of dietary lysine to energy ratio (g/MJ ME) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g feed/g live weight gain), live weight (g/bird aged 91 days), apparent metabolisable energy (MJ /kg), nitrogen retention (g/bird/day) and mortality (%) of female Venda chickens aged eight to thirteen weeks

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.86	0.92	1.00	1.09	SE
Feed intake	62.40 ^{d}	83.61 ^{a}	77.28 ^{b}	75.68 ^{c}	2.327
Growth rate	11.8 ^{c}	19.3 ^{a}	18.8 ^{a}	13.8 ^{b}	0.97
FCR	7.90 ^{a}	4.40 ^{c}	4.20 ^{d}	5.80 ^{b}	0.445
Live weight	959.3 ^{d}	1053.0 ^{c}	1240.0 ^{a}	1113.0 ^{b}	30.77
ME	11.23 ^{b}	12.19 ^{a}	11.87 ^{b}	10.53 ^{c}	0.291
N-retention	2.24 ^{d}	3.01 ^{a}	2.79 ^{b}	2.69 ^{c}	0.084
Mortality	0.22	0.25	0.23	0.23	0.001

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

ME :Metabolisable energy

N-retention :Nitrogen retention

SE : Standard error

$Y = -493.556 + 1048.089x - 534.798x^2$

$r^2 = 0.667$

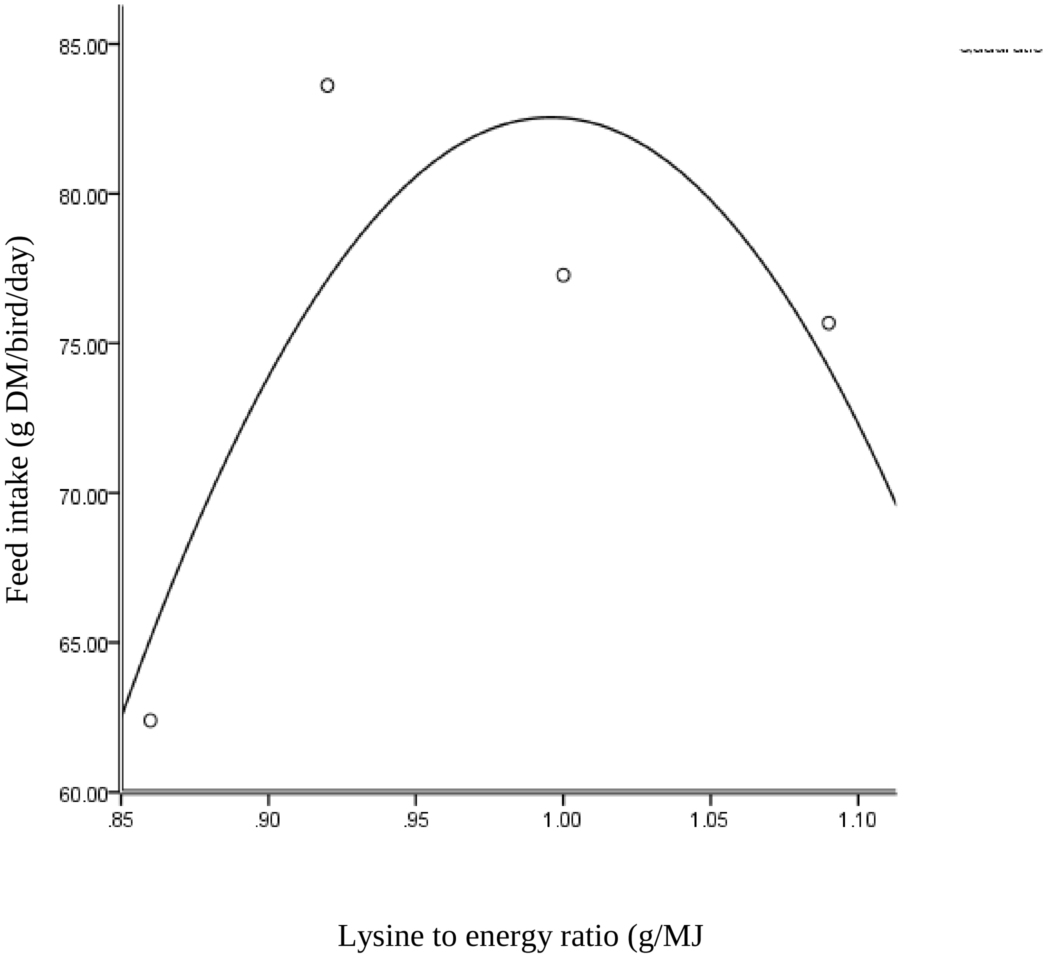


Figure 4.38 Effect of dietary lysine to energy ratio on feed intake of female Venda chickens aged eight to 13 weeks

$$Y = -493.556 + 1048.089x - 534.798x^2$$

$$r^2 = 0.932$$

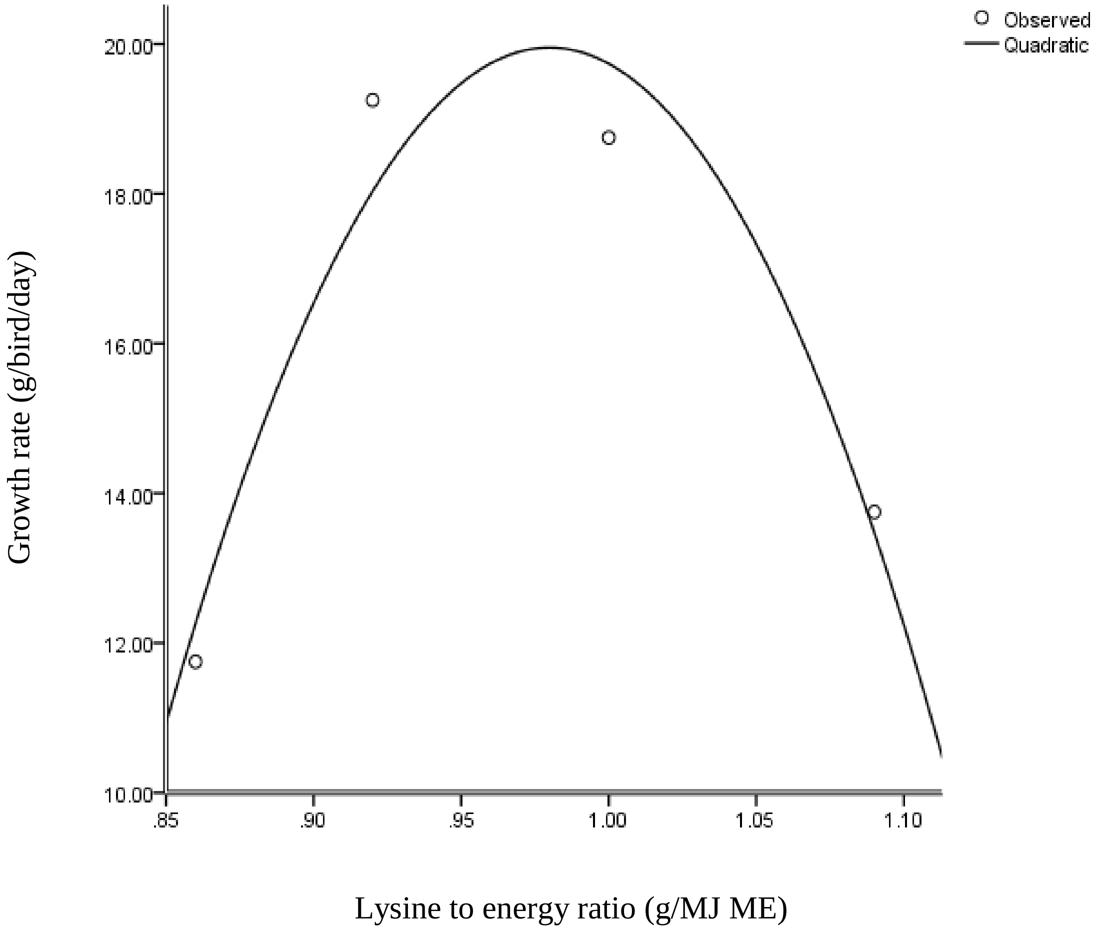


Figure 4.39 Effect of dietary lysine to energy ratio on growth rate of female Venda chickens aged eight to 13 weeks

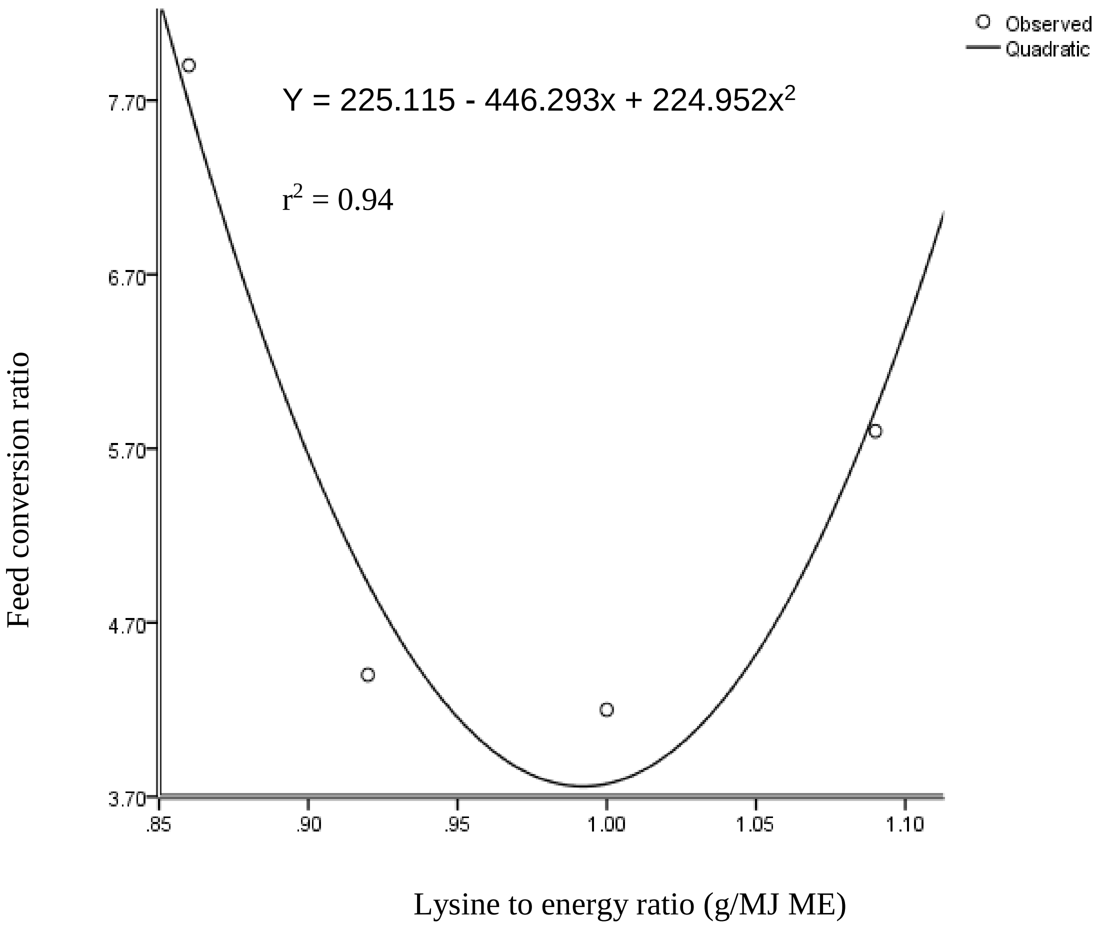


Figure 4.40 Effect of dietary lysine to energy ratio on feed conversion ratio of female Venda chickens aged eight to 13 weeks

$Y = -10658.900 + 23478.974x - 11622.051x^2$

$r^2 = 0.878$

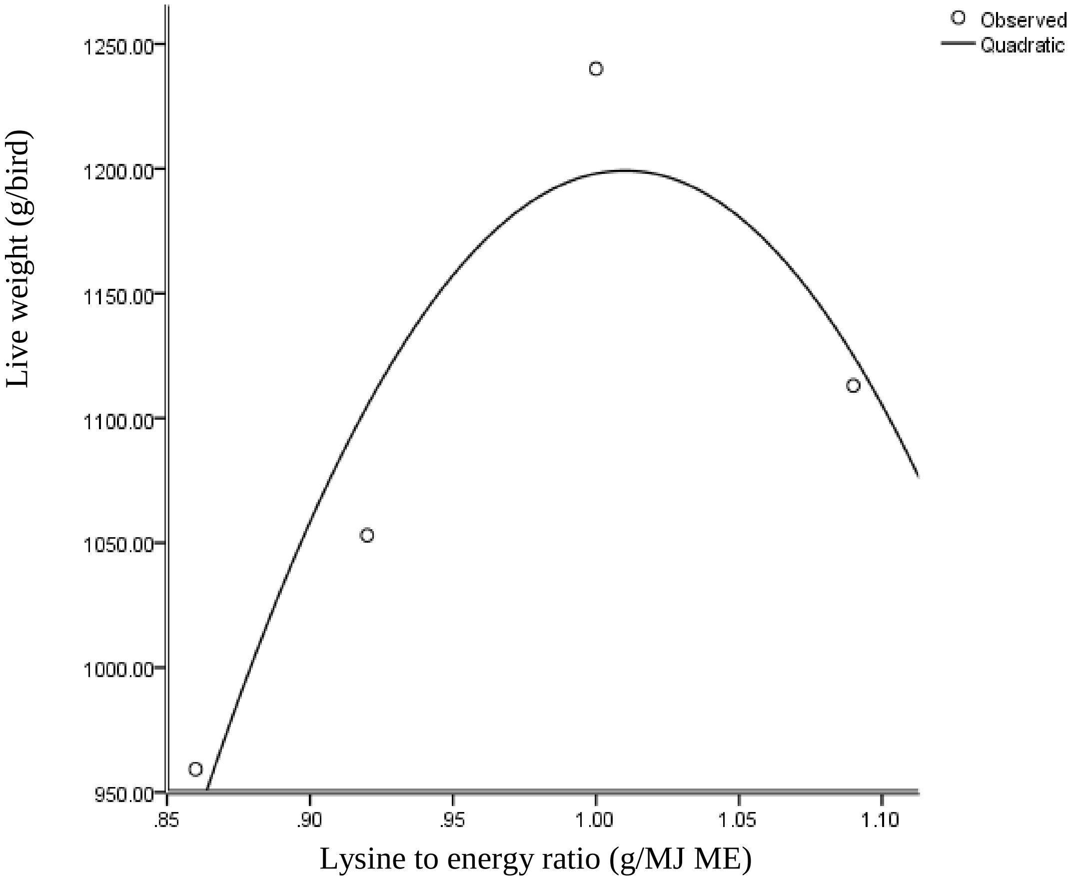


Figure 4.41 Effect of dietary lysine to energy ratio on live weight of female Venda chickens aged 91 days

