CHAPTER 1

INTRODUCTION

1.1 Back ground

Poultry industry in developing countries such as South Africa can be divided into two sub-sectors, namely commercial and traditional sub-sectors (John, 1995; Gueye, 1998). Each of them has its own peculiarities that make them special to national food security. The commercial sub-sector consists mainly of exotic breeds of layer and broiler chickens with high egg and meat production, respectively (John, 1995). Usually, they are confined to the urban and peri-urban areas where the infrastructure necessary for the production and market of produce exists. However, the traditional sub-sector on the other hand consists mainly of indigenous birds which are made up of different breeds and or lines such as the Venda chickens. This sub-sector is very important for the livelihood of most rural households as it is mainly found in the rural areas (Sonaiya, 2001). This sub-sector, currently, constitutes about 80 % of the country's rural poultry flock and is a major source of readily available protein in the form of eggs and meat as well as for cash money for 90 % of the rural households (Gueye, 1998). However, when compared to commercial layer and broiler chickens, the indigenous chickens produce fewer eggs and have smaller body weights (Ebangi and Ibe, 1994; Safalaoh, 2001). Furthermore, it has been shown that the indigenous chickens tend to have lower feed efficiency (King'ori *et al.,* 2003; Tadelle *et al.,* 2003b). Improved indigenous poultry production in Limpopo province offers a viable approach to improving nutritional and economic status of the rural households. Improvement in genetic potential of the indigenous chicken should be accompanied by a concomitant improvement in the standard of management with particular attention to their nutrient requirements in order to enhance food sufficiency and economic empowerment of the rural people. Thus, improved nutritional management is necessary to assist in achieving optimal performance in terms of diet intake, growth rate, feed conversion ratio, live weight, high meat yield and low mortality, especially when commercialization of the breed is of utmost importance. Such approach may help the farmers to improve productivity of their chickens.

1.2 Problem statement

Poultry production contributes a lot to the household nutrition and income in rural areas of Limpopo province (Swatson *et al.,* 2001). Most of the poultry in these areas are indigenous breeds such as the Venda chickens. However, the indigenous chickens are considered to be of low productivity in terms of poor growth rates, few eggs produced, high mortalities, susceptibility to diseases and long brooding periods (Tadelle *et al.,* 2000). This implies that their contribution to the household protein food security may not be fully realized without appropriate management, feeding and husbandry interventions. Often, the reasons for the poor productivity of indigenous village chickens have been attributed to their poor food resource base, limited foraging ranges and poor management practices (Alders *et al.,* 2001; Swatson *et al.,* 2001). However, extensive research has not been done to determine the production potential of these breeds. Production parameters, nutrient requirements and carcass characteristics have not been adequately studied. Furthermore, very little in terms of nutritional improvement has been done to improve their productivity while maintaining their good qualities like hardiness and hatchability values. Improvement of these factors would enhance food sufficiency and economic empowerment of the rural people.

1.3 Motivation

Data on nutrient requirements of the Venda chickens is limited, particularly on energy and crude protein requirements. Knowing requirements of these nutrients will help in the formulation of diets to optimize productivity of the birds. This will improve the economic, social and nutritional status of the rural farming households. Furthermore, carcass weight and meat yield of chickens are receiving considerable attention. There is an emphasis on increasing the meat yield, especially breast meat and decreasing the fat content of the chicken carcass (Bedford and Summers, 1985; Hickling *et al.,* 1990; Rezaei *et al.,* 2004). Summer and Leeson (1979) demonstrated that chickens with widely differing amounts of carcass fat could be produced by the manipulation of the dietary energy to protein ratio value of the diet. These authors concluded that dietary energy to protein ratio value is directly correlated with carcass fat and hence, the value of the ratio becomes very important as it affects productivity. No similar studies have been done with indigenous Venda chickens. Determination of the dietary energy to protein ratio requirements of the Venda chickens for optimal production under different feed energy and protein concentrations will enhance the economic, social and nutritional status of the rural farming households.

1.4 Objectives

The objectives of this study were:

1 To determine dietary energy to protein ratio levels for optimal feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy needs, nitrogen retention and carcass characteristics of indigenous Venda chickens raised in closed confinement from day-old up to 13 weeks of age.

2 To determine optimal response trends in feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy levels, nitrogen retention and carcass characteristics to differing feed energy and protein levels in indigenous Venda chickens raised in closed confinement from day-old up to13 weeks of age.

3 To determine the relationships between dietary energy to protein ratio levels and optimal responses in feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy levels, nitrogen retention and carcass characteristics of indigenous Venda chickens raised in closed confinement from day-old up to 13 weeks of age.

4 To determine the efficiency of energy and protein utilization for growth in indigenous Venda chickens raised in closed confinement from day-old up to 13 weeks of age.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Indigenous chickens (*Gallus domesticus*) are the predominant poultry species in the rural areas of Africa (Andrews, 1990; Jalaludin, 1992). They are kept for nutritional, economic and social purposes (Sonaiya *et al.,* 1999). These chickens form an integral part of the farming systems in rural areas. The number of indigenous chickens kept by households varies significantly, depending on the farmers' management skills and feeding resources.

Generally, their production systems can be described as of low input with output accessible at both inter and intra-household levels. As in other Sub-Saharan countries (Sonaiya, 1997), the largest proportion of the feed of the indigenous chickens in South Africa is based on a scavenging system, constituting materials from the surrounding environment, by-products from harvesting and processing of grains as well as cultivated and wild vegetation. Though indigenous chickens can survive under these harsh nutritional and environmental conditions (Tadelle and Ogle, 2000), it has been shown that their productivity under scavenging conditions is very low (Alders *et al.,* 2001).

Perhaps the major constraint to indigenous chicken production on a larger scale is the wide variations in the productivity of indigenous chickens as compared to broiler chickens. However, as suggested by Hutanuwat (1988), there is a need to increase the productivity of indigenous chickens to ensure adequate nutrition for the increasing population. This is a requirement that scavenging rearing conditions cannot meet adequately.Thus, to ensure adequate food security for the increasing population, intensive rearing conditions seem to be the most viable options. Therefore, there is need to understand their nutrient requirements under intensive rearing conditions in order to develop appropriate nutritional intervention strategies for optimal productivity. Thus, in selecting a management intervention and feeding programs for indigenous chickens in confinement, their nutrient requirements must be met in terms of energy and protein to ensure optimal growth and productivity. Research into this will help to improve their productivity.

2.2 Improving the productivity of indigenous chickens under intensive management systems

During the past few decades, developing countries globally have seen a decline in the rearing of indigenous poultry, mainly due to their poor productive performance (Bhatti *et al.*, 1990) and an increase in commercially produced poultry meat and eggs from exotic poultry breeds (Gueye, 2000). This increased productivity was achieved because of improved intensive management strategies, research into nutrition and growth of the exotic chicken breeds. In contrast to the above scenario, little effort has been made to improve the productivity of indigenous chickens under improved intensive management systems. In fact, most studies aimed at improving the performance of indigenous chickens have been carried out under scavenging conditions (Alders *et al.,* 2001; Sonaiya *et al.,* 1999). However, it has been shown that their productivity under scavenging conditions is very low (Alders *et al.,* 2001).

For birds to be productive, they need feeds that will give them the necessary nutrients for body function, including growth and meat production. Thus, it is very unlikely that nutrients in the feed under scavenging conditions especially protein and energy will be present in the same ratio as required by the chickens for improved productivity. Sometimes protein content is too low in relation to energy, which places a heavy nutritional burden on the chickens. Birds have a genetically defined requirement for nutrients and they will attempt to consume a ‘desired’ amount of feed in order to meet their requirements for the first-limiting nutrient in the feed (Emmans, 1987). This is a requirement that scavenging rearing conditions do not meet adequately.

To attain a balanced diet in order to improve their productivity, intensive rearing conditions seem to be the most viable options. As suggested by Tadelle and Ogle (1996) small management changes practised under intensive rearing conditions such as regular watering, continuous lighting, regular feeding regimes, vaccination for common diseases, and energy and protein supplements can bring about significant improvement in the productivity of indigenous chickens. Barley and Phororo (1992) indicated that supplementing the nutrition of indigenous chickens with energy and protein nutrients gave a significant improvement in productivity. Hickling *et al.* (1990), Plavnik *et al.* (1997) and Rose (1997) reported that energy and protein are important in a poultry diet as they affect productivity of the birds. Larry (1989) stated that proper nutrition is a key factor in determining performance and productivity of birds. Thus, it is very important to feed indigenous chickens under intensive production systems optimum levels of nutrients to allow them to express their genetic potential for growth.