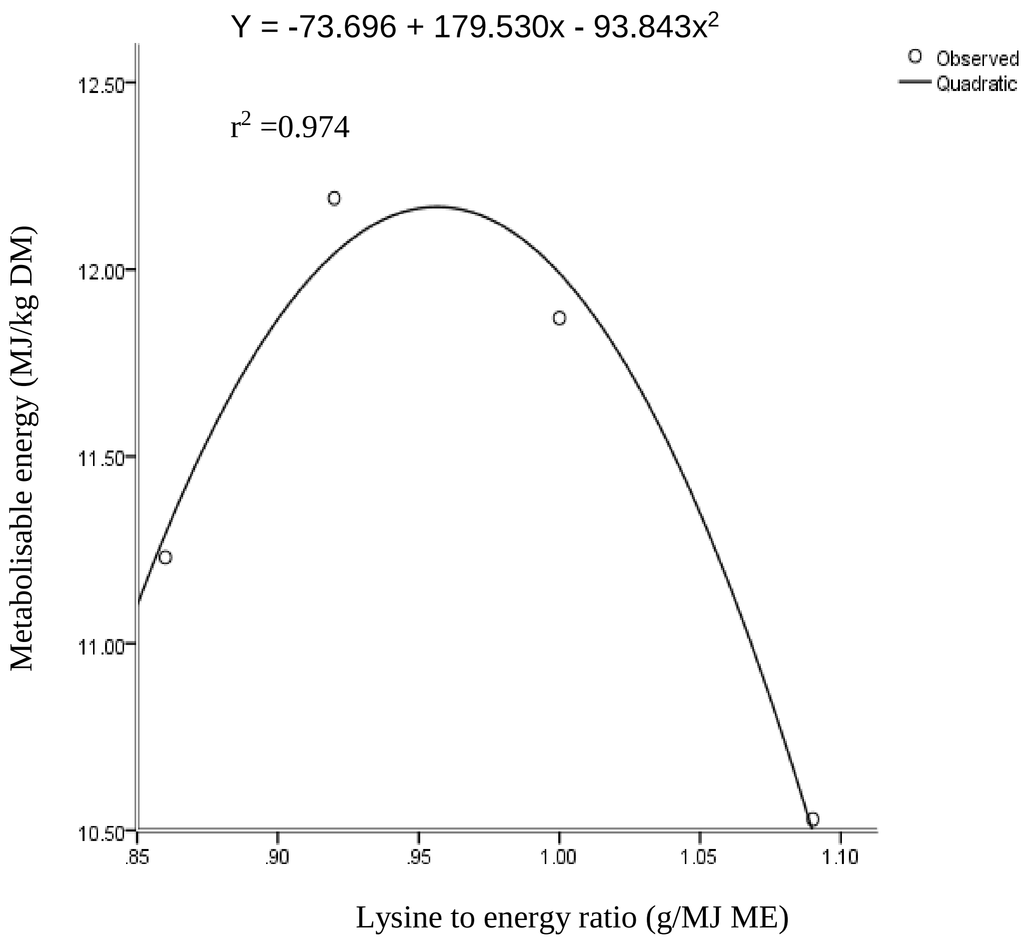


Figure 4.42 Effect of dietary lysine to energy ratio on apparent metabolisable energy of female Venda chickens aged 13 weeks

$$Y = -32.614 + 71.671x - 36.083x^2$$

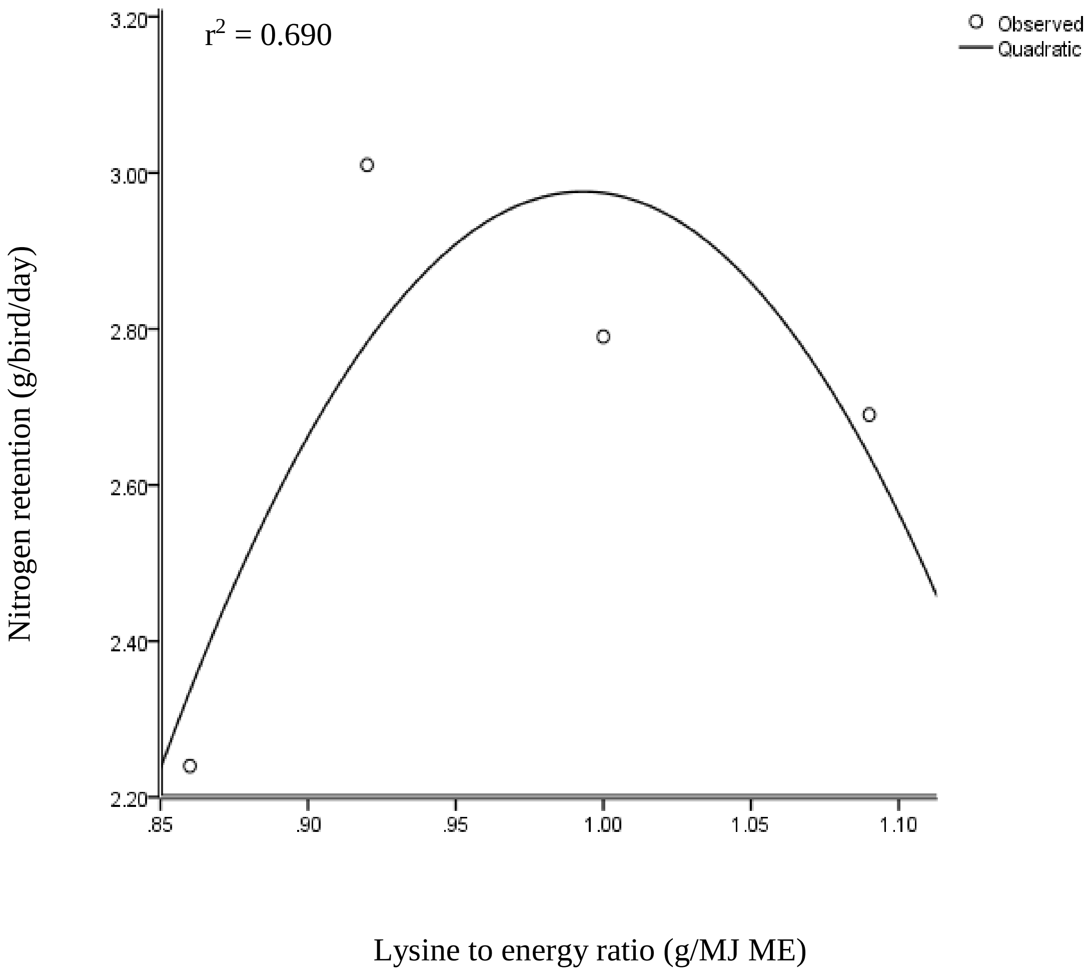


Figure 4.43 Effect of dietary lysine to energy ratio on nitrogen retention of female Venda chickens aged 13 weeks

Table 4.35 Dietary lysine to energy ratios for optimal feed intake (g/bird/day), growth rate (g/bird/day), FCR (g feed/g live weight gain), live weight (g/bird aged 91 days), apparent metabolisable energy (MJ/kg DM) and nitrogen retention (g/bird/day) of female Venda chickens aged eight to thirteen weeks

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Feed intake	$Y = -853.318 + 1879.597x - 943.748x^2$	0.667	0.996	82.55
Growth rate	$Y = -493.556 + 1048.089x - 534.798x^2$	0.932	0.980	19.95
FCR	$Y = 225.115 - 446.293x + 224.952x^2$	0.940	0.991	3.76
Live weight	$Y = -10658.90+23478.97x-11622.05x^2$	0.878	1.010	1199.2
ME	$Y = -73.696 + 179.530x + -93.843x^2$	0.974	0.957	12.17
N-retention	$Y = -32.614 + 71.671x - 36.083x^2$	0.690	0.993	2.978

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

The effects of dietary lysine to energy ratio on carcass characteristics of female Venda chickens aged 91 days are presented in Table 4.36. Carcass weight, dressing percentage and drumstick weights of female Venda chickens offered a diet having a lysine to energy ratio of 1.00 were higher (P<0.05) than those of chickens on diets having lysine to energy ratios of 0.86, 0.92 or 1.09. Chickens on a diet having a lysine to energy ratio of 0.92 had higher (P<0.05) carcass, weight dressing percentage and drumstick weights than those of birds on diets having lysine to energy ratios of 0.86 or 1.09. Similarly, chickens on a diet having a lysine to energy ratio of 1.09 had higher (P<0.05) carcass weight, dressing percentage and drumstick weights than those of chickens on a diet having a lysine to energy ratio of 0.86. Female Venda chickens offered a diet having a lysine to energy ratio of 0.92 had a higher (P<0.05) breast meat weight than those on diets having lysine to energy ratios of 0.86, 1.00 or 1.09. Breast meat weights of chickens on a diet having a lysine to energy ratio of 1.09 were higher (P<0.05) than those of chickens offered a diet having a lysine to energy ratio of 0.86. Female Venda chickens offered a diet having a lysine to energy ratio of 1.00 had higher (P<0.05) liver weights than those on diets containing 0.86, 0.92 or 1.09 lysine to energy ratios. Liver weights of chickens offered a diet having a lysine to energy ratio of 1.09 were higher ($P<0.05$) than those of chickens on diets with lysine to energy ratios of 0.86 or 0.92. Similarly, chickens on a 0.92 lysine to energy ratio diet had higher ($P<0.05$) liver weights than those on a 0.86 lysine to energy ratio diet.

Thigh, wing, fat pad, gizzard and heart weights were not influenced ($P>0.05$) by dietary lysine to energy ratio (Table 4.36).

Carcass weight, dressing percentage, breast meat, drumstick and liver were optimized at dietary lysine to energy ratios of 0.992 ($r^2 = 1.000$) and 0.974 ($r^2 = 0.645$), 0.991 ($r^2 = 0.999$), 0.992 ($r^2 = 1.000$) and 1.023 ($r^2 = 0.980$), respectively (Figures 4.54, 4.55, 4.56, 4.57 and 4.58, respectively and Table 4.37).

Table 4.36 Effect of lysine to energy ratio (g/MJ ME) on carcass characteristics (g) of female Venda chickens aged 91 days

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.86	0.92	1.00	1.09	SE
Carcass weight	780.90 ^{d}	993.92 ^{b}	1081.06 ^{a}	914.40 ^{c}	33.285
Dressing (%)	81.41 ^{d}	94.39 ^{a}	87.18 ^{b}	82.16 ^{c}	1.552
Breast meat	138.32 ^{d}	194.41 ^{b}	220.10 ^{a}	171.63 ^{c}	9.068
Drumstick	92.67 ^{d}	119.20 ^{b}	129.74 ^{a}	105.70 ^{c}	4.209
Thigh	94.02	133.59	134.52	115.23	4.981
Wing	88.18	94.14	113.79	101.77	2.879
Fat pad	2.71	2.84	2.79	2.81	0.015
Gizzard	30.99	39.71	58.37	42.42	2.983
Liver	16.51 ^{d}	20.13 ^{c}	21.30 ^{a}	20.76 ^{b}	0.888
Heart	5.94	5.49	5.87	5.14	0.596

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

SE : Standard error

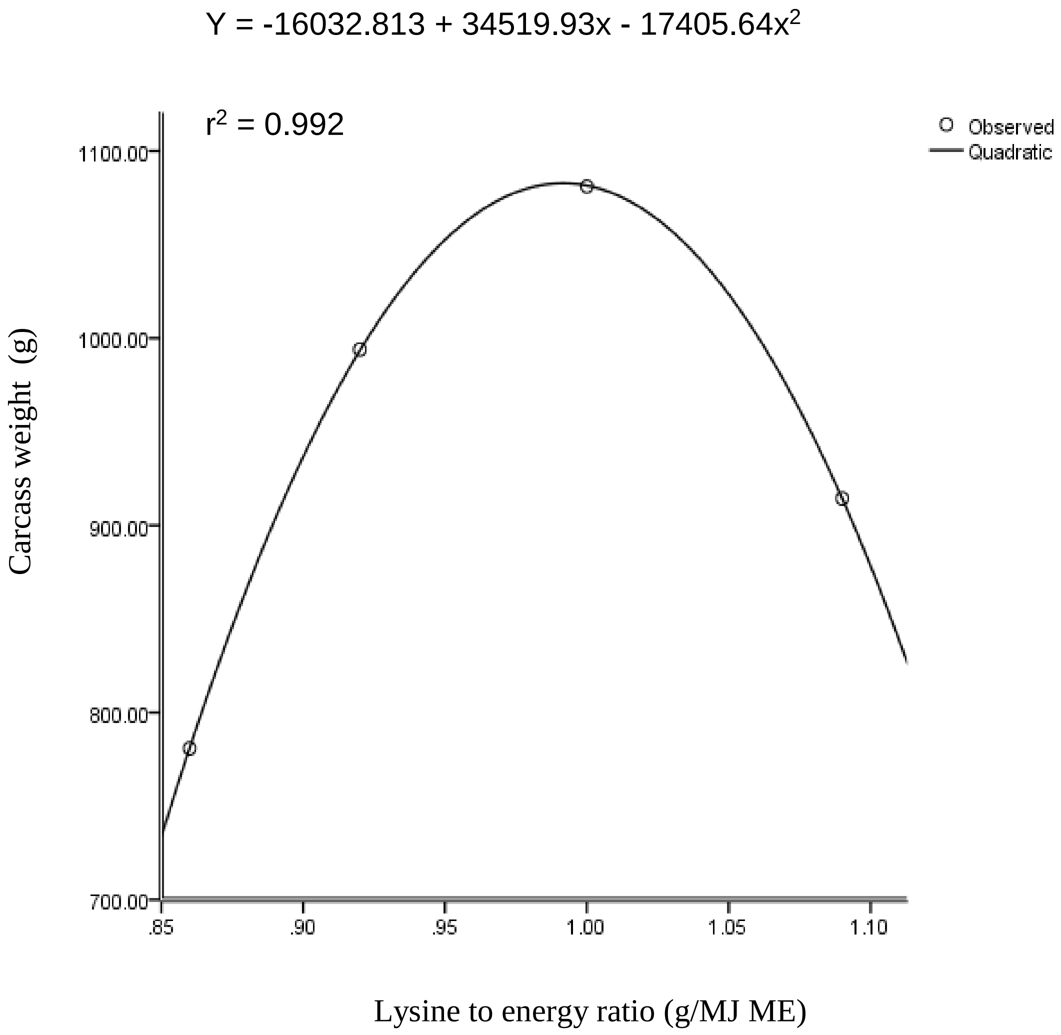


Figure 4.44 Effect of dietary lysine to energy ratio on carcass weight of female Venda chickens aged 91 days

$Y = -566.761 + 1359.797x - 702.216x^2$

$r^2 = 0.645$

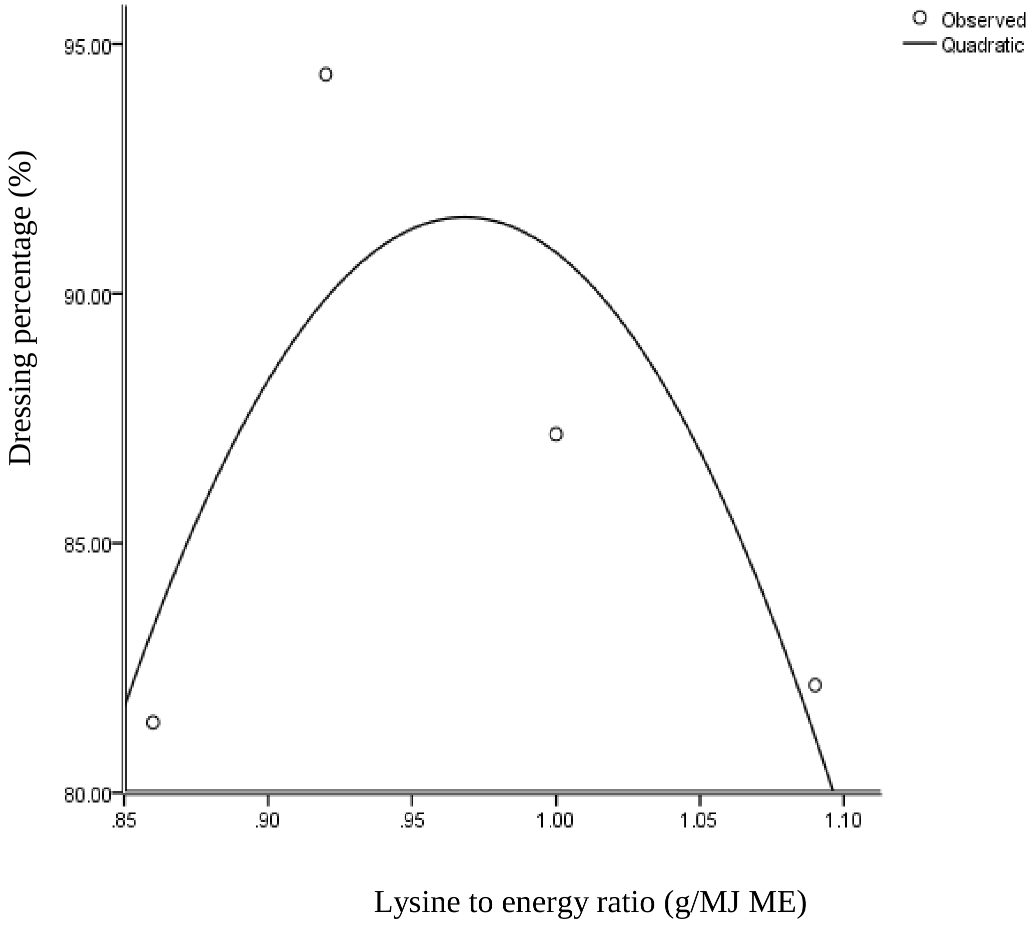


Figure 4.45 Effect of dietary lysine to energy ratio on dressing percentage of female Venda chickens aged 91 days