2.3 Nutrient requirements and growth in chickens

Chinrasri (2004) and Laohakaset (1997) defined nutrient requirement as the amount of nutrients needed by animals to maintain their activities, maximize growth and feed utilization efficiency, improve laying capacity and hatchability and optimize fat accumulation. Nutrients like carbohydrates, lipids and protein that the chicken utilizes as sources of energy or as parts of its metabolic machinery are essential requirements for growth. Growth involves deposition of bones, muscle and fat, each exhibiting an individual pattern of development (Carlson, 1969). When based on the percentage increase over the weight at the end of a production cycle, the most rapid growths or weight gains are made when the chick is young (Mignon-Grasteaus *et al*., 2001). As the chick grows older, the weekly increments of weight increases become materially less although nutrient requirement increases (Mignon-Grasteaus *et al*., 2001).

It is a generally recognized concept that the growth of animals from conception to maturity occurs in a sigmoidal response of size over time, usually presented by plotting live weight against age (Figure 1).

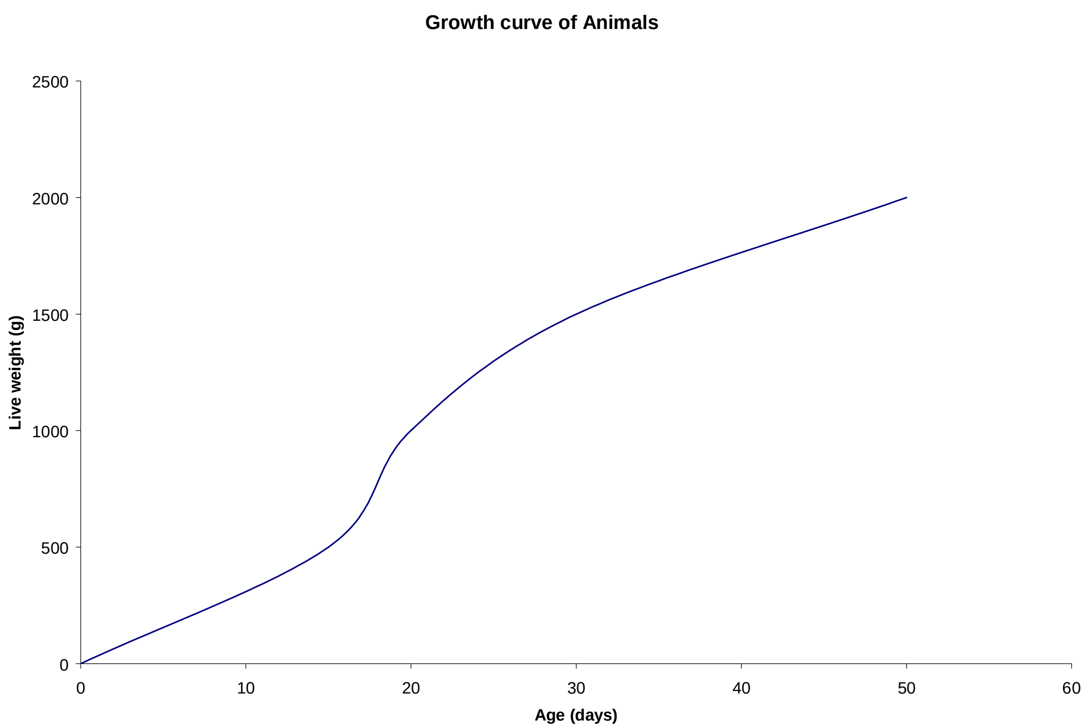

Figure 1: A graph showing the sigmoid shape of growth curve

Source: Heath and Olusanya (1988)

This sigmoidal response indicates that growth is self accelerating during the early growth phase until the inflexion when it becomes self-inhibiting for the final phase approaching maturity (Siegel, 1993). In practice, however, the middle part of the curve often appears to be linear. Although animal growth is thought to follow a generalized sigmodial response, the actual shape of the curve can be affected by numerous factors such as nutrition, environment, health, gender and genotype.

Amongst all these factors, nutrition plays a significant role in growth of animals. As suggested by Larry (1989) proper nutrition is a key factor in determining performance and productivity of birds.

There is need therefore to formulate rations that will fulfill all the nutrient requirements, including energy and protein, for growth. Often, energy requirements in poultry are expressed in terms of metabolisable energy per day (Smith, 1990). Poultry usually consume just enough food to meet their energy requirements since the control of feed intake is believed to be based primarily on the amount of energy in the diet (Nahashon *et al*., 2006). Increasing the dietary energy concentration leads to a decrease in feed intake and vice versa (Veldkamp *et al*., 2005), thus affecting growth. However, as suggested by Smith (1990), this is valid as long as the diet is adequate enough in all other essential nutrients, and that nutrient density, accessibility and palatability do not limit feed intake. On the other hand, dietary requirements for protein are actually requirements for the amino acids contained in the protein (NRC, 1994). Amino acids obtained from dietary protein are used by chickens to fulfill a diversity of functions such as growth, meat or egg production. Protein deficiency in a feed reduces growth. Harper and Rogers (1965) reported that protein deficiency in a feed reduced growth in broiler chickens as a consequence of depressed appetite and, thus, intake of nutrients. Feeding animals below their energy or protein requirements thus reduces growth and efficiency of nutrient utilization.

Perhaps, the most important trait in intensive chicken production is the efficient utilization of nutrients as feed cost is one of the major components of total cost of poultry production. According to Hinrich and Steinfield (2007), feed alone contributes about 60 to 70 % of the total cost of poultry production. Therefore, optimal utilization of feed and avoiding unnecessary feed wastage could be the leading factors in minimizing total cost of production. However, knowledge about optimal energy and protein requirements of indigenous Venda chickens for growth and productivity is limited and variable. Research into this aspect will help to find answers for improvement of the productivity of these birds.

2.4 Energy requirement of chickens

Energy by itself is not a nutrient but a property of energy yielding nutrients, primarily carbohydrates, lipids and proteins when they are oxidized during metabolism. However, in formulating poultry diets, the nutrient requirements of broiler chickens have frequently been expressed per unit of dietary metabolizable energy (Gonzalez-a and Pesti, 1993). This practice is based on the theory that birds will adjust their feed intake according to their metabolisable energy requirements and was summarized by the NRC (1984) 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 necessary daily requirement.” However, based on a re-evaluation of numerous research data, the NRC (1994) have revised their previous conclusions by stating that the practice of relating nutrient concentrations as a function of dietary metabolisable energy seems to apply more to leghorn type chickens fed diets with a low metabolisable energy concentration while, as a result of the over-consumption of energy on diets with a high metabolisable energy concentration, the application of specific nutrient-to-metabolisable energy ratios in broiler chickens and turkeys should be questioned. Leeson *et al.* (1996) showed that broiler chickens fed up to 25 days and 49 days of age were able to adjust their feed intake to a constant energy intake over a range of dietary metabolisable energy levels from 11.29 to 13.80 MJ ME/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). However, on closer observation of the data by Leeson *et al.* (1996), it can be seen that early feed intake to 25 days of age was not greatly affected by dietary metabolisable energy concentrations over the range of 12.13 to 13.80 MJ ME/kg DM and that it was only at the lowest metabolisable energy concentration of 11.29 MJ ME/kg DM that a significant increase in feed intake occurred.

Also, the effects of metabolisable energy concentration on feed intake were very different between the early (0-25 days) and later (26-49 days) growth periods, with the metabolisable energy concentration having a far greater effect on increasing feed intake during the grower-finisher phase. This led to the overall conclusion by these authors that broiler chickens do indeed eat to a constant metabolisable energy intake when viewed over the entire 49-day growing period.

In a similar manner, several researches have shown that feed efficiency is influenced by changes in dietary energy concentration in two partially dependent pathways. Firstly, as dietary energy increases, feed efficiency is improved as less feed is taken in to satisfy the energy needs of the chickens. Secondly, growth rate is promoted by increasing levels of dietary energy (Donaldson, 1985; Dublecz *et al.,* 1999; Jackson *et al.,* 1982; Petsi *et al.,* 1983; Plavnik *et al.,* 1997; Yalcin *et al.,* 1998).

The importance of energy level in the diets for indigenous chicken breeds is similar to that of broiler chicken breeds. That is, dietary energy level has an effect on feed intake, feed conversion ratio, growth and carcass quality. However, 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 DM of feed. NRC (1994) recommended that the required energy in growing indigenous chicken diets should be 12.14 MJ ME/kg DM of feed. However, Payne (1990) recommended 11.46 MJ ME/kg DM feed during the 1-6 weeks of growing period and 10.86 MJ ME/kg DM feed during the 6-12 weeks of growing period.

Irrespective of the differences in estimated energy requirements, information on effect of dietary energy levels on production variables in indigenous chickens is limited and not extensive. There is, therefore, need to ascertain such responses in indigenous Venda chickens during the growing phase including both starter and grower periods.

2.5 Protein requirements in chickens

Proteins have been described as complex organic compounds of high molecular weight composed of 22 different amino acids or derivatives that are linked by peptide bonds to form a primary chain structure. As a result of steric constraints this primary structure has been reported to form an α-helical structure stabilized by hydrogen bonds as well as by cross-linking of individual amino acid residues. The α-helix that describes the primary structure of the protein has been found to be subsequently folded and arranged into more complex secondary and tertiary structures which, with the specific number and sequences of different amino acids, ultimately determine the biological characteristics and functionality of the protein (Leeson and Summers, 2001; Horton *et al*., 2002). Because body proteins are in a dynamic state, with synthesis and degradation occurring continuously, an adequate intake of proteins is required.

If dietary protein is inadequate, there is a reduction or cessation of growth or productivity and a withdrawal of protein from less vital body tissues to maintain the functions of more vital tissues (NRC, 1994). As such, protein requirements vary considerably according to the physiological state of the bird, that is, the rate of growth or egg production. Other factors contributing to variations in protein requirements of the chickens include age, body size, sex and breed. Matching the feed protein levels with animal protein requirements is crucial for maximizing animal performance. For instance, turkey poults and broiler chickens have high protein requirements to meet the needs for rapid growth (Sklan and Noy, 2003) while the indigenous chickens such as the Venda breed will require less protein to meet their needs because of their slow growth rate and small body size (Safaloah, 2001).

Male broiler chickens have higher protein requirements than females (Han and Baker, 1993; Thomas *et al.,* 1986), because male chickens contain more protein and less fat in their weight gain (Edwards *et al.,* 1973; Han and Baker, 1991). Like the effect of body size and sex, Breed differences also affect dietary protein requirements in chickens. NRC (1994) recommended 23, 20 and 18 % dietary protein levels respectively, for the broiler chickens during the starter, grower and finisher phases, for optimal growth and maximum productivity. In contrast, Tadelle and Ogle (1996) observed that the protein requirement of growing indigenous chickens varies between 16 and 18 % during the growing phase for optimal performance. Chemjor (1998) reported that a dietary protein level of 13 % was adequate for indigenous chickens aged between 14 and 21 weeks. Kingori *et al.* (2003) observed that indigenous chickens require a protein level of 16 % to optimize feed intake and growth between 14 and 21 weeks of age. Furthermore, Ndegwa *et al.* (2001) reported that indigenous chickens fed diets containing 17 to 23 % CP had similar growth rates and feed intakes, suggesting that a 17 % CP diet was sufficient for these chickens. Apparently, information on dietary protein requirements for indigenous chickens is limited and variable. Therefore, there is need to determine protein levels for optimal productivity in indigenous chickens.

2.6 Effect of varying dietary energy or protein density on productivity of chickens

Several researchers (Albuquerque, 2003; Araujo, 1998; Donaldson, 1985; Dublecz. *et al*., 1999; Jackson *et al.,* 1982; Leeson *et al*., 1996; Oliveira Neto *et al*., 1999; Pesti *et al.,* 1983; Plavnik *et al.,* 1997; Yalcin *et al.,* 1998) have investigated the response of production variables in broiler chickens to varying diet energy or protein density. However, results from these studies have not been consistent. Leeson *et al*. (1996) found that an increase in dietary energy level was followed by higher abdominal fat deposition. Contrary to the above result, Oliveira-Neto *et al*. (1999) and Albuquerque (2003) did not find significant effect of dietary energy level on abdominal fat deposition in broiler chickens. In another study, Araujo (1998) investigated the effect of energy levels on carcass and breast meat yield in broiler chickens. In this study, birds offered a diet having 15

MJ ME//kg DM increased carcass and breast meat yields as compared to those offered a diet having 13.38 MJ ME/kg DM.

However, Leeson *et al*. (1996) and Oliveira-Neto *et al*. (1999) reported no effect of dietary energy level on carcass and breast meat yields in broiler chickens. Furthermore, Donaldson (1985), Dublecz. *et al*. (1999), Jackson *et al.* (1982), Pesti *et al* (1983), Plavnik *et al.* (1997) and Yalcin *et al.* (1998) indicated that feed efficiency is influenced by changes in dietary energy concentration in two partially dependent pathways. Firstly, as dietary energy increases, feed conversion ratio is improved as less feed is taken in to satisfy the energy needs. Secondly, growth rate is promoted by increasing levels of dietary energy. Other reports have also shown no effect of dietary metabolisable energy concentration on feed conversion ratio and growth rate in broiler chickens (Summers *et al*., 1992).

Dietary energy levels have also been shown to affect broiler chickens' feed intake. Plavinik *et al.* (1997) and Nahashon *et al* (2005) have shown that as dietary energy level increases, birds satisfy their energy needs by decreasing feed intake. Decreases in feed intake with high energy levels in the diets of broiler chickens have also been reported by Leeson (2000) and Veldkamp *et al*. (2005). However, Araujo (1998) did not find differences in feed intake between two groups of broiler chickens fed ad-libitum diets containing two energy levels of 13.38 and 15 MJ ME/kg DM.

Like the effect of diet energy concentration, protein density has also been shown to affect productivity in broiler chickens. Feeding low protein diets to broiler chickens have been shown to decrease growth performance (Ferguson *et al*., 1998; Jacob *et al*., 1994). In other studies, Moran *et al*. (1992) and Bartov (1996) compared the effect of varying dietary crude protein levels with the NRC (1994) recommended levels in broiler chickens and observed that diets lower in protein than those recommended by NRC (1994) reduced breast meat yield and increased fattening in broiler chickens. In support of the above observation, Buyse *et al.* (1992) also reported increased fat accretion in broiler chickens fed diets with a low protein content. Though in the same study, these authors reported a reduction in feed efficiency and production of leaner birds in diets with excess dietary crude protein. However, the effect of protein density on feed intake responses in broiler chickens has not been consistent.

Buyse *et al.* (1992) reported that broiler chickens reared on lower protein density of 15 % crude protein in the diet increased their feed intake in an attempt to meet their protein requirement. Contrary to these findings, a decrease in feed intake with reduced protein density has been reported in broiler chickens by Kemp *et al.* (2005) and Berhe and Gous (2005). These authors observed that Ross 308 broiler chickens decreased their feed intake as dietary protein content was reduced, resulting in a lower growth rate.

The effect of dietary energy or protein density in indigenous chickens is similar to that of broiler chickens. Studies have revealed that indigenous chickens responded significantly to different feed protein density and husbandry environment. Kingori *et al.* (2003) compared the effect of varying crude protein levels of 100, 120, 140, 160 and 180 g/kg DM on the feed intake, feed conversion ratio and live weight of growing indigenous chickens raised intensively between 14 and 21 weeks of age. Results from this study indicate that feed intake per bird increased with increasing dietary protein levels. Similarly, live weight gain increased with increasing protein levels while feed conversion ratio decreased with increasing dietary protein levels. However, feed intakes, feed conversion ratio and live weight gain for birds offered diets containing 160 and 180g CP/kg DM did not differ significantly. Thamabood and Choprakan (1982) studied the response of indigenous chickens to supplementary feeding with 10, 12 and 14 % dietary protein besides their natural scavenging. They found that the growth rates of indigenous chickens less than 16 weeks old were 10.6, 8.5 and 8.7 g/bird/day, respectively. It was quite remarkable that the chickens that were fed with the 10 % dietary protein supplement had the highest growth rate. However, Choprakan *et al.* (1985) indicated that the growth rate of indigenous chickens could be higher at a rate of 13 g/bird/day when fed diets with 12 to 18 %

crude protein. Thus, growth was better with a diet having a higher protein density as similarly observed by RDI/KKU (1988) who found that the weight gain of indigenous chickens was 15 g/bird/day when fed a commercial broiler diet with 23 % crude protein content. Contrary to the above results, Ndegwa *et al.* (2001) reported no effect of varying dietary crude protein levels on growth and feed intake of indigenous chickens. Importantly, no similar studies were found with indigenous Venda chickens. Research into this aspect will help to find ways of improving their productivity.