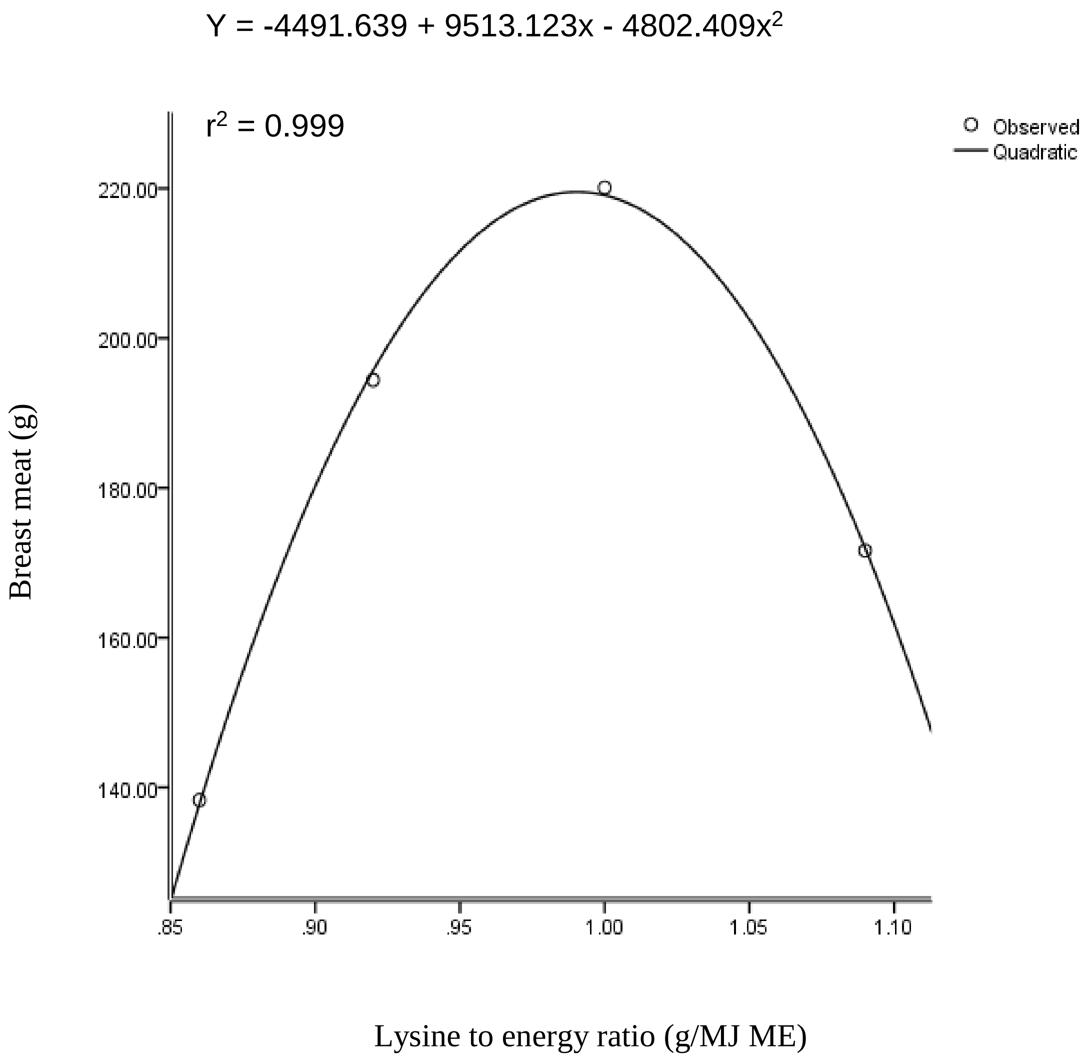


Figure 4.46 Effect of dietary lysine to energy ratio on breast meat of female Venda chickens aged 91 days

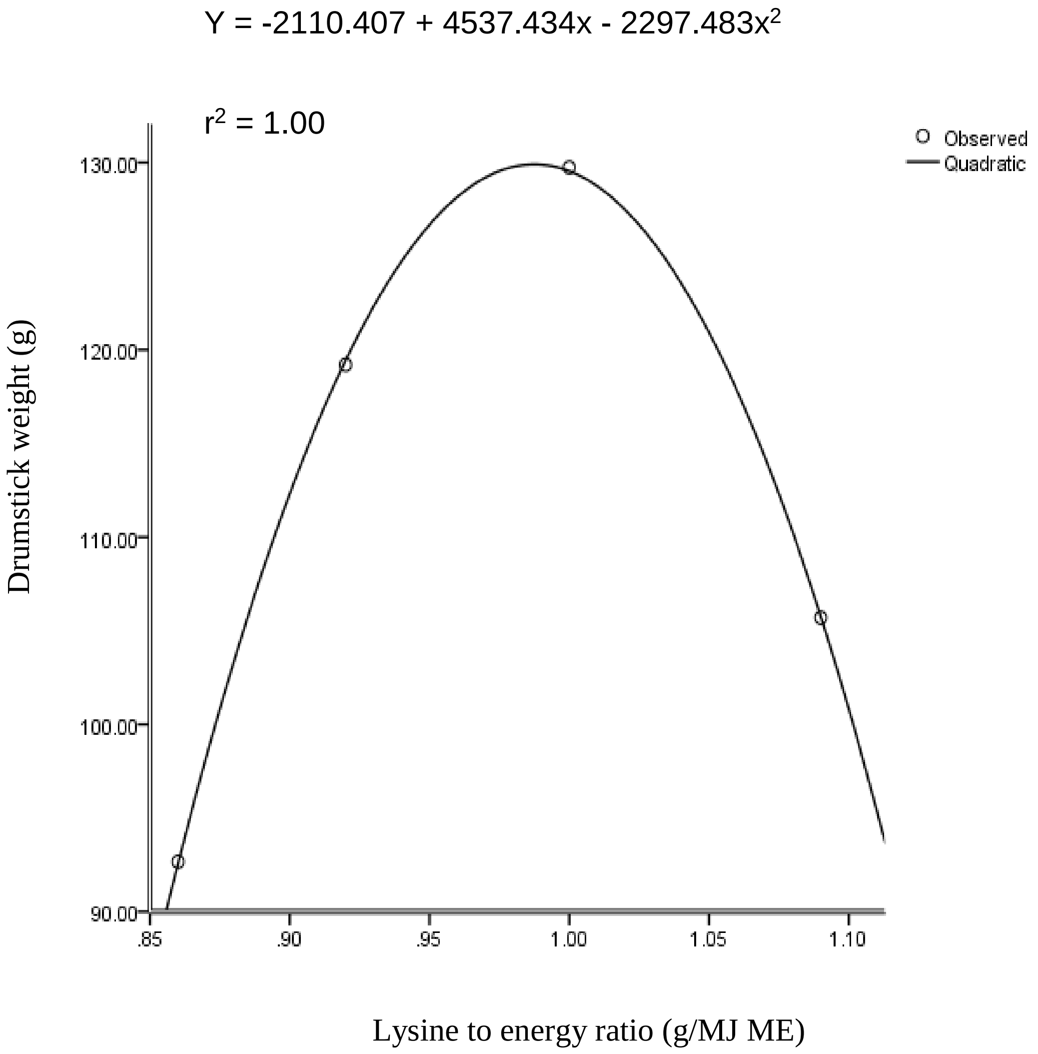


Figure 4.47 Effect of dietary lysine to energy ratio on drumstick weight of female Venda chickens aged 91 days

$$Y = -184.708 + 405.203x - 198.883x^2$$

$$r^2 = 0.980$$

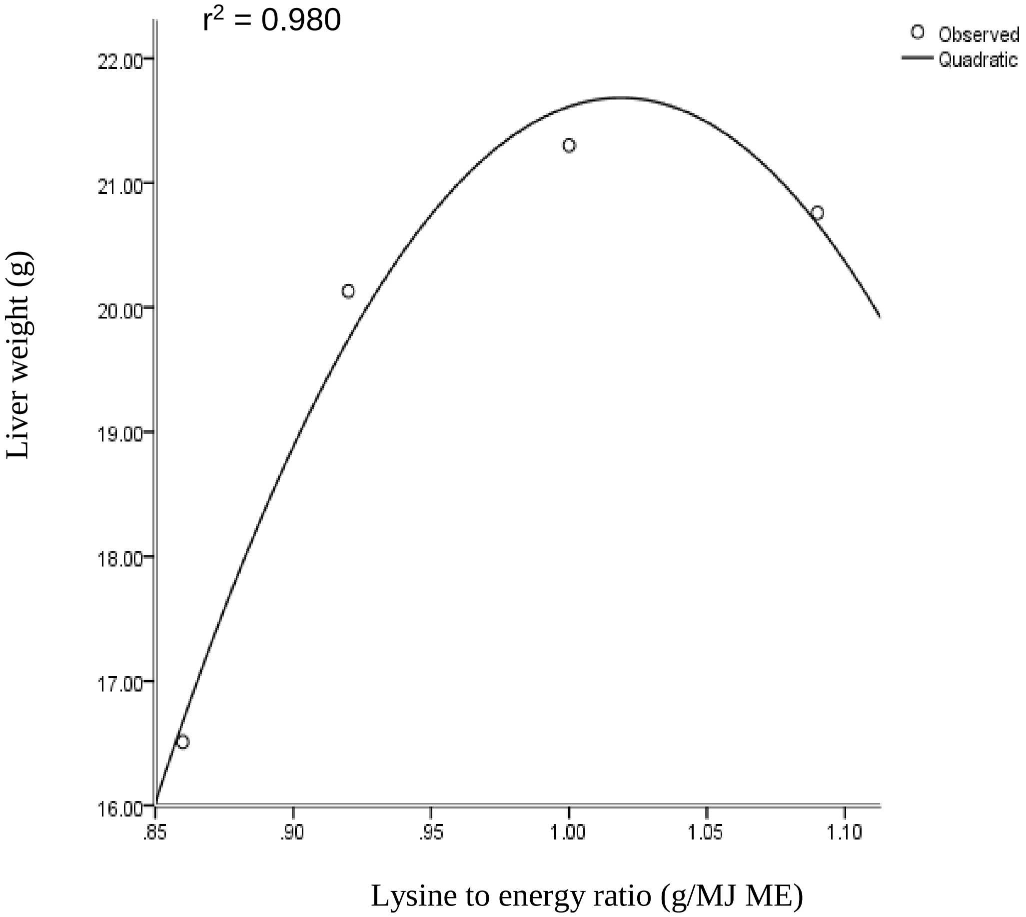


Figure 4.48 Effect of dietary lysine to energy ratio on liver weight of female Venda chickens aged 91 days

Table 4.37 Dietary lysine to energy ratios for optimal carcass weight (carcass wt), dressing percentage, breast meat, drumstick, and liver weights of female Venda chickens aged 91 days

Trait	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Carcass wt	$Y = -16032.81 + 34519.93x - 17405.64x^2$	1.000	0.992	1082.70
Dressing %	$Y = -566.761 + 1359.797x - 702.216x^2$	0.645	0.974	91.523
Breast meat	$Y = -4491.639 + 9513.123x - 4802.409x^2$	0.999	0.991	219.51
Drum	$Y = -2110.407 + 4537.434x - 2297.483x^2$	1.000	0.992	129.90
Liver	$Y = -184.708 + 405.203x + -198.883x^2$	0.980	1.023	21.68

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

Results of the effect of dietary lysine to energy ratio on breast meat pH at different times, drip loss after slaughter, tenderness, juiciness and flavour of female Venda chickens aged 91 days are presented in Table 4.38. Dietary lysine to energy ratio affected ($P<0.05$) tenderness, juiciness and flavour. However, dietary lysine to energy ratio did not ($P>0.05$) affect all the other parameters

Female Venda chickens offered a diet having a lysine to energy ratio of 1.00 had a better ($P<0.05$) meat tenderness score than those on diets containing dietary lysine to energy ratios of 0.86, 0.92 or 1.09. Chickens offered a diet with a lysine to energy ratio of 0.92 had a better ($P<0.05$) meat tenderness score than those on diets having lysine to energy ratios of 0.86 or 1.09. However, the meat tenderness scores for chickens offered diets with lysine to energy ratios of 1.09 or 0.86 were similar ($P>0.05$). Meat juiciness scores of chickens on diets having lysine to energy ratios of 0.92 or 1.00 were higher ($P<0.05$) than those of chickens on diets having lysine to energy ratios of 0.86 or 1.09. Venda chickens on diets having lysine to energy ratios of 0.92 or 1.00 had similar ($P>0.05$) meat juiciness scores. Similarly, chickens on diets having lysine to energy ratios of 0.86 or 1.09 had similar ($P>0.05$) meat juiciness scores. Female

Venda chickens offered a diet containing a lysine to energy ratio of 0.92 had a better ($P<0.05$) meat flavour score than those offered diets having lysine to energy ratios of 0.86, 1.00 or 1.09. Chickens offered a diet having a lysine to energy ratio of 0.86, also, had a better ($P<0.05$) meat flavour score than those chickens offered diets having lysine to energy ratios of 1.00 or 1.09. Similarly, chickens on a diet having a lysine to energy ratio of 1.00 had a better ($P<0.05$) meat flavour score than those on a diet having a lysine to energy ratio of 1.09.

Breast meat tenderness, juiciness and flavour were optimized at different dietary lysine to energy ratios of 0.981 ($r^2=0.995$), 0.979 ($r^2=0.907$) and 0.815 ($r^2 = 0.805$), respectively (Figures 4.60 to 4.62, respectively and Table 4.39).

Table 4.38 Effect of lysine to energy ratio (g/MJ ME) on breast meat pH at different times after slaughtering, drip loss after slaughter (%), tenderness, juiciness and flavour of meat of female Venda chickens aged 91 days

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.86	0.92	1.00	1.09	SE
pH at slaughter	5.71	5.77	5.89	5.82	0.241
pH at 30 minutes	5.60	5.72	5.86	5.74	0.265
pH at 2 hours	5.55	5.60	5.82	5.76	0.264
pH at 12 hours	5.64	5.67	5.75	5.62	0.243
pH at 24 hours	5.64	5.57	5.75	5.52	0.254
Drip loss	3.44	3.40	3.41	3.40	0.016
Tenderness	3.00^{c}	3.45^{b}	3.65^{a}	3.10^{c}	0.199
Juiciness	3.00^{b}	3.40^{a}	3.35^{a}	3.10^{b}	0.194
Flavour	4.00^{b}	4.25^{a}	3.50^{c}	3.20^{d}	0.118

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

SE : Standard error

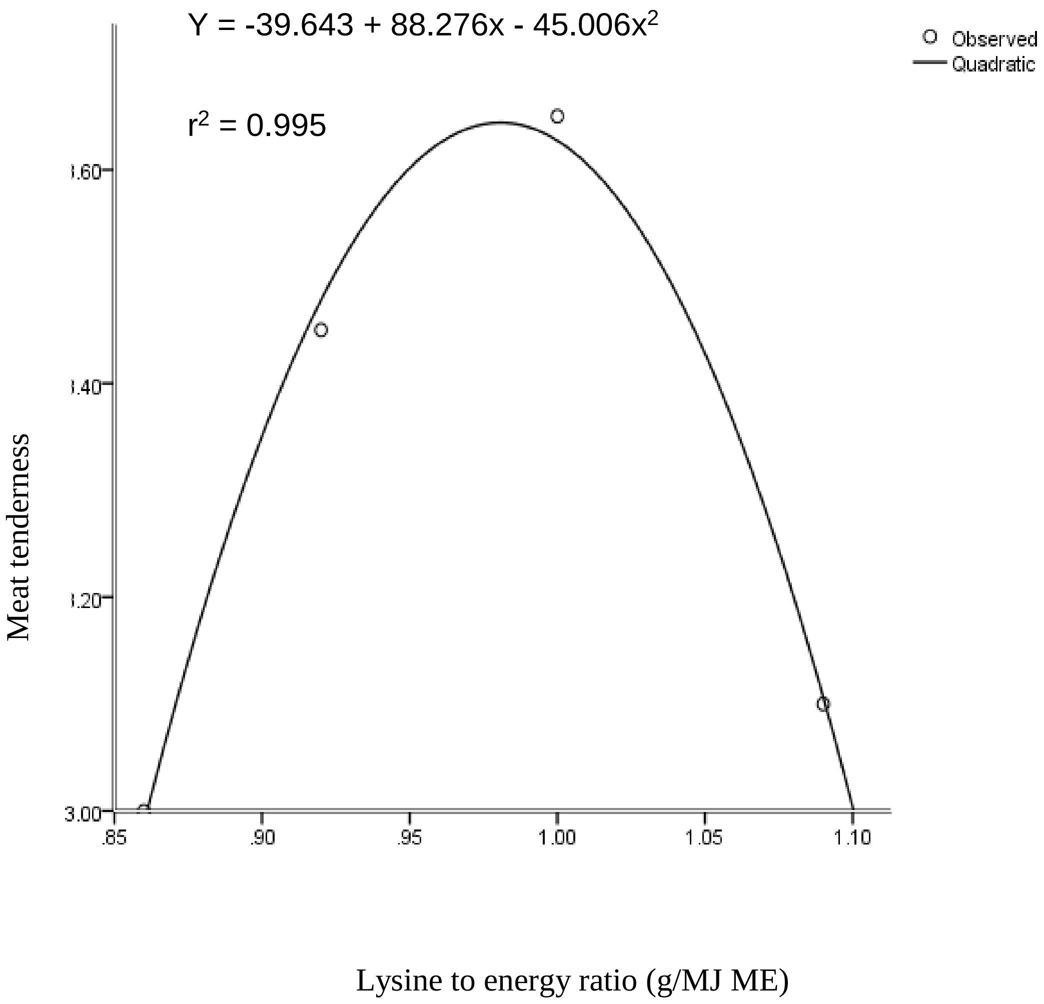


Figure 4.49 Effect of dietary lysine to energy ratio on meat tenderness of female Venda chickens aged 91 days