2.7 Effect of dietary energy to protein ratio value on productivity of chickens

Because chickens can adjust their feed intake over a considerable range of feed energy levels to meet their daily energy needs, dietary energy levels are used to set the levels of other nutrients including proteins (Gonzalez-a and Pesti, 1993). As a result, the concept of dietary energy to protein ratio has been used extensively in chicken feed formulation (NRC, 1994). The energy to protein ratio value of a diet can be manipulated by altering the energy level, protein level or both (Buyse *et al.,* 1992; Jones and Smith, 1986; Lin *et al.,* 1980). The value of the ratio becomes very important as it affects productivity. Summer and Leeson (1979) demonstrated that chickens with widely differing amounts of carcass fat could be produced by the manipulation of the dietary energy to protein ratio value of the diet. These authors concluded that dietary energy to protein ratio value is directly correlated with carcass fat. This means that increasing the dietary energy to protein ratio value of a diet increases fat deposition while narrowing the dietary energy to protein ratio value prevents excessive fat deposition. However, Bartov (1987) investigated the effects of altering the metabolisable energy to crude protein ratio on body weight gain in broiler chickens and found that birds fed a diet low in metabolisable energy to crude protein ratio performed better than those on a higher ratio diet. It is important to note that in this study the metabolisable energy to crude protein ratio was increased by decreasing the crude protein concentration in the starter diets from 25.3 to 18.7 % while also increasing the dietary metabolisable energy from 11.86 to 12.61 MJ ME/kg DM.

Therefore, since it has been shown that broiler chickens respond to increasing dietary crude protein concentrations independent of the dietary metabolisable energy level (Burnham *et a*l., 1992), it was not surprising that performance was improved on the high crude protein diets that had a low metabolisable energy to crude protein ratio. Swatson *et al.* (2000) and Swatson *et al.* (2002a,b) reported that altering the dietary energy to protein ratio levels in broiler chicken diets affected weight gain, feed conversion ratio as well as the efficiency of utilization of dietary protein in the chickens. However, other reports have shown no effect of dietary metabolisable energy to crude protein ratio on dietary feed intake by broiler chickens (Summers *et al*., 1992).

Gonzalez-a and Pesti (1993) evaluated the concept of a single metabolisable energy to protein ratio level for optimal responses 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 while there was no single metabolisable energy to protein ratio level for optimal body weight and feed intake, these could best be predicted as quadratic functions of both crude protein and metabolisable energy levels. This implied that both nutrients affect body weight gain and feed intake and should be included in any model aimed at predicting dietary energy to protein ratio level for optimal intake and body weight in chickens. Considerable differences exist in the literature concerning the level of dietary energy to protein ratio for optimal responses in chickens. Kamran *et al.* (2008), Nascimento *et al*. (2007) and NRC (1994) estimated different single ratios of 55.22, 57.30 and 58.17 MJ ME/kg protein, respectively, for all production variables in broiler chickens during the entire starter phase. However, these values are slightly lower than the ratio of 61.12 MJ ME/kg protein determined for birds in the age category of 10 to 24 days by Swatson *et al.* (2002b) but higher than the ratio of 53.27 MJ ME/kg protein for optimum feed intake and growth rate in broiler chickens during the starter phase estimated from the data of Nawaz *et al.* (2006). Similar variations in the levels of dietary energy to protein ratio for optimal responses in chickens during the grower phase were also reported by several authors. Kamran *et al*. (2008) and NRC (1994) estimated single ratios of 59.83 and 66.9 MJ ME/kg protein, respectively, for all production variables in broiler chickens during the entire grower phase. Both values are lower than the ratio of 69.77 MJ ME/kg protein calculated from the data of Nawaz *et al*. (2006) for optimum feed intake and body weight gain in broiler chickens during the grower phase. These ratios are also different from the ratio of 61.73 MJ ME/kg protein for live weight in broiler chickens during the grower phase observed by Brown and McCartney (1982).

Studies on dietary energy to protein ratio level for optimal responses in indigenous chickens under intensive production systems are limited. Prachya *et al.* (1994) investigated the effect of dietary energy and protein levels on performance of indigenous Shanghai chickens reared intensively between one and 12 weeks of age. The results from that study indicated that both live weight and growth rate in indigenous Shanghai chickens were optimized at a single dietary energy to protein ratio of 58.6 MJ ME/kg protein while feed conversion ratio was optimized at a different dietary energy to protein ratio of 62.75 MJ ME/kg protein.

It is evident from the above studies that there is no single dietary energy to protein ratio level for optimal responses in chickens. However, determining dietary energy to protein ratio value for optimal responses would help to compare performance variables in chickens offered a range of diets differing in nutrient densities. This would help in optimizing feed intake, growth rate, feed conversion ratio and breast meat yield in indigenous chicken breeds.

2.8 Response trends of chickens to differing feed energy and protein levels

To be of any real value, attempts to optimize the feeding of chickens must be capable of predicting voluntary food intake. Gous (2007) suggested that where feed intake is seen as an input, as is most often the case, it is not possible to optimize feeding programs successfully since the composition of the food offered has a very important effect on voluntary food intake. As suggested by Emmans and Fisher (1986) appetite is dependent on the nutrient requirements of the animal and the contents of those nutrients in the feed and hence, responses in feed intake, therefore, are not independent of the composition of the feed and strain of the chicken as was previously believed (Hill and Dansky, 1954).

The theory of feed intake and growth in birds proposed by Emmans (1981; 1989) was based on the premise that birds attempt to grow at their genetic potential, which would imply that they would attempt to eat as much of a given feed as would be necessary to grow at that rate. Factors that would prevent them from achieving this goal would be the bulkiness of the feed or the inability to lose sufficient heat to the environment in order to enable them to remain in thermal balance. This theory has been shown to predict feed intake and hence growth and carcass composition with considerable accuracy in birds (Ferguson and Gous, 1997; Ferguson *et al*., 1997). Additionally, Cobb 500 broiler chickens (Burnham *et a*l., 1992) and laying hens (Gous *et al*., 1987) have been shown to increase feed intake as dietary protein content in the feed is reduced, attempting thereby, to obtain more of the limiting protein irrespective of the feed energy level until a dietary concentration is reached where performance is so constrained that feed intake falls.

However, Kemp *et al.* (2005) and Berhe and Gous (2005) have demonstrated that the Ross 308 strain of broiler chickens does not apparently conform to this theory. Instead of increasing feed intake as dietary protein content is reduced these birds reduce feed intake, resulting in a lower growth rate than the strain Cobb 500 whose feed intake increases as dietary protein content is reduced (Figure 2). These authors concluded that the Ross 308 broiler chickens have been selected for improved growth and feed efficiency using high protein feeds. Such selection results in leaner carcasses (Pym and Solvens, 1979) and perhaps a reduced ability to fatten when faced with feeds marginally deficient in protein.

These observations on limitations in feed intake response patterns in Ross 308 broiler chickens and Cobb 500 chickens contradict the strongly held theory that chickens eat to satisfy their energy requirements (Hill and Dansky, 1954; Leeson et al., 1996; Scott et al., 1982) or that chickens will eat less of a feed higher in energy content than the one having a lower energy value (Nahashon *et al.,* 2006; Plavik *et al.,* 1997; Veldkamp *et al.,* 2005). In fact, the nutritional factors involved in broiler chicken feed intake control mechanisms are not completely understood. However, it has been shown that chickens will increase their feed intake in response to marginal levels of first limiting feed nutrient, independent of the diet energy level (Boarman, 1979) since appetite is assumed to be dependent on the nutrient requirements of the animal and the contents of those nutrients in the feed (Emmans and Fisher, 1986). As such, other macronutrients other than energy may influence feed behaviour in chickens (Buyse *et al*., 1992). Parson *et al*. (1993) pointed out that in many experiments, where only responses to dietary energy level are involved, such feed intake responses could be confounded with variable intake of other nutrients such as protein and hence differences in feed intake response patterns to limiting feed protein content observed for Ross 308 broiler chickens and Cobb 500 chickens as indicated in (Figure 2) below. Importantly, it is interesting to note that these differing feed intake response patterns to limiting feed protein content were achieved regardless of the energy value of the feed.