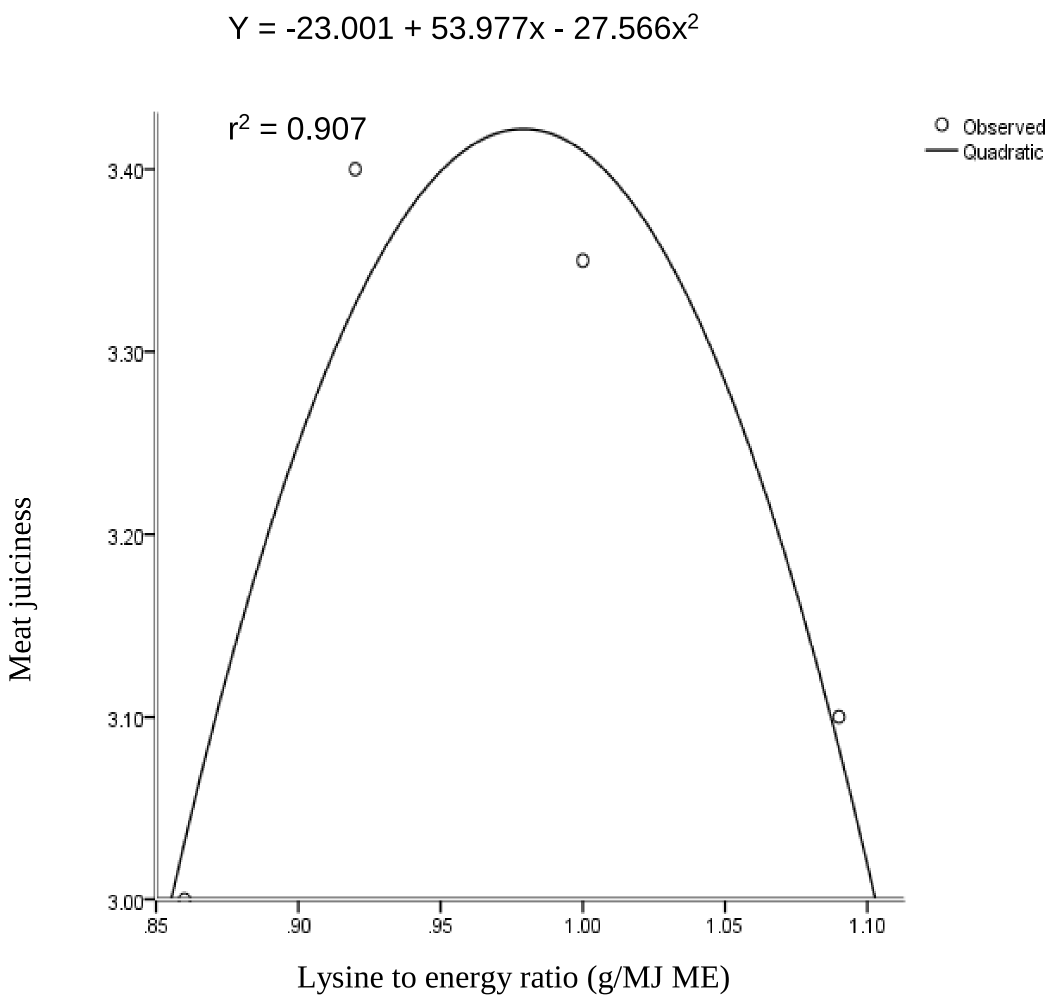
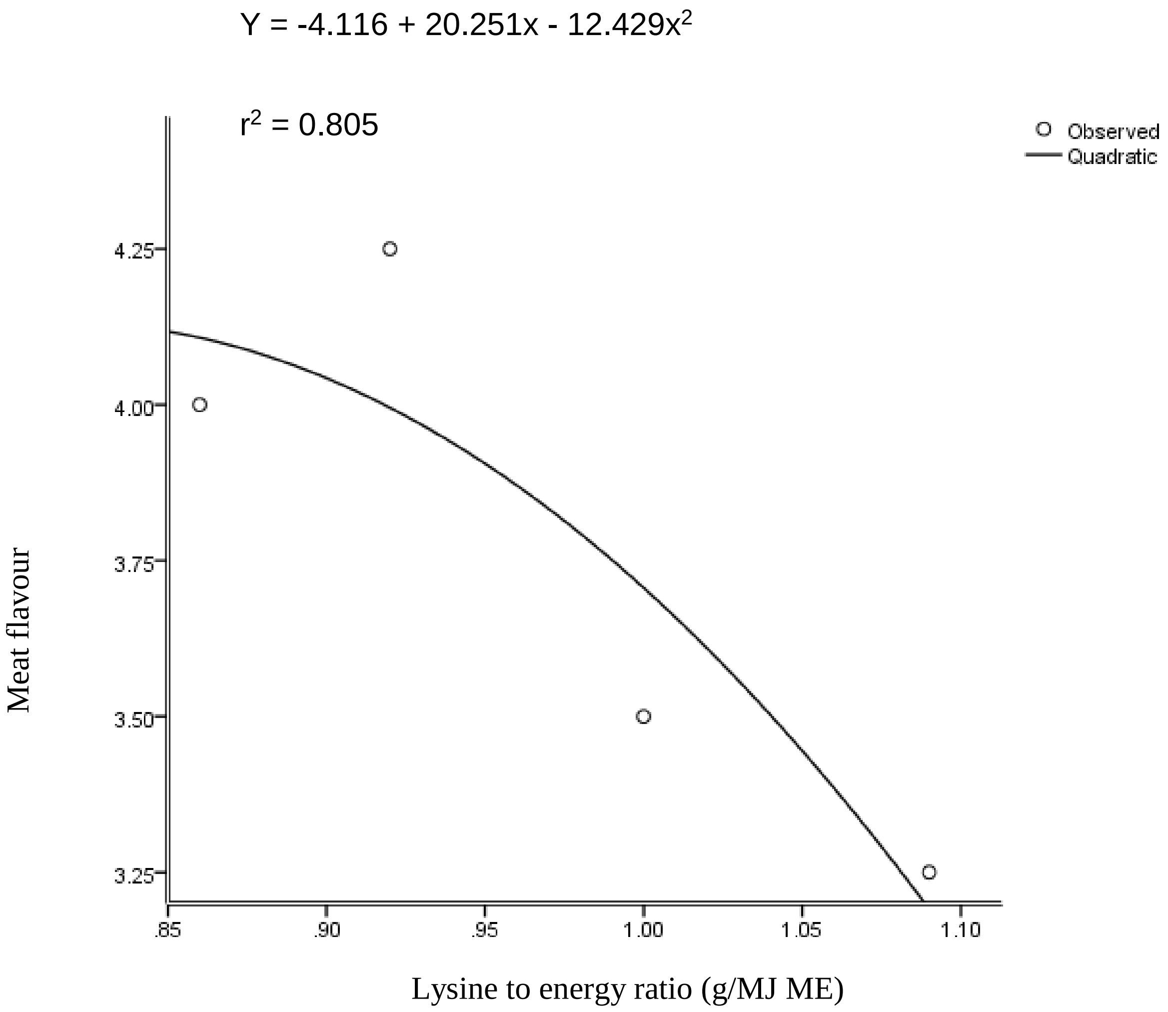


Figure 4.50 Effect of dietary lysine to energy ratio on meat juiciness of female Venda chickens aged 91 days



$$Y = -4.116 + 20.251x - 12.429x^2$$

$$r^2 = 0.805$$

Figure 4.51 Effect of dietary lysine to energy ratio on meat flavour of female Venda chickens aged 91 days

Table 4.39 Dietary lysine to energy ratios for optimal breast meat tenderness, juiciness and flavour of meat of female Venda chickens aged 91 days

Trait	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Tenderness	$Y = 23.244 - 37.157x + 17.241x^2$	0.995	0.981	3.64
Juiciness	$Y = 23.244 - 37.157x + 17.240x^2$	0.907	0.979	3.42
Flavour	$Y = -4.116 + 20.251x - 12.429x^2$	0.805	0.815	4.13

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

The effects of dietary lysine to energy ratio on haematological values of female Venda chickens aged 91 days are presented in Table 4.40. Dietary lysine to energy ratio did not influence the haematological parameters of female Venda chickens aged 91

Table 4.40 Effect of lysine to energy ratio (g/MJ ME) on white blood cell (WBC), red blood cell (RBC), haemoglobin (Hb), pack cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) in female Venda chickens aged 91 days

	Dietary lysine to energy ratio (g lysine/MJ ME)				
Variable	0.86	0.92	1.00	1.09	SE
WBC $(10)^3$ µL	24.34	26.56	26.28	25.25	0.228
RBC $(10)^4$ µL	2.60	2.76	2.80	2.56	0.031
HB (g/dL)	11.88	10.49	13.10	11.60	0.279
PCV (%)	33.68	35.87	36.73	40.20	0.716
MCV (fl)	138.67	136.90	139.18	142.33	1.101
MCH (pg)	45.48	49.60	47.87	45.98	0.492
MCHC (g/dL)	32.30	36.30	32.36	33.27	0.472

SE : Standard error

Discussion

In this experiment the diets were designed to have the highest lysine level of 12 g/kg DM and an isonitrogenous level of 240 g CP/kg DM but with different energy levels of 11, 12, 13 or 14 MJ of ME/kg DM . Thus, the diets ended up with varying lysine to energy ratios of 0.86, 0.92, 1.00 and 1.09. The diets contained similar levels of other nutrients, which met the chicken's requirements as recommended by the NRC (1994).

Feed intake, growth rate, live weight, ME intake and nitrogen retention in the present study increased as the dietary lysine to energy ratio increased until they were optimized. Thereafter an increase in dietary lysine to energy ratio resulted in a decrease in these parameters. Feed intake in the present study was optimized at a dietary lysine to energy ratio of 0.996. This ratio is higher than those of 0.71 and 0.74 reported by Mbajiorgu *et al*. (2011) for male Venda chickens aged seven to 13 weeks and Araujo *et al*. (2005) for broiler chickens aged 44 to 55 days, respectively. However, the ratio of 0.996 in the present study is lower than a ratio of 1.07 reported by Hind *et al.* (2012) for broiler chickens.

A dietary lysine to energy ratio of 0.980 optimized growth rate. A similar ratio was reported by Berri *et al.* (2008) in broiler chickens. The ratio of 0.980 for optimal growth rate reported in this study is, however, higher than those of 0.75 and 0.76 reported by the NRC (1994) and Mbajiorgu *et al*. (2011) for broiler and male Venda chickens, respectively. Hind *et al*. (2012) reported a higher dietary lysine to energy ratio of 1.05 for optimal growth rate of broiler chickens. The differences could be attributed to the breeds and sex of the chickens used. Shahin and Elazeem (2005) came to the same conclusion.

The present results indicate that dietary lysine to energy ratio of 0.991 optimized FCR. This ratio is higher than the ratio of 0.98 reported by Kerr *et al.* (1999) for broiler chickens aged one to six weeks but lower than a ratio of 1.04 reported by Hind *et al*. (2012) for broiler chickens aged one to six weeks. Mbajiorgu *et al*. (2011) reported that a dietary lysine to energy ratio of 0.81 optimized FCR in male Venda chickens aged seven to 13 weeks. The difference in the ratios could be attributed to breeds and sexes of the chickens used in the different studies. It might also be due to dietary differences (NRC, 1994).

The live weight of female Venda chickens in the present study was optimized at a dietary lysine to energy ratio of 1.010. a similar ratio for broiler chickens was reported by Hind *et al*. (2012). However, Mbajiorgu *et al*. (2011) reported a lower ratio of 0.85 for male Venda chickens aged seven to 13 weeks. The difference between ratios of 1.010 and 0.85 could be as a result of differences in the sex of the chickens used. Mbajiorgu *et al.* (2011) varied dietary lysine contents in the diets used while the energy level was kept constant. However, in the present study, dietary lysine was kept constant while the energy levels were varied. Thus, diets formulation methods could be one of the reasons for the differences observed.

A dietary lysine to energy ratio of 0.957 optimized metabolisable energy intake. This ratio is higher than the 0.71 reported by Araujo *et al*. (2005) in broiler chickens aged 44 to 55 days. Similarly, a dietary lysine to energy ratio of 0.993 which optimized nitrogen retention in the present study is higher than the ratio of 0.61 reported by Mbajiorgu *et al*. (2011) for male Venda chickens aged seven to 13 weeks..

The results of the effect of dietary lysine the energy ratio on carcass characteristics in the present study indicated carcass weight, dressing percentage, breast meat and drumstick weights were influenced by dietary lysine to energy ratio. A dietary lysine to energy ratio of approximately 0.99 optimized carcass, breast meat and drumstick weights. This is contrary to the report of several authors who obtained different dietary lysine to energy ratios for different carcass characteristics measured (Araujo *et al*., 2005; Tang *et al*., 2007; Mbajiorgu *et al*., 2011; Hind *et al*. 2012). Araujo *et al*. (2005) reported dietary lysine to energy ratios of 0.84, 1.11, 0.57 and 0.80 for carcass weight, dressing percentage, breast meat and drumstick weights, respectively. Mbajiorgu *et al*. (2011) reported that dietary lysine to energy ratios of 1.36 and 0.81 optimized carcass and breast meat weights, respectively.

The pH values at different times after slaughter showed that dietary lysine to energy ratio had no influence on them. This is in line with what was observed by Castell *et al.* (1994) and Witte *et al.* (2000) in pork.

Breast meat tenderness, juiciness and flavour were optimized at dietary lysine to energy ratios of 0.981, 0.979 and 0.815, respectively. Tenderness is based on ease of chewing which is influenced many factors. Among them, the fibrous nature of muscles contributes to chewing resistance (Gerrard and Grant, 2003). The effect of dietary lysine to energy ratio on breast meat tenderness in the present study differs from those observed by Castell *et al*. (1994) in pork; these authors indicated that pork became tougher as dietary lysine to energy ratio increased from 1.6 to 3.3 g/Mcal of digestible energy. This might be due to the animals used, the muscular fibre of the chickens differ from those of pigs. Amino acids play a major role in eliciting the characteristics of juiciness and flavour of foods (Kobayashi *et al*., 2007). Previous studies (Fujimura *et al*., 1995; Fujimura *et al*., 1996) identified three compounds (free glutamic acid, 5'-inosinic acid and potassium ion) as the taste active components in chicken meat extracts. Glutamic and 5'-inosinic acid (also known as *umami* taste), are favourites among consumers as they constitute a characteristic taste of chicken meat. Lysine is degraded through saccharopine pathway. When lysine is degraded two moles of glutamic acid are produced (Kobayashi *et al*., 2007). This is a basic component of juiciness and flavour. It can, thus, imply that at dietary lysine to energy ratio of 0.825 this compound is adequately activated.