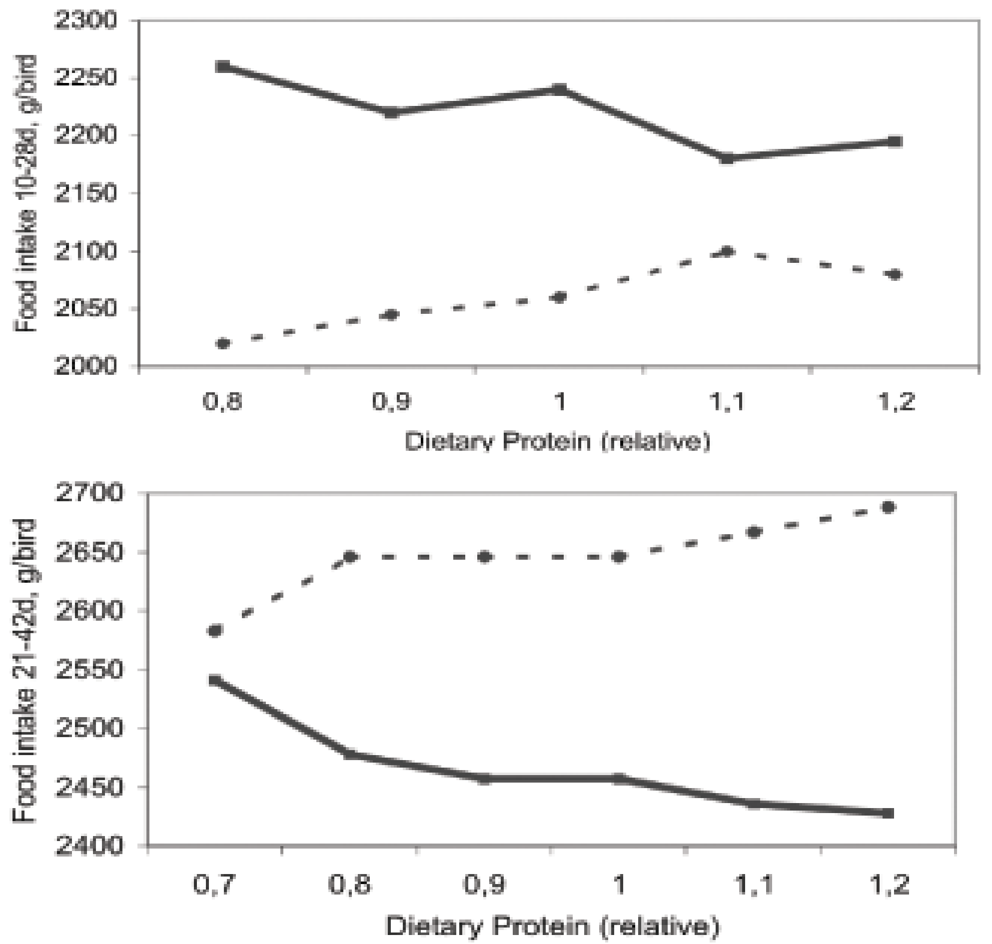

Figure 1 - Response in food intake of two strains of broiler to increasing dietary balanced protein contents. Trial 1 from Kemp *et al.* (2005); Trial 2 from Berhe & Gous (2005). Ross 308 represented by dashed line; Cobb 500, solid line. Dietary protein contents relative to the Ross standard feeding levels (Aviagen, 2006).

Source: Gous (2007).

There is also evidence that uniformity decreases as the feed becomes marginally deficient in protein (Corzo *et al*., 2004). The probable cause of decreased uniformity on feeds marginally deficient in protein content is the variation in the ability of the birds to overconsume energy when faced with a deficiency. This characteristic will enable the successful birds to show little reduction in growth, whereas the feed intake of others, without the capacity to deposit as much lipid, could be severely constrained, resulting in poor growth. Whilst it is well documented that breast meat yield is related to the protein content of the feed (Kidd *et al*., 2004; Lemme *et al*., 2006), Kemp *et al*. (2005) have shown that such responses are strain-dependent. They found that the response in breast meat yield increased in low feed intake strains of chickens over a range of different feed protein contents used in the experiment whereas the reverse was the case for high feed intake strains. Importantly, they concluded that it is not clear whether responses in breast meat yield are functions of the strain of broiler chickens or simply that of protein weight of the bird when processed.

These observations on limitations in feed intake support the revised thinking of the NRC (1994) that some chicken strains do not adjust their feed intake to changes in the dietary metabolisable energy density and, as a result, may be prone to over-consume metabolisable energy in an attempt to obtain sufficiency of a limiting nutrient when offered diets high in energy, thereby, making the long held theory that chickens do adjust feed intake to a constant metabolisable energy intake questionable. Apparently, genetic potential influences the Ross 308 broiler chickens' feeding behaviour as it affects their nutritional requirements (Gous et al., 1999). Thus, Ross 308 broiler chickens have pronounced genetic advantage for fast growth using high protein feed compared to Cobb 500 chickens and this might explain the differences in feed intake response patterns to marginally limiting feed protein content between these strains of chickens.

This general response in food intake to reduced feed protein content, namely, a linear increase followed by a decline in intake, is illustrated in Figure 3. If one assumes that the limiting protein content resulting in the lowest food intake on the right of each graph reflects an adequate supply of protein, and that strains may differ in the protein content assumed to be adequate, then it is possible to imagine a situation in which the range of protein contents chosen in a dose-response trial will result in the food intake increasing and decreasing in the two strains, respectively, as illustrated in Figure 3. Whilst this may not be the reason for the difference in their responses in food intake to protein content, it does suggest that this may not necessarily be a classical genotype *x* nutrient interaction. However, because of the important implications of these differences on productivity, knowledge of the feed intake responses are very important when attempting to optimize the feeding of chickens. No studies were found on feed intake response patterns to differing feed energy to protein ratio levels in indigenous chickens. Research into this will help to avoid feed wastage while improving productivity of indigenous Venda chickens.

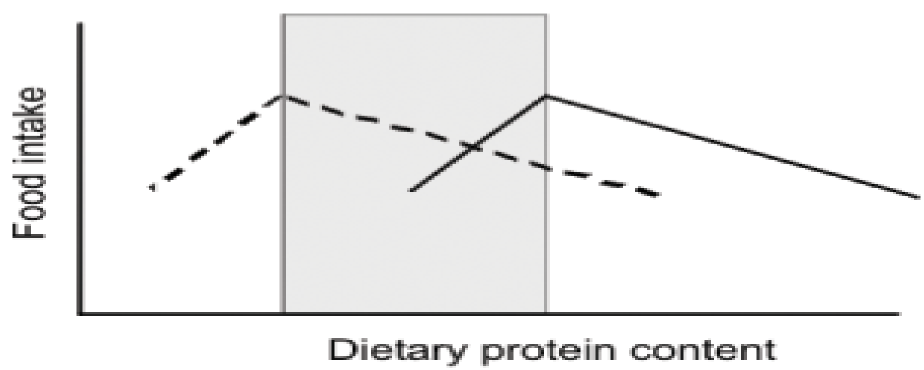

Figure 3 - Simulated responses in food intake to a range of dietary protein contents in two hypothetical broiler strains differing in the dietary protein content required to meet their potential growth. Shaded area reflects a range of dietary protein contents resulting in diametrically opposite food intake patterns in the two strains.

Source: Gous (2007).

2.9 Available local feed resources for indigenous chickens in Limpopo province:

It is important to match indigenous chickens' nutrition with locally available feed ingredients for sustainability of the indigenous chicken industry. Local feed resources of practical and economic importance for indigenous chicken production in Limpopo province include the conventional feed supplements such as brewers grain, blood meal, and unconventional animal protein sources such as caterpillars, insects, maggots, termites and earthworms.

In practice, indigenous chicken diets in Limpopo province are based largely on vegetable matter and cereal grains such as sorghum and millet and hence the main nutrient deficiency that could arise from these feeds will be that of the protein. Swatson et al. (2003) observed that several species of moth larvae including the mopane worm (*Family Saturmidae*) can provide an important source of supplementary protein to indigenous chickens. Similarly, insects that appear to be seasonally abundant in Limpopo province such as the stink bugs (*Pentatomidae*) and winged termites are also potential sources of supplementary protein. Swatson et al. (2003) observed that the analyzed protein concentrations of the mopane worm and stink bugs were 586.7 and 362.7 g/kg DM, respectively. In the same study, these authors found that the crude protein content of termites is 548.3 g/kg CP.

Research into these locally available proteins is going on at the University of Limpopo. This could help to overcome the protein quality limitations of indigenous chickens.

2.10 CONCLUSION

Predicting the response of indigenous Venda chickens to differing feed energy and protein levels would help in optimizing feeds and feeding programs of these chicken breeds while avoiding wastage of vital feed components. In addition, data on energy and protein requirements of indigenous chicken breeds such as the Venda chicken is limited. Such data is important for optimizing production and carcass characteristics of these chickens. Sub-optimum dietary energy to protein ratios result in the degradation of protein to meet the energy needs of the birds, whereas dietary energy to protein ratios much higher than the optimum result in inadequate intakes of protein. Wrong energy to protein ratios have negative effects on carcass yield and characteristics. Thus, it is important to determine the nutrient requirement levels for optimal productivity and carcass characteristics of Venda chickens. The objective of this study was to determine optimal growth and carcass characteristic responses to dietary energy to protein ratio levels in Venda chickens raised in closed confinement from day-old up to 13 weeks of age.

CHAPTER 3

EFFECT OF DIETARY ENERGY TO PROTEIN RATIO LEVEL ON GROWTH AND PRODUCTIVITY OF UNSEXED INDIGENOUS VENDA CHICKENS RAISED IN CLOSED CONFINEMENT FROM DAY-OLD UP TO SIX WEEKS OF AGE.