Results of the effect of dietary lysine to energy ratio on the haematological parameters in the present study showed that dietary treatments had no effect on the all the parameters measured. However, the haematological values were within the range for indigenous chickens (Elagib and Ahmed, 2011; Islam *et al*., 2004). It could, thus, be concluded that in a diet containing 12 g of lysine per kg DM and 240 g of CP/kg DM lysine to energy ratios of 0.86 to 1.09 are adequate for haematological parameters of female Venda chickens aged 91 days.

CHAPTER FIVE

OPTIMAL RESPONSES TO DIETARY LYSINE TO ENERGY RATIO OF UNSEXED VENDA CHICKENS AGED ONE TO THIRTEEN WEEKS

5.01 Optimal responses to dietary lysine to energy ratio in unsexed Venda chickens aged one to seven weeks

Results of the effect of dietary lysine to energy ratio on optimal feed intake, growth rate, live weight, apparent metabolisable energy and nitrogen retention of female Venda chickens aged one to seven weeks are presented in Table 5.01. Optimal feed and ME intakes decreased as the dietary lysine to energy ratio increased (Figures 5.01 and 5.04, respectively). Thus, there were negative and very strong relationships between dietary lysine to energy ratio and the optimal feed (r^2 = 0.978) and ME (r^2 = 0.950) intakes of Venda chickens aged one to seven weeks. This is similar to the findings of Dozier *et al*. (2007) who reported that increases in apparent metabolasible energy resulted in a decrease in feed consumption of broiler chickens. Nahashon *et al.* (2006) observed that consumption of Pearl gray guinea fowl pullets were higher in birds fed diets low in energy levels. This might be because small amounts of diets high in energy value were able to satisfy chicken energy requirements (Leeson *et al*., 1996). However, Mbajiorgu *et al*. (2011) did not observe a decrease in the feed intake with an increase in dietary lysine to energy ratio of unsexed Venda chickens aged one to six weeks.

Results of the optimal responses indicate that optimal growth rate, live weight and nitrogen retention were optimized at dietary lysine to energy ratios of 0.731 (r^2 = 0.978), 0.769 (r^2 = 0.992) and 0.826 (r^2 = 0.948) (Figures 5.02, 5.03 and 5.05, respectively and Table 5.02). Optimal growth rate, live weight and nitrogen retention increased until a point was reached, where thereafter, increasing the dietary lysine to energy ratio resulted in decreases of the variable. Mbajiorgu (2010) and Tang *et al*. (2007) observed similar trends in unsexed Venda chickens and broiler chickens, respectively.

Table 5.01 Dietary lysine to energy ratio for optimal feed intake (g/bird/day), growth rate (g/bird/day), live weight (g/bird aged 42 days), apparent metabolisable energy (MJ/kg DM) and nitrogen retention (g/bird/day) of female Venda chickens aged one to eight weeks

	Dietary lysine level (g/kg DM)			
Variable	8	9	11	12
Optimum feed intake	40.536	39.179	35.632	30.684
L:E ratio for optimal intake	0.722	0.719	0.817	0.908
Optimum growth rate	8.982	8.934	8.846	8.665
L:E ratio for optimal growth rate	0.719	0.742	0.883	0.962
Optimum live weight	440.084	438.019	433.16	406.952
L:E ratio for optimal live weight	0.719	0.742	0.878	0.996
Optimum ME intake	10.65	10.524	9.218	8.967
L:E ratio for optimal ME intake	0.67	0.754	0.895	0.963
Optimum nitrogen retention	1.634	2.487	1.502	1.281
L:E ratio for optimal nitrogen retention	0.712	0.789	0.955	0.951

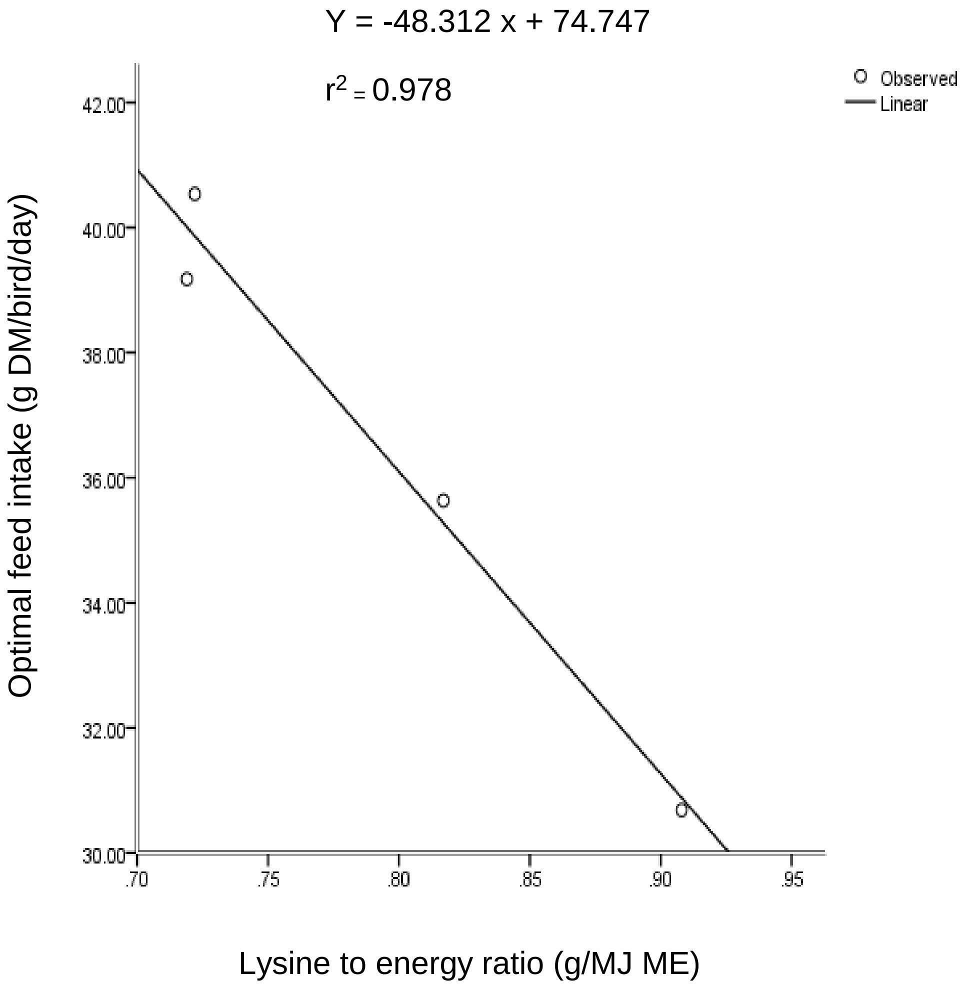


Figure 5.01 Relationship between optimal dietary lysine to energy ratio and optimal feed intake of unsexed Venda chickens aged one to seven weeks

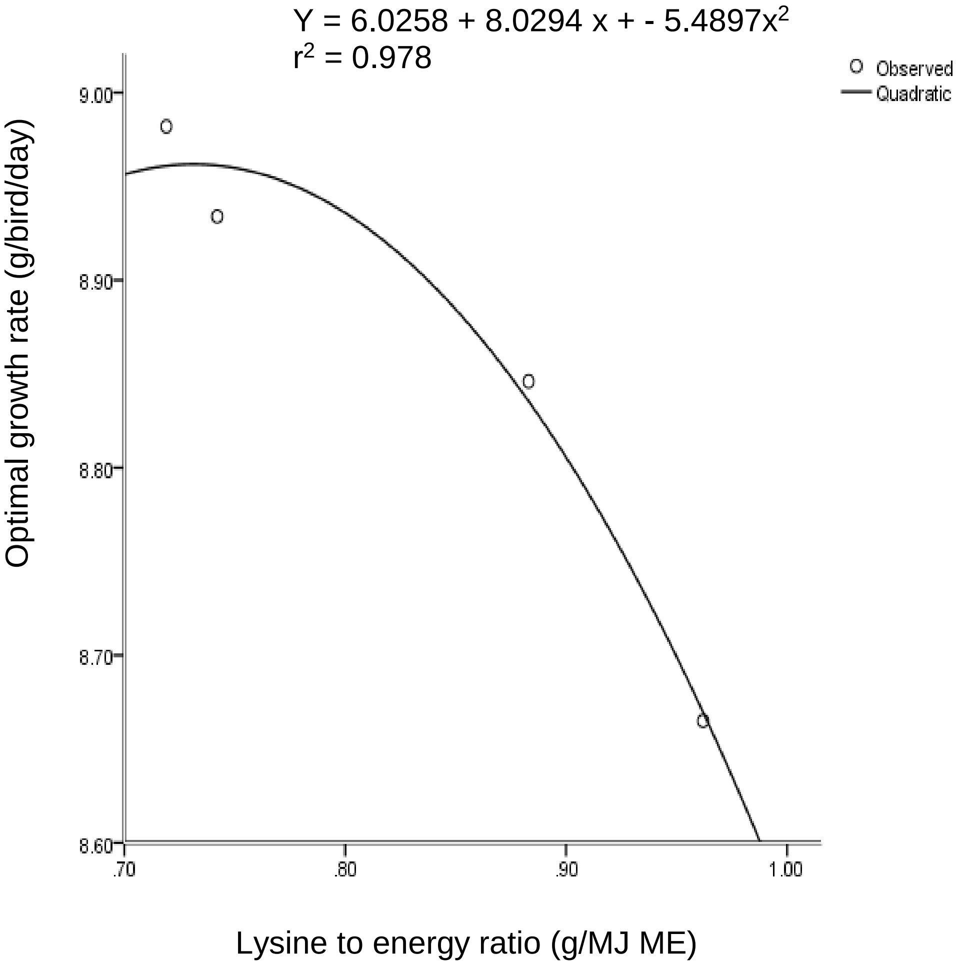


Figure 5.02 Relationship between optimal dietary lysine to energy ratio and optimal growth rate of unsexed Venda chickens aged one to seven weeks

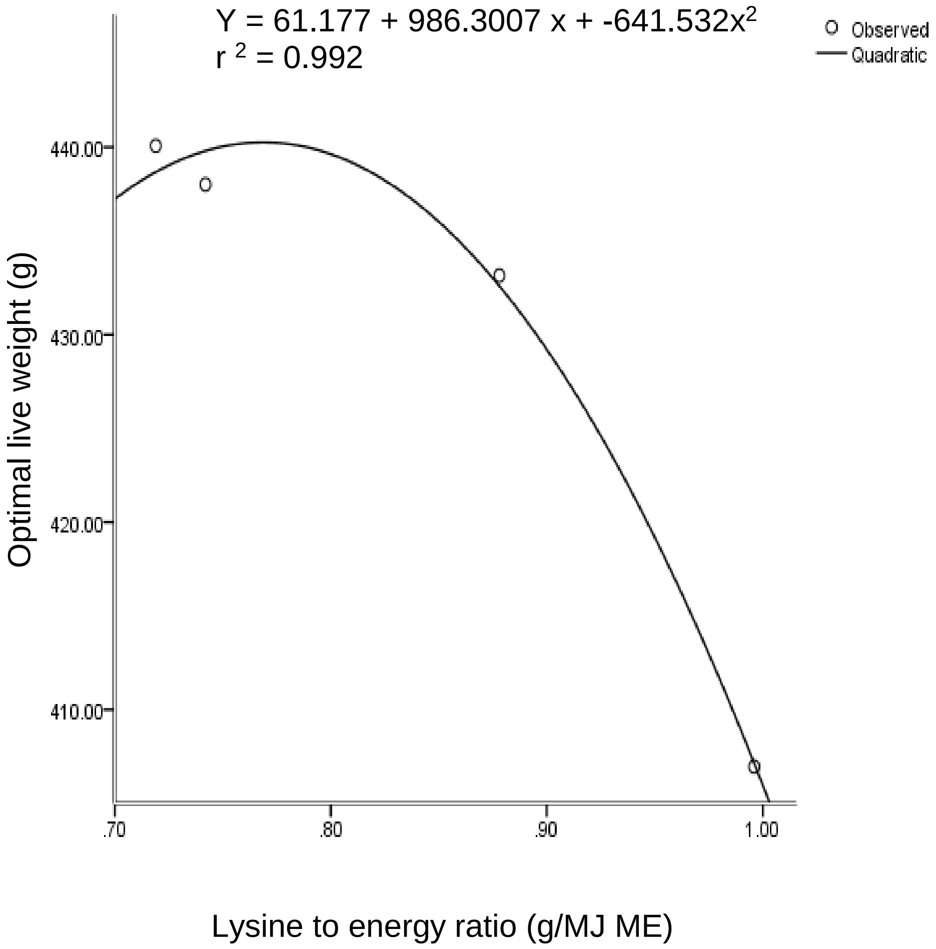


Figure 5.03 Relationship between optimal dietary lysine to energy ratio and optimal live weight of unsexed Venda chickens aged one to seven weeks

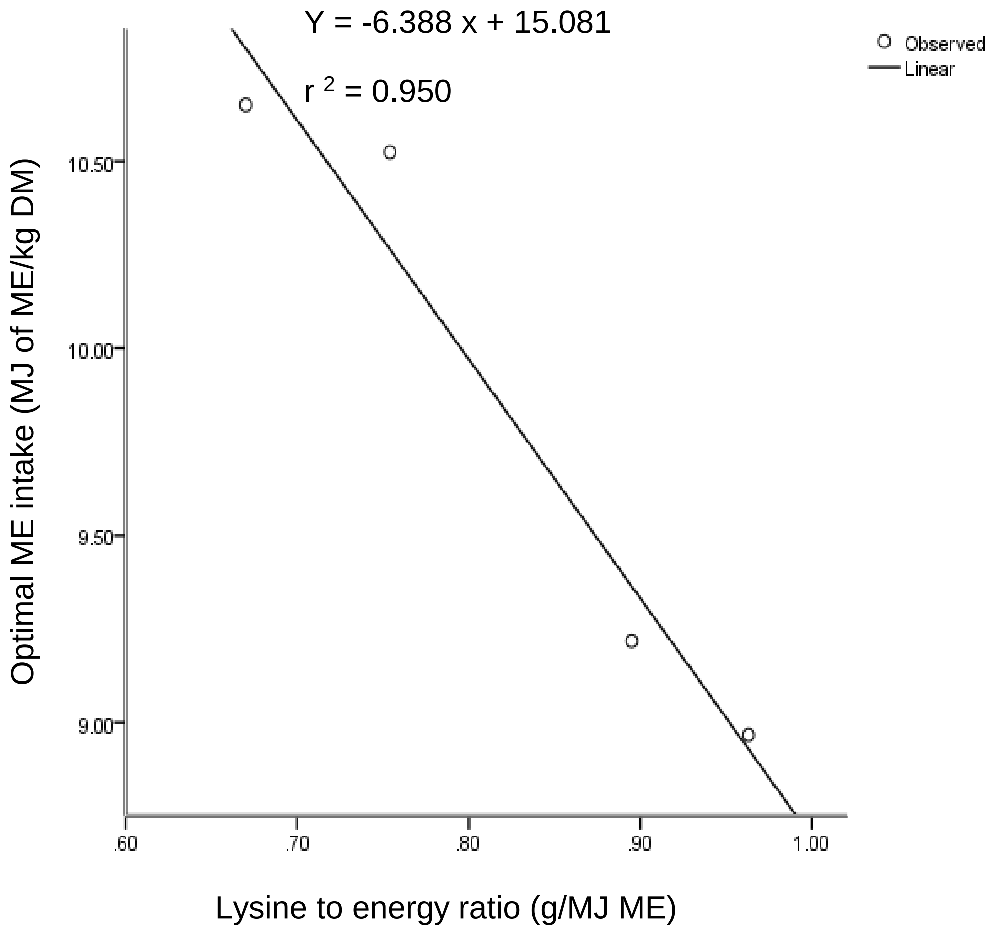


Figure 5.04 Relationship between optimal dietary lysine to energy ratio and optimal ME intake of unsexed Venda chickens aged one to seven weeks