3.1 Introduction

The improvement of indigenous Venda chickens in South Africa requires determination of their nutrient requirements. However, extensive data on nutrient requirements of these chickens is not available (Tadelle and Ogle, 2000). A comparison of the dietary energy and protein requirements for fast, medium and slow growing broiler chickens indicates large differences in nutrient requirements (Quentin *et al.,* 2005). Limited information indicates that indigenous chickens have lower energy and protein requirements than broiler chickens (Tadelle and Ogle, 2000). Tadelle and Ogle (2000) reported that the energy requirement of growing indigenous chickens as determined from the chemical analysis of their crop contents is 11.99 MJ ME/kg DM. However, NRC (1994) recommended that the required energy in growing indigenous chicken diets should be 12.14 MJ ME/kg DM. Payne (1990) recommended 11.46 MJ ME/kg DM feed for indigenous chickens between one and six weeks old.

Ndegwa *et al.* (2001) reported that a 17 % CP diet was sufficient for growing indigenous chickens. However, Tadelle and Ogle (1996) observed that the protein requirements of growing indigenous chickens vary between 16 and 18 % during the growing phase. Thus, data on energy and protein requirements of indigenous chickens during the starter period is limited and variable. The importance of energy to protein ratio in broiler chicken production has been stressed in a number of studies (Hoffman, 1987; Hoisheimer and Jensen, 1991; Bartov and Plavnik, 1998). Such studies aimed at optimal utilization of both energy and protein in a feed. However, no such studies on indigenous chickens were found. The objective of this study was, therefore, to determine energy to protein ratio levels for optimal feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy and nitrogen retention of one to six weeks old Venda chickens raised in closed confinement.

3.2 Materials and methods

3.2.1 Study site

These studies were conducted at the University of Limpopo Experimental Farm at Syferkuil. The farm is located at about 10 km northwest of the Turfloop campus. The ambient temperatures around the study area ranged between 20 and 36 $^{\circ}$C during summer and between 10 and 25 $^{\circ}$C during the winter season.

3.2.2 Experimental procedures, dietary treatments and design

Five experiments were conducted. The five experiments were based on five different dietary energy levels of 12.2, 13.0, 13.2, 13.4 and 14.0 MJ ME/kg DM as determined in the laboratory using the method of Near Infra-Red Reflectance Analysis (NIRA), as described by Valdes and Leeson (1992). Each dietary energy level had five different levels of protein concentrations of 220, 190, 180, 170 and 160 g/kg DM, thus ending up with different dietary energy to protein ratio levels (Tables 3.01 to 3.05). Each experiment commenced with 160 unsexed day-old indigenous Venda chicks with an initial live weight of 25 ± 2 g per bird and carried out for a period of 6 weeks. The chicks were obtained from the University of Limpopo Hatchery Unit. In each experiment, the chicks were randomly assigned to five treatments with four replications, each having eight birds. Thus, 20 floor pens (1.5 m^2/pen) were used in total for each experiment. All the five experiments were carried out around the same time. A complete randomized design was used for each experiment. Light was provided 24 hours daily while feed and water were provided *ad libitum* throughout the experiments. The formulated experimental diets for each experiment were purchased from Z_{etB} Feeds, Louis Trichardt, South Africa. Thus, diet compositions were not given by the company.

Table 3.01 Dietary treatments for Experiment 1*

Diet	Diet description	E:P ratio (MJ ME/kg Protein)
$E_{12.2}P_{22}$	Diet containing12.2 MJ ME/kg DM feed and 22 % crude protein	55
$E_{12.2}P_{19}$	Diet containing12.2 MJ ME/kg DM feed and 19 % crude protein	64
$E_{12.2}P_{18}$	Diet containing12.2 MJ ME/kg DM feed and 18 % crude protein	68
$E_{12.2}P_{17}$	Diet containing12.2 MJ ME/kg DM feed and 17 % crude protein	72
$E_{12.2}P_{16}$	Diet containing12.2 MJ ME/kg DM feed and 16 % crude protein	76

* Laboratory determined ME (NIRA) and CP

Table 3.02 Dietary treatments for Experiment 2*

Diet	Diet description	E:P ratio (MJ ME/kg protein)
$E_{13}P_{22}$	Diet containing13 MJ ME/kg DM feed and 22 % crude protein	59
$E_{13}P_{19}$	Diet containing13 MJ ME/kg DM feed and 19 % crude protein	68
$E_{13}P_{18}$	Diet containing13 MJ ME/kg DM feed and 18 % crude protein	72
$E_{13}P_{17}$	Diet containing13 MJ ME/kg DM feed and 17 % crude protein	76
$E_{13}P_{16}$	Diet containing13 MJ ME/kg DM feed and 16 % crude protein	81

* Laboratory determined ME (NIRA) and CP

Table 3.03 Dietary treatments for Experiment 3*.

Diet	Diet description	E:P ratio (MJ ME/kg protein)
$E_{13.2}P_{22}$	Diet containing13.2 MJ ME/kg DM feed and 22 % crude protein	60
$E_{13.2}P_{19}$	Diet containing13.2 MJ ME/kg DM feed and 19 % crude protein	69
$E_{13.2}P_{18}$	Diet containing13.2 MJ ME/kg DM feed and 18 % crude protein	73
$E_{13.2}P_{17}$	Diet containing13.2 MJ ME/kg DM feed and 17 % crude protein	78
$E_{13.2}P_{16}$	Diet containing13.2 MJ ME/kg DM feed and 16 % crude protein	83

* Laboratory determined ME (NIRA) and CP

Table 3.04 Dietary treatments for Experiment 4*

Diet	Diet description	E:P ratio (MJ ME/kg protein)
$E_{13.4}P_{22}$	Diet containing13.4 MJ ME/kg DM feed and 22 % crude protein	61
$E_{13.4}P_{19}$	Diet containing13.4 MJ ME/kg DM feed and 19 % crude protein	71
$E_{13.4}P_{18}$	Diet containing13.4 MJ ME/kg DM feed and 18 % crude protein	74
$E_{13.4}P_{17}$	Diet containing13.4 MJ ME/kg DM feed and 17 % crude protein	79
$E_{13.4}P_{16}$	Diet containing13.4 MJ ME/kg DM feed and 16 % crude protein	84

* Laboratory determined ME (NIRA) and CP

Table 3.05 Dietary treatments for Experiment 5*

Diet	Diet description	E:P ratio (MJ ME/kg protein)
$E_{14}P_{22}$	Diet containing14 MJ ME/kg DM feed and 22 % crude protein	64
$E_{14}P_{19}$	Diet containing14 MJ ME/kg DM feed and 19 % crude protein	74
$E_{14}P_{18}$	Diet containing14 MJ ME/kg DM feed and 18 % crude protein	78
$E_{14}P_{17}$	Diet containing14 MJ ME/kg DM feed and 17 % crude protein	82
$E_{14}P_{16}$	Diet containing14 MJ ME/kg DM feed and 16 % crude protein	88

* Laboratory determined ME (NIRA) and CP

3.2.3 Data collection

The initial live weights of the chickens were taken at the commencement of each experiment. Thereafter, average live weight per bird was measured at weekly intervals by weighing the chickens in each pen, and then the total live weight was divided by the total number of birds in the pen to get the average live weight per chicken. These live weights were used to calculate growth rates of the chickens. Weekly mean feed intakes were determined until termination of the experiment. Daily mean live weights and feed intakes were calculated from the weekly measurements. Daily mean growth rates and feed conversion ratios were calculated from the above measurements. Digestibility was measured when the chickens were between 36 and 42 days old. Digestibility was conducted in specially designed metabolic cages having separated watering and feeding troughs. Two birds were randomly selected from each replicate of each experiment and transferred to metabolic cages for measurement of apparent digestibility. A three-day acclimatization period was allowed prior to a three-day collection period. Droppings voided by each bird were collected on a daily basis at 09.00 hours. Care was taken to avoid contamination from feathers, scales, debris and feeds.

3.2.4 Chemical analysis.

Dry matter of the feeds, faeces and feed refusals from each experiment were determined by drying the samples in the oven for 48 hours at a temperature of 105 °C. Ash content of the feeds, feed refusals and faeces were analyzed by ashing a sample at 600 °C in a muffle furnace overnight. Nitrogen contents were determined by the Kjedahl method (AOAC, 2002). Gross energy values for feeds and faeces were determined using an adiabatic bomb calorimeter (University of Limpopo laboratory, South Africa). However, metabolisable energy levels of the diets were determined in the laboratory using the method of Near Infra-Red Reflectance Analysis (NIRA), as described by Valdes and Leeson (1992). The apparent metabolisable energy contents of the diets from each experiment were calculated. Apparent metabolisable energy was equal to energy in the feed consumed minus energy excreted in the faeces (AOAC, 2002). Diets were analyzed for fatty acid contents according to the method described by AOAC (2002).