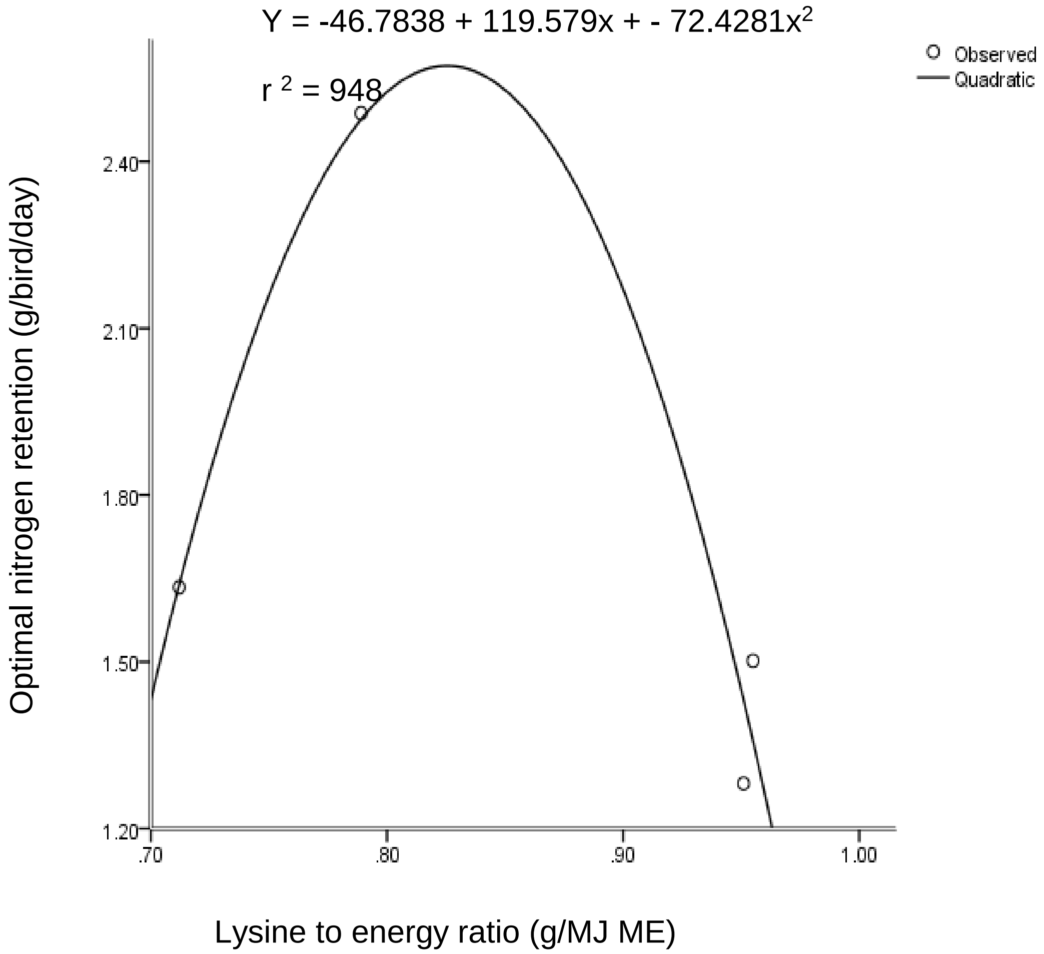


Figure 5.05 Relationship between optimal dietary lysine to energy ratio and optimal nitrogen retention of unsexed Venda chickens aged one to seven weeks

Table 5.02 Relationship between optimal dietary lysine to energy ratio and optimal growth rate, optimal live weight and optimal nitrogen retention in unsexed Venda chickens aged one to seven weeks

Variable	Formula	$r^{2`}$	L:E ratio	Optimal Y- level
Optimal growth rate	$Y = 6.0258 + 8.0294x + - 5.4897x^2$	0.978	0.731	8.962
Optimal live weight	$Y = 61.177 + 986.301x + - 641.53x^2$	0.992	0.769	440.27
Optimal N-retention	$Y = -46.784 + 119.58x + - 72.428x^2$	0.948	0.826	2.573

L:E ratio : Lysine to energy ratio for optimal variable

$r^{2`}$: coefficient of determination

5.02 Optimal responses to dietary lysine to energy ratio in female Venda chickens aged eight to 13 weeks

Presented in Table 5.03 are the results of the effect of dietary lysine to energy ratio on optimal feed intake, growth rate, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, dressing percentage and breast meat weights of female Venda chickens aged eight to 13 weeks. Optimal feed intakes decreased with increase in dietary lysine to energy ratio (Figure 5.06). Thus, there was a negative and strong relationship between optimal feed intake and dietary lysine to energy ratio. This is similar to the findings of Nahashon *et al.* (2006) and Veldkamp *et al.* (2005) who observed that broiler chickens eat to satisfy their energy requirements. Leeson (2000) reported that broiler chickens will eat less when the dietary energy level is high. These findings suggest that feed intake in these chickens can also be linked to the dietary energy level and hence birds attempt to adjust their feed intakes according to the energy level of the diet. This is contrary to the findings of Mbajiorgu *et al*. (2011) on Venda chickens aged seven to 13 weeks. This might be because the authors used only one dietary energy level and four lysine levels in formulating the diets used in their study as opposed to four dietary energy and four lysine levels used in the present study.

No clear relationships were observed between dietary lysine to energy ratio and optimal growth rate, FCR, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, dressing percentage and breast meat weights of female Venda chickens aged eight to 13 weeks. The reasons for these results are not quite clear. There is, thus, need for further research on the subject.

Table 5.03 Dietary lysine to energy ratio for optimal feed intake (g/bird/day), growth rate (g/bird/day), live weight (g/bird aged 91 days), apparent metabolisable energy (MJ/kg DM) and nitrogen retention (g/bird/day) of female Venda chickens aged eight to 13 weeks

	Dietary lysine level (g/kg DM)			
	8	9	11	12
Optimum feed intake	109.9	97.39	73.23	82.55
L:E ratio for optimal feed intake	0.672	0.798	0.964	0.996
Optimum growth rate	17.89	22.61	13.28	19.95
L:E ratio for optimal growth rate	0.646	0.732	0.902	0.980
Optimum FCR	6.05	3.92	5.27	3.76
L:E ratio for optimal FCR	0.639	0.613	0.743	0.991
Optimum live weight	1121.8	1176.63	1070.44	1199.2
L:E ratio for optimal live weight	0.649	0.712	0.894	1.010
Optimum ME intake	11.33	10.83	10.64	12.17
L:E ratio for optimal ME intake	0.655	0.750	0.912	0.957
Optimum nitrogen retention	1.63	1.69	2.05	2.98
L:E ratio for optimal nitrogen retention	0.682	0.777	0.970	0.993
Optimum carcass weight	1239.03	1091	1055.01	1082.76
L:E ratio for dietary L:E ratio	0.656	0.742	0.9	0.992
Optimum dressing percentage	90.89	87.78	91.17	91.52
L:E ratio for dietary L:E ratio	0.664	0.75	0.91	0.974
Optimum breast meat weight	210.33	239.42	128.73	219.51
L:E ratio for dietary L:E ratio	0.67	0.73	0.89	0.99

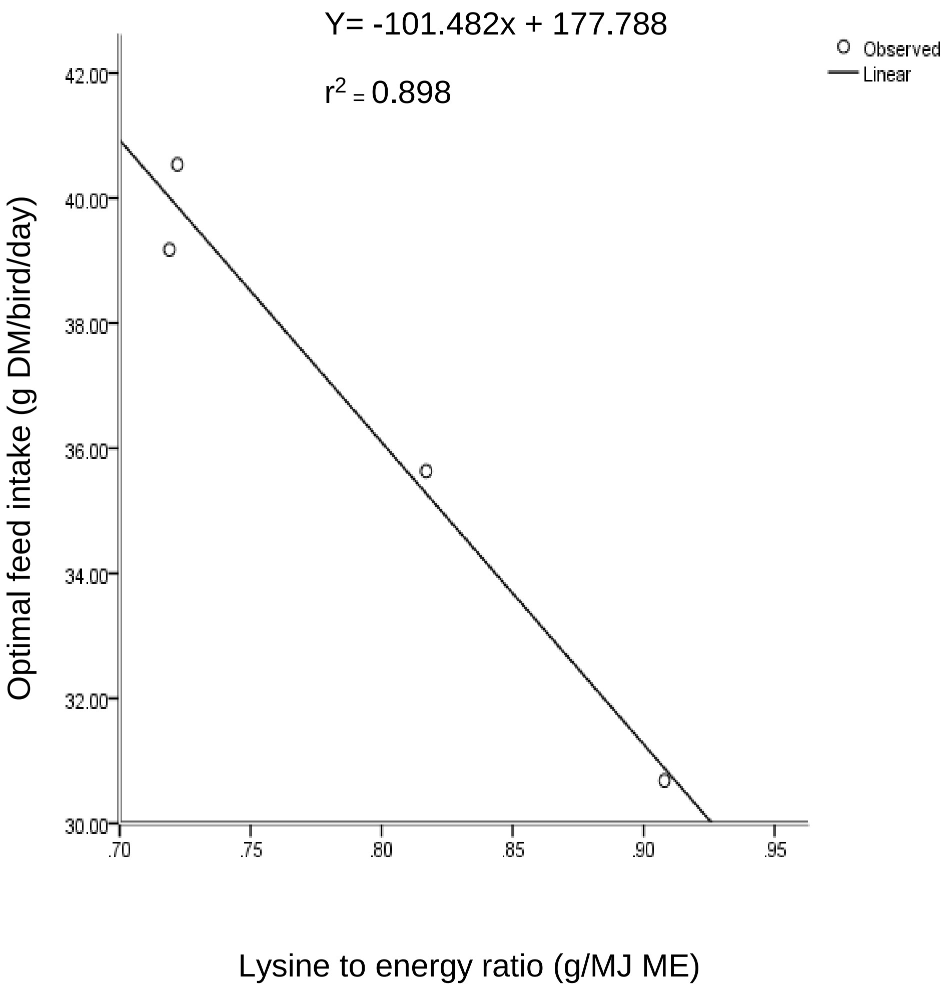


Figure 5.06 Relationship between optimal dietary lysine to energy ratio and optimal feed intake of female Venda chickens aged eight to 13 weeks

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.01 Conclusions

This study showed that varying dietary lysine to energy ratio affected the productivity, carcass characteristics, sensory attributes and blood profiles of indigenous Venda chickens aged one to 13 weeks.

Similar dietary treatments were used in Experiments 1 and 5. These had a similar lysine content of 8 g/kg DM but different energy levels of 11, 12, 13 and 14 MJ of ME/kg DM, thus forming dietary lysine to energy ratios of 0.72, 0.67, 0.62 and 0.57, respectively. In Experiment 1, feed intake, growth rate, live weight and apparent metabolisable energy of unsexed Venda chickens aged one to seven weeks were optimized at different dietary lysine to energy ratios of 0.722, 0.719, 0.719 and 0.670, respectively. However, in Experiment 5 which had similar dietary treatments to those used in Experiment 1, lower dietary lysine to energy ratios of 0.672, 0.646, 0.649 and 0.655 optimized feed intakes, growth rate, live weight and apparent metabolisable energy of female Venda chickens aged eight to 13 weeks, respectively. Carcass weight, dressing percentage, breast meat, drumstick and thigh weights of female Venda chickens aged eight to 13 weeks were optimized at different dietary lysine to energy ratios of 0.656, 0.664, 0.669, 0.665 and 0.659, respectively. Similarly, drip loss at slaughtering, breast meat juiciness and flavour of female Venda chickens aged 13 weeks were optimized at different dietary lysine to energy ratios of 0.631, 0.708 and 0.623, respectively. Dietary lysine to energy ratios of 0.556 and 0.609 optimized haemoglobin and pack cell volume, respectively. It is concluded that varying dietary lysine to energy ratios optimized different production variables.

Experiments 2 and 6 used similar dietary treatments. They had a similar lysine content of 9 g/kg DM but different energy levels of 11, 12, 13 and 14 MJ of ME/kg DM, thus forming dietary lysine to energy ratios of 0.82, 0.75, 0.69 and 0.64, respectively. In Experiment 2, dietary lysine to energy ratios of 0.719, 0.742, 0.788 and 0.742 optimized feed intake, growth rate, feed conversion ratio and live weight, respectively, in unsexed Venda chickens aged one to seven weeks. In Experiment 6 which had similar dietary treatments to those used in Experiment 2, lower ratios of 0.732, 0.613 and 0.712 optimized growth rate, feed conversion ratio and live weight of female Venda chickens aged eight to 13 weeks, respectively. However, feed intake was optimized at a higher dietary lysine to energy ratio of 0.798 for chickens aged eight to

13 weeks as opposed to a ratio of 0.719 which optimized feed intake of unsexed Venda chickens aged one to seven weeks. In a diet containing 9 g of lysine per kg DM, 12.13 MJ of ME/kg DM and 180 g of CP/kg DM, dietary lysine to energy ratios of 0.742 and 0.712 supported optimal live weights in Venda chickens aged one to seven and eight to 13 weeks, respectively. Carcass weight, dressing percentage, breast meat weight, red blood cell and haemoglobin values of female Venda chickens aged 13 weeks were optimized at different dietary lysine to energy ratios of 0.742, 0.753, 0.729, 0.748 and 0.634, respectively.

Experiments 3 and 7 used similar dietary treatments. These dietary treatments were based on a 11 g/kg DM of lysine but different energy levels of 11, 12, 13 and 14 MJ of ME/kg DM, thus forming dietary lysine to energy ratios of 1.00, 0.92, 0.85 and 0.79, respectively. In experiment 3, feed intake, growth rates, FCR and live weight of unsexed Venda chickens aged one to seven weeks were optimized at different dietary lysine to energy ratios of 0.817, 0.886. 0.920 and 0.878, respectively. However, in Experiment 7 feed intake, growth rates, FCR and live weight of female Venda chickens aged eight to 13 weeks were optimized at higher dietary lysine to energy ratios of 0.964, 0.902, 0.743 and 0.894, respectively. Carcass weight, breast meat, drumstick weights, drip loss, breast meat juiciness, flavour, white blood cell and haemoglobin values were optimized at different dietary lysine to energy ratios of 0.900, 0.890, 0.910, 1.090, 0.934, 0.895, 0.927 and 0.996, respectively, in female Venda chickens aged 13 weeks.

A similar lysine content of 12 g/kg DM but different energy levels of 11, 12, 13 and 14 MJ of ME/kg DM, forming dietary lysine to energy ratios of 1.09, 1.00, 0.92 and 0.86, respectively, were used in Experiments 4 and 8. In Experiment 4, dietary lysine to energy ratios of 0.908, 0.962, 1.023 and 0.996 optimized feed intake, growth rate, FCR and live weight gain, respectively, in unsexed Venda chickens aged one to seven weeks. However, in Experiment 8, higher dietary lysine to energy ratios of 0.996, 0.980 and 1.010 optimized feed intake, growth rate and live weight in female Venda chickens aged eight to 13 weeks. A dietary lysine to energy ratio of 0.991 for optimal FCR in female Venda chickens aged eight to 13 weeks was, however, lower than a ratio of 1.023 which supported optimal FCR of unsexed Venda chickens aged one to seven weeks. Carcass weight, dressing percentage, breast meat, drumstick weights, breast meat tenderness, juiciness and flavour of female Venda chickens aged 13 weeks were optimized at different dietary to energy ratios of 0.992, 0.974, 0.991, 0.992, 0.981, 0.979 and 0.815, respectively.

Optimal responses to dietary lysine to energy ratio in unsexed Venda chickens aged one to seven weeks indicated negative and strong relationships existed between dietary lysine to energy ratio and the optimal feed and ME intakes of Venda chickens. Also, optimal responses indicated that growth rate, live weight and nitrogen retention of unsexed Venda chickens were optimized at dietary lysine to energy ratios of 0.731, 0.769 and 0.826, respectively. Optimal responses to dietary lysine to energy ratio in female Venda chickens aged eight to 13 weeks showed that there was a negative and strong relationship between optimal feed intake and dietary lysine to energy ratio. No clear relationships were observed between dietary lysine to energy ratio and optimal growth rate, FCR, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, dressing percentage and breast meat weights of female Venda chickens aged eight to 13 weeks.

When diets with lower dietary lysine to energy ratios (0.57 to 0.82) were used, growth rates and live weight of unsexed Venda chickens aged one to seven weeks were optimized at high lysine to energy ratios than those of female Venda chickens aged eight to 13 weeks. However, when diets with higher dietary lysine to energy ratios (0.79 to 1.09) were used, growth rates and live weights of female Venda chickens aged eight to 13 weeks were optimized at higher lysine to energy ratios than those of unsexed Venda chickens aged one to seven weeks.