3.2.5 Data analysis

Data on feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy and nitrogen retention for all the five experiments were analyzed by one-way analysis of variance (SAS, 2008). Where there was a significant F-test ($P < 0.05$), the 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 energy to protein ratio levels were modeled using the following quadratic equation (SAS, 2008):

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

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 equations, x = dietary energy to protein ratio level and $-b_1/2b_2$ = x value for optimum response. 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 optimal responses in feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy and nitrogen retention across the five experiments and dietary energy to protein ratio levels were modelled using a linear regression equation (SAS, 2008) of the form:

$$Y = a + bx$$

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

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

3.3 Results

3.3.1 Experiment 1

Results of the nutrient composition of the diets used in Experiment 1 are presented in Table 3.06. The diets had a similar energy level of 12.2 MJ ME/kg DM but different protein levels. Protein levels ranged between 160 and 220 g CP/kg DM.

Results of the effect of energy to protein ratio level on feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens from one to six weeks of age, based on a dietary energy level of 12.2 MJ ME/kg DM, are presented in Table 3.07. Venda chickens offered a diet having 64 MJ ME/kg protein had higher (P<0.05) feed intake than those offered diets having 55, 68, 72 and 76 MJ ME/kg protein ratios. However, those offered diets having 55 and 76 MJ ME/kg protein ratios had similar (P>0.05) feed intakes.

Venda chickens offered a diet having 64 MJ ME/kg protein ratio had higher (P<0.05) growth rates than those offered diets having 55, 68, 72 and 76 MJ ME/kg protein ratios. However, Venda chickens offered diets having 55 and 68 MJ ME/kg protein ratios had similar (P>0.05) growth rates. Venda chickens offered diets having 55, 64, 68 and 72 MJ ME/kg protein ratios had similar (P>0.05) live weights. Birds offered diets having 72 and 76 MJ ME/kg protein ratios had similar (P>0.05) live weights. Venda chickens on a diet having 68 MJ ME/kg protein ratio had a better (P<0.05) feed conversion ratio than those on diets having 55, 64, 72 and 76 MJ ME/kg protein ratios. Dietary energy to protein ratio had no (P>0.05) effect on apparent ME and nitrogen retention values of Venda chickens.

Results of the effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens between one and six weeks old are presented in Figures 3.01 to 3.06 and Table 3.08. Feed intake and growth rate were optimized at dietary energy to protein ratio of 62 MJ ME/kg protein (Figures 3.01 and 3.02, respectively). Live weight and feed conversion ratio were optimized at a dietary energy to protein ratio of 63 MJ ME/kg protein (Figures 3.03 and 3.04, respectively) while apparent ME and nitrogen retention were optimized at dietary energy to protein ratios of 74 and 68 MJ ME/kg protein, respectively (Figures 3.05 and 3.06, respectively).

Table 3.06 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					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{12.2}P_{22}$	931.4	12.2	220	11.0	12.3	6.2
$E_{12.2}P_{19}$	931.0	12.2	190	10.9	12.1	6.1
$E_{12.2}P_{18}$	931.6	12.2	185	10.8	12.0	5.8
$E_{12.2}P_{17}$	931.4	12.2	170	11.1	11.9	5.6
$E_{12.2}P_{16}$	931.8	12.2	160	11.2	11.8	5.7

Table 3.07 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) between one and six weeks of age, live weight at six weeks old (g/bird) and apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) of Venda chickens between 36 and 42 days of age, based on a dietary energy level of 12.2 MJ ME/kg DM*

Variable	Treatment (E:P ratio)					SE
	55	64	68	72	76	
Intake	32^{b}	34^{a}	30^{c}	32^{b}	29^{d}	0.00
Growth	9^{b}	10^{a}	9^{b}	8^{c}	7^{d}	0.00
FCR	3.6^{c}	3.4^{d}	3.3^{e}	4.0^{b}	4.1^{a}	0.00
Live weight	400^{a}	425^{a}	405^{a}	380^{ab}	345^{b}	15.50
ME	11.1	12.4	12.6	12.9	12.8	1.56
N-retention	2.3	2.4	2.2	2.0	1.8	0.36

^{abcde} :Means in the same row not sharing a common superscript are significantly different (P < 0.05)

ME :Apparent metabolisable energy

N-retention : Nitrogen retention

SE : Standard error

* :Dietary ME determined by NIRA (Valdes and Leeson, 1992)

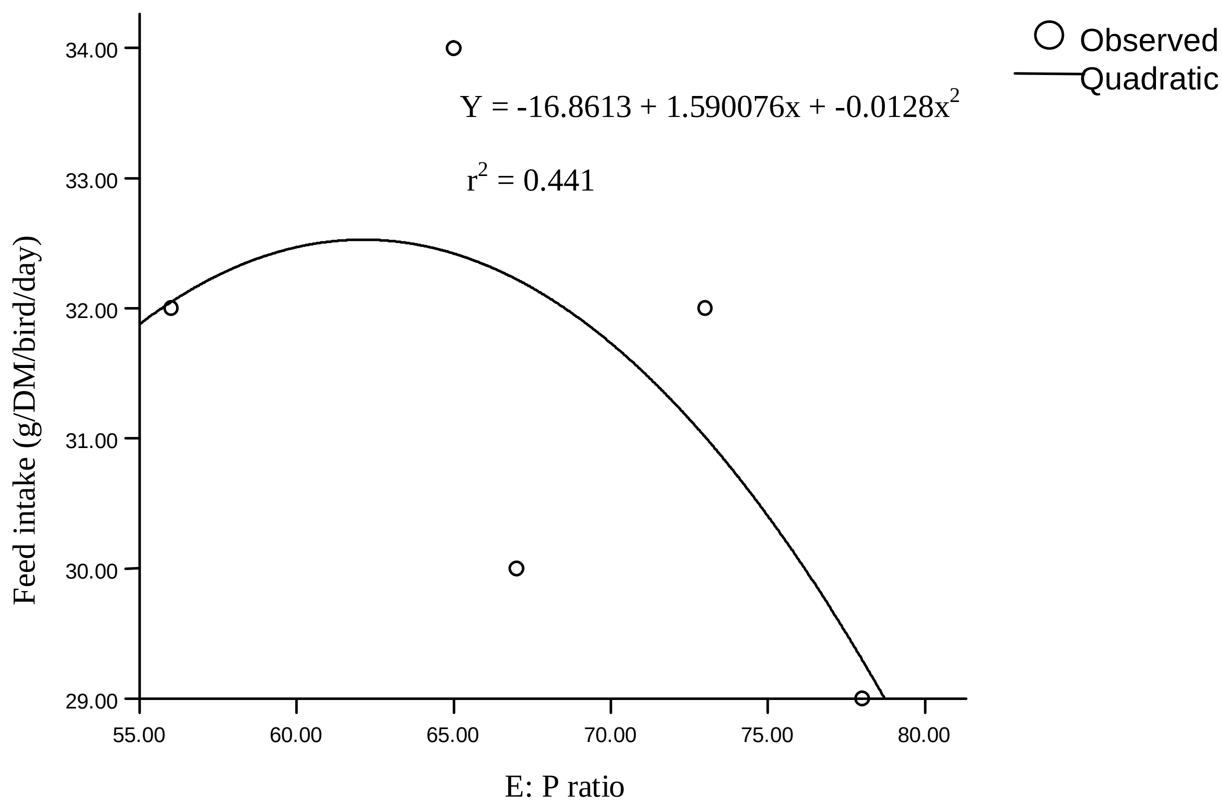

Figure 3.01 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on daily DM feed intake of Venda chickens between one and six weeks old