6.02 Recommendations

Different production parameters of Venda chickens were optimized at different lysine to energy ratios. This may imply that the nutrient requirements of indigenous Venda chickens are dynamic and dependent on the production parameters of interest. This has implications on ration formulations for these chickens.

In a diet containing 8 g of lysine per kg DM, 11.13 MJ of ME/kg DM and 150 g of CP/kg DM, dietary lysine to energy ratios of 0.719 and 0.649 are recommended for optimal live weight of Venda chickens aged one to seven and eight to 13 weeks, respectively. In a diet containing 9 g of lysine per kg DM, 12.13 MJ of ME/kg DM and 180 g of CP/kg DM, dietary lysine to energy ratios of 0.742 and 0.712 are recommended for optimal live weight of Venda chickens aged one to seven and eight to 13 weeks, respectively. In a diet containing 11 g of lysine per kg DM, 12.51 MJ of ME/kg DM and 220 g of CP/kg DM, dietary lysine to energy ratios of 0.878 and 0.894 are recommended for optimal live weight of Venda chickens aged one to seven and eight to 13 weeks, respectively. In a diet containing 12 g of lysine per kg DM, 12.05 MJ of ME/kg DM and 240 g of CP/kg DM, dietary lysine to energy ratios of 0.996 and 1.010 are recommended for optimal live weight of Venda chickens aged one to seven and eight to 13 weeks, respectively.

More research is suggested to fully understand the effect of dietary lysine to energy ratio on optimal productivity of indigenous Venda chickens aged eight to 13 weeks as no clear and strong relationships were observed in the production parameters, carcass characteristics, breast meat pH and the haematological values.

CHAPTER SEVEN

REFERENCES

Abdallah, A., Ebdel-Khalik, A., Shahaan, M. and N. Radwan. 2011. Optimal ratio between digestible lysine and metabolisable energy in broler diets formulated based on ideal amino acid profile. XIIth European Poultry conference.

Abdou, I. and J.G. Bell. 1992. Dynamique de la volaille villageoise dans la région de Keita au Niger. In Village Poultry Production in Africa, Proceedings of an International Workshop Held in Rabat. Morocco, 7–11 May 1992. pp. 6–11.

Adeyemo, G. O. and O.G. Longe. 2007. Effects of graded levels of cottonseed cake on performance, haematological and carcass characteristics of broilers fed from day old to 8 weeks of age. *African Journal of Biotechnology* 6 (8): 1064-1071.

Aftab, U. 2007. Effect of graded levels of dietary protein, lysine, methionine+ cystine, and threonine on the performance of broilers fed low-energy diets under tropical conditions. PhD thesis, Quid-e-Azam University, Islamabad, Pakistan

Aini, I. 1990. Indigenous chicken production in South-east Asia. *World Poultry Science Journal* 46: 51-57.

Akishinonomiya, F., Miyake, T., Takada, M., Shingu, R., Endo, T., Gojobori, T., Kondo, N., and S. Ohno. 1996. Monophyletic origin and unique dispersal patterns of domestic fowls. Proceedings of National Academy of Sciences of the United States of America. pp. 6792–6795.

Alabi O.J., J.W. Ng`ambi and D. Norris. 2012. Effect of egg weight on physical egg parameters and hatchability of indigenous Venda chickens. *Asian Journal of Animal and Veterinary Advances 7: 166-172.*

Alders, R.G., Spradbrow, P.B., Young, M.P., Mata, B.V., Meers, J., Lobo, Q.J.P. and J.W. Copland. 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” 20-23rd August 2001, pp. 199-205, Copenhagen, Denmark.

American Meat Science Association, 1995. Research Guidelines for Cookery, Sensory Evaluation and Instrumental Measurements of Fresh Meat. American Meat Science Association, Cicago, IL., USA.

AOAC 2005. Official Method of Analysis of Association of Official Analytical Chemists, International (18th ed.), Washington D.C.

Apple, J. K., C.V., Maxwell, B., deRodas, H.B., Watson and Z.B. Johnson. 2000. Effect of magnesium mica on performance and carcass quality of growing-finishing swine. *Journal of Animal Science* 78: 2135-2143.

Apple, J.K., Maxwell, C.V., Brown, D.C., Friesen, K.G., Musser, R.E. Johnson, Z.B., and T.A. Armstrong. 2004. Effects of dietary lysine and energy density on performance and carcass characteristics of finishing pigs fed ractopamine. *Journal of Animal Science* 82: 3277-3287.

Araujo, L.F., Junqueira, O.F. and J.H. Stringhini. 2005. Energy and lysine for broilers from 44 to 55 days of age. *Brazilian Journal of Poultry Science* 7(4): 237-241

Baker, D.H., A.B. Batal, T.M. Parr, N.R. Augspurger and C.M. Parsons. 2002. Ideal ratio (relative to lysine) of tryptophan, threonine, isoleucine, and valine for chicks during the second and third weeks post-hatch. *Poultry Science* 81: 485-494.

Bartov, I. 1987. Effect of early nutrition on fattening and growth of broiler chicks at 7 weeks of age. *British Poultry Science* 28(3): 507-518.

Battula, V., Schilling, M.W., Vizzier-Thaxton, Y., Behrends, J.M.. Williams, J.B. and T.B. Schmidt. 2008. The effects of low-atmosphere stunning and deboning time on broiler breast meat quality. *Poultry Science* 87:1202-1210.

Ben Larbi, M. M’hamdi, N. and B. Haddad. 2013. Indigenous chicken production systems in villages in the south of Tunisia. *Livestock Research for Rural Development.* 25:99*.*

Berri, C., Besnard, J. and C. Relandeau. 2008. Increasing dietary lysine increases final pH and decreases drip loss of broiler breast meat. *Poultry Science* 87: 480-484.

Bhartti, B.M., Qureshi, M.S., Sahota, A.W. and M. Ashraf. 1990. Evolving of a chicken with potential of higher meat and egg yield for rural areas of Pakistan. Proceedings of 3rd International Congress. Pakistan Veterinary Medical Association. November 28-29, Islamabad, pp. 340-345.

Boleman, S.J., Miller, R.K., Buyck, M.J., Cross, H.R. and J.W. Savell. 1996. Influence of realimentation of mature cows on maturity, colour, collagen solubility, and sensory characteristics. *Journal of Animal Science* 74: 2187-2194.

Botha, S.S.C., Hoffman, L.C. and T.J. Britz. 2008. Effects of post mortem temperature on rigor tension, shortening and pH in ostrich muscle. *South African Journal of Animal Science* 38: 184-192.

Bruce, H.L., Ball, R.O. and D.N. Mowat. 1991. Effects of compensatory growth on protein metabolism and meat tenderness of beef steers. *Canadian Journal of Animal Science* 71: 659-668.

Carpenter, C.E., Solomon, M.B., Snowder, G.D., Cockett, N.E. and J.R. Busboom. 1997. Effects of electrical stimulation and conditioning, calcium chloride injection and aging on the acceptability of callipyge and normal lamb. *Sheep and Goat Research Journal* 13: 127-134.

Castell, A.G., Cliplef, R.L., Poste-Flynn, L.M. and G. Butler. 1994. Performance, carcass and pork characteristics of castrates and gilts self-fed diets differing in protein content and lysine:energy ratio. *Canadian Journal of Animal Science* 74: 519–528.

Chemjor, W., 1998. Energy and protein requirements of indigenous chickens of Kenya. Msc thesis, Egerton University, Kenya, pp. 83.

Chen, C., Sander, J.E. and N.M. Dale. 2003. The effect of dietary lysine deficiency on immune response to Newcastle disease vaccination in chicken. *Avian Disease* 47: 1341–1351.

Collias, N.E. and E.C. Collias. 1996. Social organization of a red junglefowl, *Gallus gallus*, population related to evolution theory. *Animal Behaviour* 51: 1337–1354.

Collier, P. Radwan, S. Wangwe, S. and A. Wagner. 1986. Labour and poverty in rural Tanzania. In: Ujamaa and Rural Development in the United Republic of Tanzania. Oxford. United Kingdom, Oxford University Press, pp. 143.

Corzo, A., Moran Jr. E.T. and D. Hoehler. 2002. Lysine need of heavy broiler males applying the ideal protein concept.. *Poultry Science* 81:1863–1868.

D'Mello, J.P.F. 1994. Amino Acids In Farm Animal Nutrition. CAB International, Wallingford, Oxon, UK.

D'Souza, D.N., Warner, R.D., Leury, B.J. and F.R. Dunshea. 1998. The effect of dietary magnesium aspartate supplementation on pork quality. *Journal Animal Science* 76: 104-109.

Dairo, F.A.S., Adesehinwa, A.O.K., Oluwasola, T.A. and J. A. Oluyemi. 2010. High and low dietary energy and protein levels for broiler chickens. *African Journal of Agricultural Research* 5 (15) : 2030-2038.

Dozier III, W.A., Purswell, J.L., Kidd, M.T., Corzo, A. and S.L. Branton. 2007. Apparent metabolizable energy needs of broilers from two to four kilograms as influenced by ambient temperature. *Journal of Applied Poultry Research* 16: 206–218.

Du, M. and D.U. Ahn. 2002. Effect of dietary conjugated linoleic acid on the growth rate of live birds and on the abdominal fat content and quality of broiler meat. *Poultry Science* 81: 428-433.

Dublecz, K., Vincze, G., Szüts, L., Wagner, L., Pal, A. and F.W. Edens, 1997. Potential for organic selenium to replace selenite in poultry diets. *Zootecnea. International* 20: 28-31.

Edozien J.C. and B.R. Switzer. 1977. Effect of dietary protein fat and energy on blood haemoglobin and haematocit in rats. *Journal of Nutrition* 107: 1016-1021.

Egbunike, G.N., Agiang, E.A., Owosibo, A.O. and A.A. Fatufe. 2009. Effect of protein on performance and haematology of broilers fed cassava peel-based diets. Archivos de *Zootecnea. 58: 655-662.*

Eits, R.M., Kwakkel, R.P., Verstegen, M.W.A., Stoutjesdijk, P. and K.H. de Greef. 2002. Protein and lipid deposition rates in male broiler chickens: Separate responses to amino acids and protein-free energy. *Poultry Science* 81: 472-480.

Elagib, H.A.A. and A.D.A. Ahmed. 2011. Comparative study on haematological values of blood of indigenous chickens in Sudan. Asian Journal of *Poultry Science* 5: 41–45

Emmert, J.L. and D.H. Baker. 1997. Use of the ideal protein concept for precision formulation of amino acid levels in broiler diets. *Journal of Applied Poultry Science Research* 6: 462-470.

Eriksson, J., Larson, G., Gunnarsson, U., Bed'hom, B., Tixier-Boichard M., Strömstedt, L., Wright, D., Jungerius, A., Vereijken, A., Randi, E., Jensen, P. and Andersson, L. 2008. Identification of the *Yellow skin* gene reveals a hybrid origin of the domestic chicken. PLoS Genetics 4(2): e1000010. doi:10.1371/journal.pgen.1000010.

FAO, 1997. Human Nutrition in the Developing World. In: Latham M.C. FAO Food and Nutrition. Series No. 29.

FAO, 2002. World Agriculture Towards 2015/2030. Rome,Italy.

FAO, 2008. An Analysis of the Poultry Sector in Ethiopia. Poultry Sector Country Review. FAO. Rome. Italy. pp. 48.

Fatufe, A.A., Timmler, R. and M. Rodehutscord. 2004. Response to lysine intake in composition of body weight gain and efficiency of lysine utilization of growing male chickens from two genotypes. *Poultry Science* 83: 1314-1324.

Fujimura, S., Kawano, S., Koga, H., Takeda, H., Kadowaki, M. and T. Ishibashi. 1995. Identification of taste-active components in the chicken meat extract by omission test involvement of glutamic acid, IMP and potassium ion. *Animal Science Technology* (Japan) 66: 43-51.

Fujimura, S., Koga, H., Takeda, H., Tone, N., Kadowaki, M. and T. Ishibashi. 1996. Role of taste-active components, glutamic acid, 5'-inosinic acid and potassium ion in taste of chicken meat extract. *Animal Science Technology* (Japan) 67: 423-429.

Gerrard, D.E. and Grant, A.L. 2003. Principles of Animal Growth and Development. Kendall/Hunt Publishing, UK.

Ghaffari, M., Shivazard, M., Zaghari M. and R. Taherkhani. 2007. Effect of energy of diet formulation on total or digestible amino acid basis on broiler performance and carcass traits. *Asian Journal of Poultry Science* 1(1): 16–21.

Gichohi, C.M. and J.G. Maina. 1992. Poultry production and marketing, Ministry of Livestock Production. Paper presented in Nairobi-Kenya, Nov., 23-27.

Gondwe, T.N.P., 2004. Characterization of local chicken in low input-low output production systems: Is there scope for appropriate production and breeding strategies in Malawi? PhD thesis, Georg-August-Universität Göttingen, Germany.

Gonzalez-a, M.J. and G.M. Pesti. 1993. Evaluation of the protein to energy ratio concept in broiler and turkey nutrition. *Poultry Science* 72: 2115-2123.

Guèye, E.F. 2003. Production and consumption trends in Africa. *World Poultry Science* 19(11): 12-14.

Guèye, E.F., 2009. The role of networks in information dissemination to family poultry farmers. World's *Poultry Science Journal*., 65: 115-123.

Han, Y. and Baker, D.H. 1991. Lysine requirement of fast and slow growing broiler chicks. *Poultry Science* 70: 2108-2114.

Han, Y. and D.H. Baker. 1993. Effects of sex, heat stress, body weight and genetic strain on the dietary lysine requirement of broiler chicks. *Poultry Science* 72: 701-708.

Han, Y. and D.H. Baker. 1994. Digestible lysine requirement of male and female broiler chicks during the period three to six weeks posthatching. *Poultry Science* 73: 1739 –1745.

Hind A.A, Elagib and the late E.A. Elzubeir. 2012. The effect of feeding different levels of lysine and energy on broiler performance under high environmental temperature. *Journal of Agricultural and Veterinary Sciences* 5 (2): 121-131

Holsheimer, J.P. and E.W. Ruesink. 1998. Effect of performance, carcass composition, yield and financial return of dietary energy and lysine levels in starter and finisher diets fed to broiler. *Poultry Science* 77: 806-815.

Holsheimer, J.P. and Veerkamp, C.H. 1992. Effect of dietary energy, protein, and lysine content on performance and yields of two strains of male broiler chicks. *Poultry Science* 71: 872-879.

Islam, M.S., Lucky, N.S., Islam, M.R., Ahad, A., Das, B.R., Rahman, M.M. and, M.S.I. Siddiui 2004. Haematological parameter of fayoumi, assil and local chicken reared in Sylhet region in Bangladesh. *International Journal of Poultry Science* 3: 144-147.

Jackson, S., Summers, J.D. and S. Leesons. 1982. Effect of dietary protein and energy on broiler performance and production cost. *Poultry Science* 61: 2232- 2240.

Jaturasitha, S., Srikanchai, T., Kreuzer, M. and M. Wicke 2008. Differences in carcass and meat characteristics between chicken indigenous to Northern Thailand (Black-boned and Thai native) and imported extensive breeds (Bresse and Rhode Island Red). *Poultry Science* 87: 160−169.

Kelly, L. 2006. The Little Chicken Book. Caledon, Ontario: Blue Barn Publishing, UK.

Kerr, B.J., Kidd, M.T., Halpin, K.M., McWard, G.W. and C.L. Quarles 1999. Lysine level increases live performance and breast yield in male broilers. *Journal of Applied Poultry Research* 8: 381-390.

Kidd, M.T. and B.I. Fancher. 2001. Lysine needs of starting chicks and subsequent effects during the growth period. *Journal of Applied Poultry Research* 10: 385-393.

Kidd, M.T., Kerr, B.J. and N.B. Anthony. 1997. Dietary interactions between lysine and threonine in broilers. *Poultry Science* 76: 608-614.

King'ori, A.M. 2004. The protein and energy requirements of indigenous chickens (*Gallus domesticus*) of Kenya. Ph.D. Thesis. Egerton University, Kenya, pp: 93

King'ori, A.M., Tuitoek, J.K. Muiruri, H.K. and A.M. Wachira. 2007. Protein intake of growing indigenous chickens on free-range and their response to supplementation. *International Journal of Poultry Science* 6: 617-621.

King'ori, A.M., Tuitoek, J.K., Muiruri, H.K. and A.M. Wachira. 2003. Protein requirements of growing indigenous chickens during the 14-21 weeks growing period. *South African Journal Animal Science* 33 (2): 78-82.

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

Knowles, T.A. and L.L. Southerns. 1998. The lysine requirement and ratio of total sulfur amino acids to lysine for chicks fed adequate or inadequate lysine. *Poultry Science* 77: 564–569.

Kobayashi H., Eguchi A., Takano W., Shibata M., Kadowaki M. and S. Fujimura. 2007. Effect of dietary protein levels on muscle free glutamic acid contents and there regulation mechanism. 53rd International Congress of Meat Science and Technology. pp. 379-380

Kuit, H.G., Traore, A. and R,T, Wilson 1986. Livestock production in Central Mali: ownership, management and productivity of poultry in traditional sector. *Tropical Animal Health and Production* 18: 222–231.

Kutu, F.R. and J.A.N. Asiwe. 2010. Assessment of maize and dry bean productivity under different intercrop systems and fertilization regimes. *African Journal of Agricultural Research* 5 (13) : 1627-1631

Labadan, M.C. (JR)., Hsu, K.N. and R.E. Austic. 2001. Lysine and arginine requirements of broiler chickens at two to three week intervals to 18 weeks of age. *Poultry Science* 80: 599-606.

Lawrie, R. A. 1998. Meat Science. Woodhead Publishing Ltd, Cambridge, UK.

Leclercq, B. 1998. Specific effects of lysine on broiler production: Comparison with threonine and valine. *Poultry Science*. 77, 118-123.

Leeson, S. 2000 Is Feed Efficiency Still a Useful Measure of Broiler Performance? Department of Animal and Poultry Science/University of Guelp, Ministry of Agriculture, Food and Rural Affairs, Canada. http://.omafra.gov.on.ca/english/livestock/poultry/facts/efficiency.htm

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

Lönnerdal, B. and C.L. Chen. 1990. Effects of formula protein level and ratio on infant growth, plasma amino acids and serum trace elements. II. Follow-up formula. Acta Paediatrica Scandinavic **7**9: 266-273.

MacDonald, K.C. and Edwards, D.N. 1993. Chickens in Africa - The importance of Qasr Ibrim, *Antequity*. 67: 584-590.

MacGregor, R.G. and L.A. Abrams. 1996. Development, implementation and evaluation of poultry development scheme for resource-poor communities in South Africa. In Proceedings. 20th World Poultry Congress, New Belhi, India, 1–5 September 1996, Vol. 3, pp. 297–302.

Mack, S., Bercovici, D., De Groote, G., Leclercq, B., Lippens, M. and M. Pack. 1999. Ideal amino acid profile and dietary lysine specification for broiler chickens of 20 to 40 days of age. *British*. *Poultry Science* 40: 257–265.

Madruga, M.S., W.H. Sousa, M.D. Rosales, M.G.G. Cunha and J. F. Ramos. 2005. Quality of Santa Inês lamb meat terminated with different diet. *Revista Brasileira de Zootecnia*. 34 (1): 309-315

Mahdavi, A., Shivazad, M., Alemi, F., Zaghari, M., Moravej, H. and B. Darabighane, 2012. Digestible lysine requirement of broilers based on practical diet. Italian *Journal of Animal Science* 11: 13-18.

Mbajiorgu, C.A, Ngambi J.W, Norris D. and O.J. Alabi. 2011. Effect of dietary lysine to energy to ratio on performance of unsexed indigenous Venda chickens. *Asian Journal of Animal and Veterinary Advances* 6 (5): 517-524.

Mbajiorgu, C.A. 2010. Effect of dietary energy to protein ratio levels on growth and productivity of indigenous Venda chickens raised in closed confinement from one day up to 13 weeks of age. PhD Thesis, Animal Production Department, University of Limpopo.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D., Morgan, C. A., Sinclair L.A. and Wilkinson R.G. 2011. Animal Nutrition. Seventh edition. Prentice Hall. London.

Mekonnen, G., Forsido, T., Gebrewold, A., Dagnatchew, Z. and A. Anteneh. 1991. The Ethiopian livestock industry: Retrospects and prospects. In: Proceedings of the third National Livestock Improvement Conference, Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia, pp. 9-17 .

Mendonca, C.X. and L.S. Jensen. 1989. Influence of protein concentration on the sulphur containing amino acid requirement of broiler chickens. *British Poultry Science* 30: 889-898.

Mohammad, S.A. and H.K. Sohail. 2008. Effects of different energy and protein ratio on the performance of Desi Native chickens during growing phase. *Asian Journal of Poultry Sciende*, 2:42-47.

Moreki, J.C., Dikeme, R. and B. Poroga 2010. The role of village poultry in food security and HIV/AIDS mitigation in Chobe District of Botswana. *Livestock Research and Rural Development* 22: 5-7.

Morris, T.R., AL-Azzawi, K., Gous, R.M. and L.S. Glenda. 1987. Effects of protein concentration on responses to dietary lysine by chicks. *British Poultry Science* 28: 185-195.

Muchadeyi, F.C., Sibanda, S., Kusina, N.T., Kusina, J. and S.M. Makuza. 2004. The village chicken production system in Rushinga District of Zimbabwe. *Livestock Research and Rural Development*. 16. Accessed March, 2011. http://www.cipav.org.co/lrrd/lrrd16/6/much16040.html..

Muchenje, V. Dzama, K., Chimonyo, M., Raats, J. G. and P.E. Strydom. 2008. Meat quality of Nguni, Bonsmara and Angus steers raised on natural pasture in the Eastern Cape, South Africa. *Meat Science* 79: 20–28.

Mwalusanya, N.A., Katule, A.M., Mutayoba, S.K. and M.M.A. Mtambo. 2002. Productivity of local chickens under village management conditions. *Tropical Animal and Health Production* 34: 405-416.

Nahashon, S.N., Adefope, N. Amenyenu, A. and D. Wright, 2006. Effect of varying metabolizable energy and crude protein concentrations in diets of pearl gray guinea fowl pullets. 1. Growth performance. *Poultry Science* 85: 1847-1854.

Nasr, J. and F. Kheiri. 2012. Effects of lysine levels of diets formulated based on total or digestible amino acids on broiler carcass composition. *Brazilian Journal of Poultry Science* 14(4): 233–304.

Ndegwa, J.M., Mead, R., Norrish, P., Kimani, C.W. and A.M. Wachira. 2001. The performance of indigenous Kenyan chickens fed diets containing different protein levels during rearing. *Tropical Animal Health and Production* 33: 441-448.

Newcombe, M. and J.D. Summers. 1984. Effect of previous diet on feed intake and body weight gain of broiler and Leghorn chicks. *Poultry Science Journal* 63: 1237-1242.

Ng'ambi, J.W., Maoba, S.M., Norris, D., Malatje, M.S. and Mbajiorgu C.A. 2009. Effect of dietary lysine to crude protein ratio on performance of male Ross 308 broiler chickens. *Tropical Animal Health and Production* 41: 11–16.

Nishibori, M., Shimogiri, T., Hayashi, T. and H. Yasue. 2005. Molecular evidence for hybridization of species in the genus *Gallus* except for *Gallus varius*. *Animal Geneitics* 36: 367–375.

Norman, N.P. 1973. *Food Science.* 2nd ed. Westport, Connecticut, USA, AVI Publishing Company, pp. 391–423.

Norris, D. and J.W. Ng'ambi. 2006. Genetic parameter estimates for body weight in local Venda chickens. *Tropical Animal Health and Production* 38: 7–8.

NRC. 1984. Nutrient Requirements of Poultry. 8th Revised edition. National Academy Press: Washington, DC.

NRC, 1994. Nutrient Requirements of Poultry. 9th Revised edition. National Academy Press: Washington, DC.

Okitoi, L.O. and E.A. Mukisira. 2001. Improved Management of Indigenous Chickens. KARI Technical Notes Series, No. 8, pp 7.

Ouandaogo, Z.C. 1990. Programme de développement des animaux villageois (PDAV). In *Proceedings, CTA* Seminar on Smallholder Rural Poultry Production, Thessaloniki, Greece, 9–13 October 1990. Vol. 2, p. 29–36.

Parr, J.F. and J.D. Summers. 1991. The effect of minimizing amino acid excesses in broiler diets. *Poultry Science* 70: 1540-1549.

Payne, W.J.A. 1990. An introduction to Animal Husbandry in the Tropics, 4th edition: pp 684-744. Longman Scientific and Technical, Essex and New York.

Permin, A., Pedersen G. and J.C. Riise. 2000. Poultry as a tool for poverty alleviation: Opportunities and problems related to poultry production at village level. Network for Smallholer Poultry Development, The Royal Veterinary and Agricultural University, Bulowsuej 17, 1870 Frederiksberg, Denmark.

Plumstead, P. W., N. D. Romero-Sanchez, N. D. Paton, J. W. Spears and J. Brake. 2007. Effects of dietary metabolizable energy and protein on early growth responses of broilers to dietary lysine. *Poultry Science* 86: 2639-2648.

Priyankarage, N., Ross, S.P., Silva, S.S.P. and N.R. Pirgozliev. 2008. The efficiency of energy retention of broiler chickens and turkeys fed on diets with different lysine concentration. *British Poultry Science* 48(6): 721–730.

Rezaei, M., Nassiri, M.H., Pour, R. J. and D.H. Kermanshahi 2004. The effects of dietary protein and lysine levels on broiler performance, carcass characteristics and Nitrogen excretion. *International Journal of Poultry Science* 3 (2): 148-152.

Rhone-Poulenc, 1993. Animal Nutrition, Rhodmet Nutrition Guide. 2nd ed., Rhône-Poulenc Animal Nutrition Publishng., Antony Cedex, France.

Richard, J.J. 2005. Production and growth related disorder and other metabolic disease of poultry: A review. *The Veterinary Journal* 169 (3): 350-360.

Rincker, M.J, Clarke, S L. Eisenstein, R.S. Link, J.E. and G.M. Hill. 2005. Effects of iron supplementation on binding activity of iron regulatory proteins and the subsequent effect on growth performance and indices of haematological and mineral status of young pigs. *Journal of Animal Science* 8 (9): 2137-2145.

Ruiz, J. A., Perez-Vendrell, A. M. and E. Esteve-Garcia. 2000. Effect of dietary iron and copper on performance and oxidative stability in broiler leg meat. *British Poultry Science* 41: 163-167.

SAS, 2008. Statistical Analysis System. SAS User Guide: Release 9.2. SAS Institute Inc, Cary NC, USA.

Schmid-Hempel, P. 2009 Immune defence, parasite evasion strategies and their relevance for ‘macroscopic phenomena’ such as virulence. *Philosophical Transactions of the Royal Society* 364, 85–98

Schutte, J.B., and J. de Jong. 1998. Ideal amino acid profile for poultry. in Proceedings. II Conference of Feed Manufacturers of the Mediterranean. Reus, Spain. pp 259-263.

Shahin K.A. and Elazeem F.A. 2005. Effects of breed and sex and diet and their interactions on carcass composition and tissue weight distribution of broiler chickens. *Archives of Animal Breeding* 48: 612-626.

Si, J., Fritts, C.A., Burham, D.J. and P.W. Waldroup. 2004. Extent to which crude protein may be reduced in corn soybean meal based broiler diets through amino acid supplementation. *International Journal of Poultry Science.* 3: 46-50.

Simoons, F.J. 1994 Eat Not This Flesh: Food Avoidances From Prehistory to the Present. Madison: University of Wisconsin Press. pp 550

Sinurat, A.P. and Balnave, D. 1985. Effect of dietary amino acids and metabolisable energy on the performance of broilers kept at high temperature. *British Poultry Science* 26: 117–128.

Sonaiya, E.B**.** 1990. The context and prospects for development of smallholder rural poultry production in Africa. In *Proceedings,* CTA Seminar on Smallholder Rural Poultry Production, Thessaloniki, Greece, 9–13 October 1990, Vol. 1, p. 35–52.

Sonaiya, E.B., Brankaert, R.D.S. and E.F. Guèye. 1999. Research and Development options for family poultry. Introductory paper. 1st INFPD/FAO Electronic Conference.

Spanier, A.M. and Miller, J.A. 1993. “Role of proteins and peptides in meat flavor.” In Food Flavour and Safety*.* Spanier, A.M., Okai, H. and Tamura, M, Eds. ACS Symposium Series No. 528. Am. Chem. Soc. Washington, D.C., Chapt. 6, pp. 78-97.

Stoller, G.M., Zerby, H.N., Moeller, S.J., Baas, T.J., Johson, C. and L.E. Watkins. 2003. The effect of feeding ractopamine (Paylean) on muscle quality and sensory characteristics in three diverse genetic lines of swine. *Journal Animal Science* 81: 1508-1516.

Summer, J.D. and S. Leeson. 1984. Influence of dietary protein and energy level on broiler performance and carcass composition. *Nutrition and Reproduction International* 29: 757-767.

Summers, J.D., Spratt, D. and J.L. Atkinson 1992**.** Broiler weight gain and carcass composition when fed diets varying in amino acid balance, dietary energy, and protein level. *Poultry science* 71 (2): 263-273.

Sveinsdóttir, K., Martinsdóttir, E., Green-Petersen, D., Hyldig, G., Schelvis, R. and C. Delahunty. 2009. Sensory characteristics of different cod products related to consumer preferences and attitudes. *Food Quality and Preference* 20: 120–132.

Tadelle, D. 1996. Effect of maize (*Zea mays*) and noug (*Guizotia abyssinica*) cake supplementation on egg production performance of local birds under scavenging conditions in the central highlands of Ethiopia. M.Sc Dissertation, Swedish University of Agricultural Sciences, pp14-20.

Tadelle, D. and B. Ogle. 2000. Nutritional status of village poultry in the Central Highlands of Ethiopia as assessed by analyses of crop contents. *Ethiopian Journal of Agricultural Science* 17: 47-57

Tadelle, D. and Ogle, B. 1996. Nutritional Status of Village Poultry in The Central Highlands of Ethiopia as Assessed By Analyses of Crop Contents and Carcase Measurements. M.Sc Thesis, Swedish Univeristy of Agricultural Sciences, pp 15

Tang, M.Y., Ma, Q.G., Chen, Z. D. and C. Ji. 2007. Effects of dietary metabolizable energy and lysine on carcass characteristics and meat quality in arbor acres broilers. *Asian-Australian Journal Animal Science* 20: 1865-1873.

Tesseraud, S., Peresson, R., Lopes, J. and A. M. Chagneau. 1996. Dietary lysine deficiency greatly affects muscle and liver protein turnover in growing chickens. *British Journal of Nutrition* 75: 853-865.

Underhill A.P. 1997. Current Issues in Chinese neolithic archaeology. *Journal of World Prehistory* 11: 103–160.

Van Marle-Koster, E. and E.C. Webb. 2000. Carcass characteristics of South Africa native chicken lines. *South African Journal of Animal Science* 30 (1): 53–56.

van Veluw, K. 1987. Traditional poultry keeping in Northern Ghana. ILEIA 3(4).

Veldkamp, T., Kwakkel, R.P., Ferket, P.R. and M.W.A. Verstegen. 2005. Growth response to dietary energy and lysine at high and low ambient temperature in male turkeys. *Poultry Science Journal* 84: 273-282.

Waldroup, P.W. Oviedo-Rondon, E.O. and C.A. Fritts. 2006. Influence of dietary formulation methods on response to Argonne and Lysine in diets of young broiler chickens. *International Journal of Poultry Sciences* 5(11): 1016-1022.

Wattanachant, S. 2008. Factors affecting the quality characteristics of Thai indigenous chicken meat. *Suranaree Journal of Science and Technology* 15(4): 317-322.

Witte, D. P., Ellis, M., McKeith, F. K. and E. R. Wilson. 2000. Effect of dietary lysine level and environmental temperature during the finishing phase on the intramuscular fat content of pork. *Journal of Animal Science* 78: 1272–1276.

Wood, J.D., Enser, M., Fisher, A.V., Nute, G.R., Sheard, P.R., Richardson, R.I., Hughes, S.I. and F.M. Whittington. 2008. Fat deposition, fatty acid composition and meat quality: A review. *Meat Science* 78: 343–358

Zaman, M.A. Sorensen, P. and Howlider, M.A.R. 2004. Egg production performance of a breed and three crossbreds under semi- scavenging systems of management*. Livestock Research for Rural Development. 16: www. Cipav. Org.co.Lrrd 16/8/Zama/16060. htm. Accessed November, 2012*