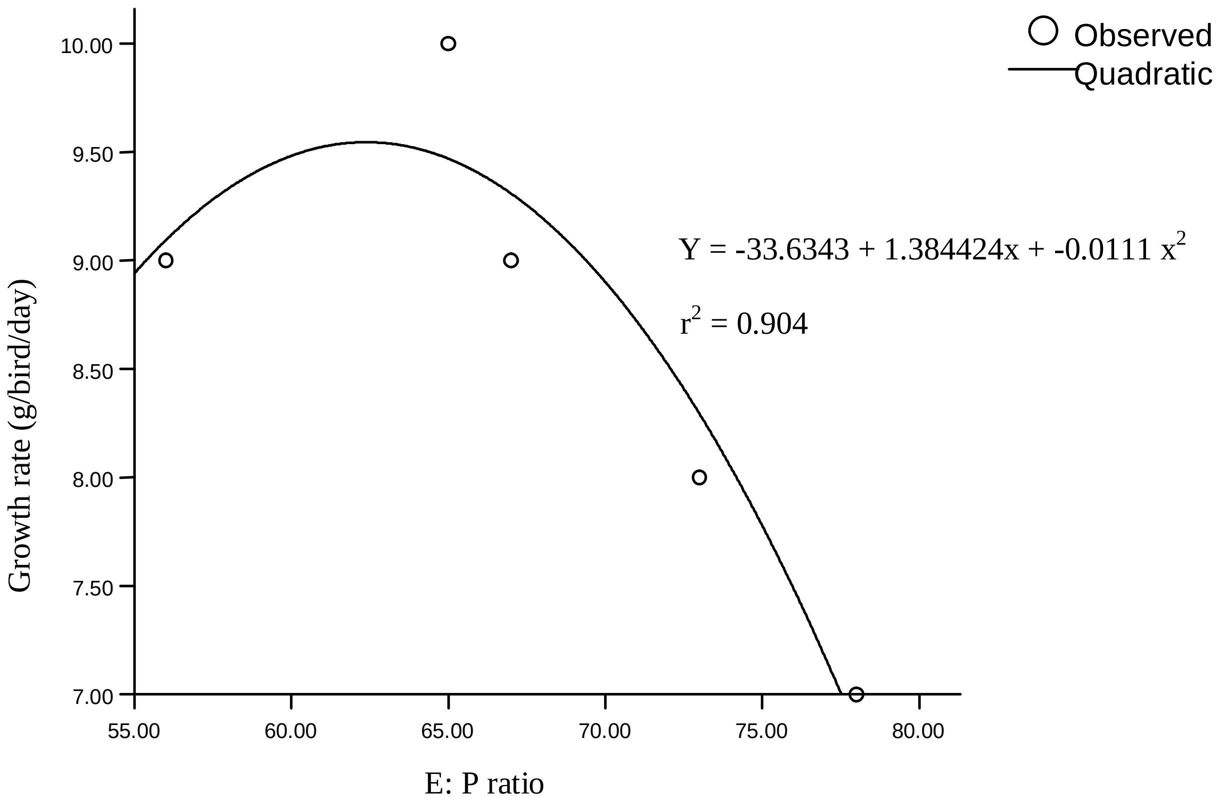

Figure 3.02 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on growth rate of Venda chickens between one and six weeks old

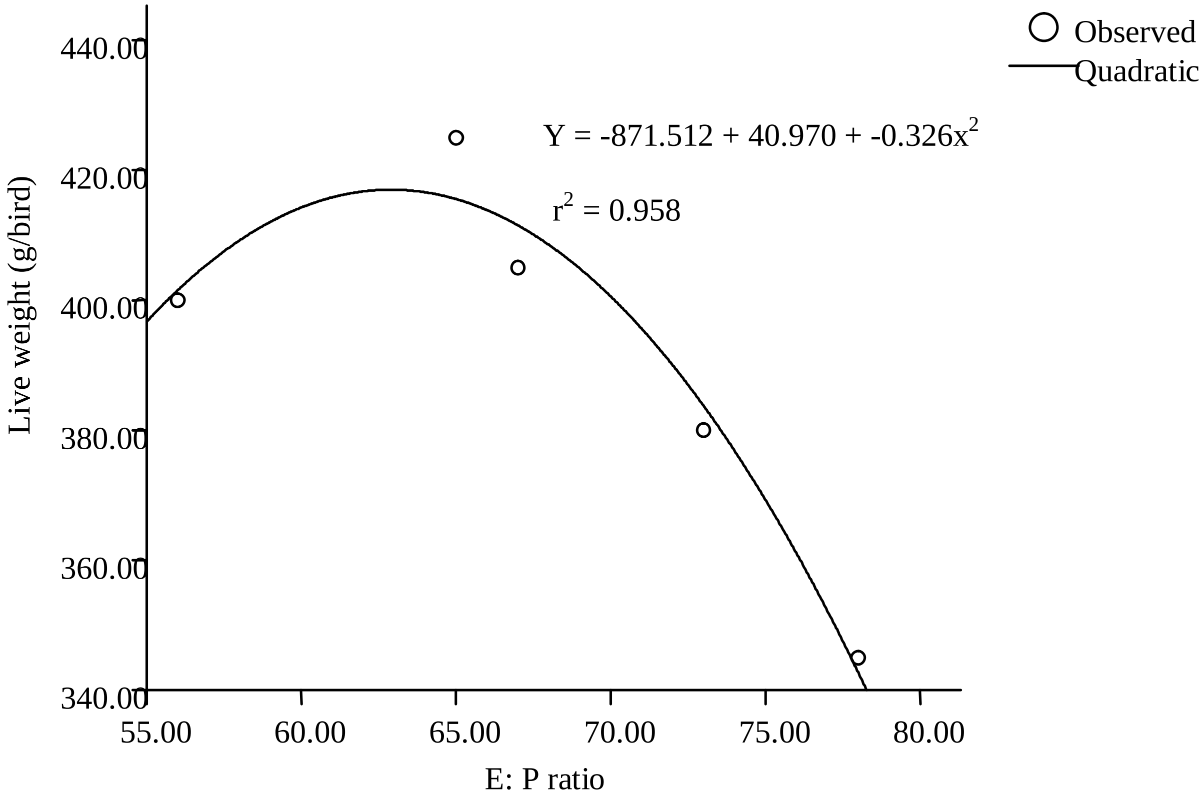

Figure 3.03 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on live weight of Venda chickens at six weeks old

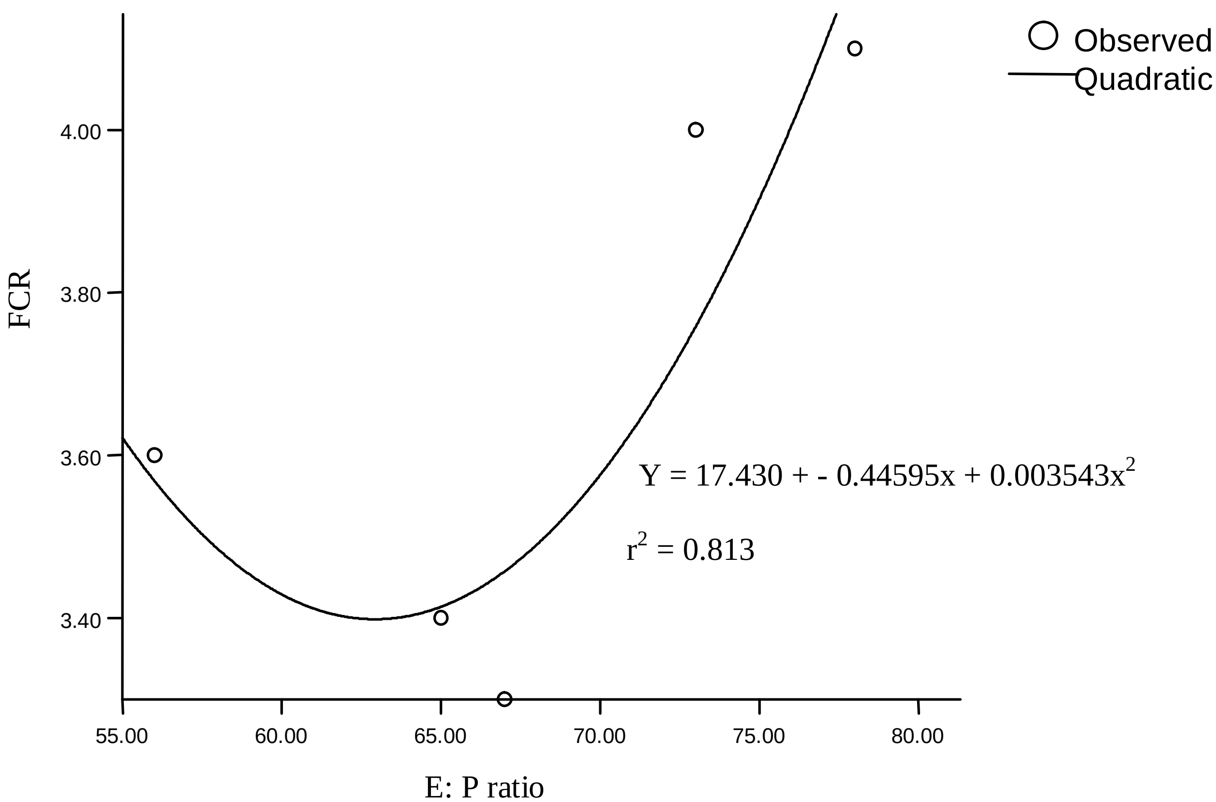

Figure 3.04 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 ME MJ/kg DM, on FCR of Venda chickens between one and six weeks old

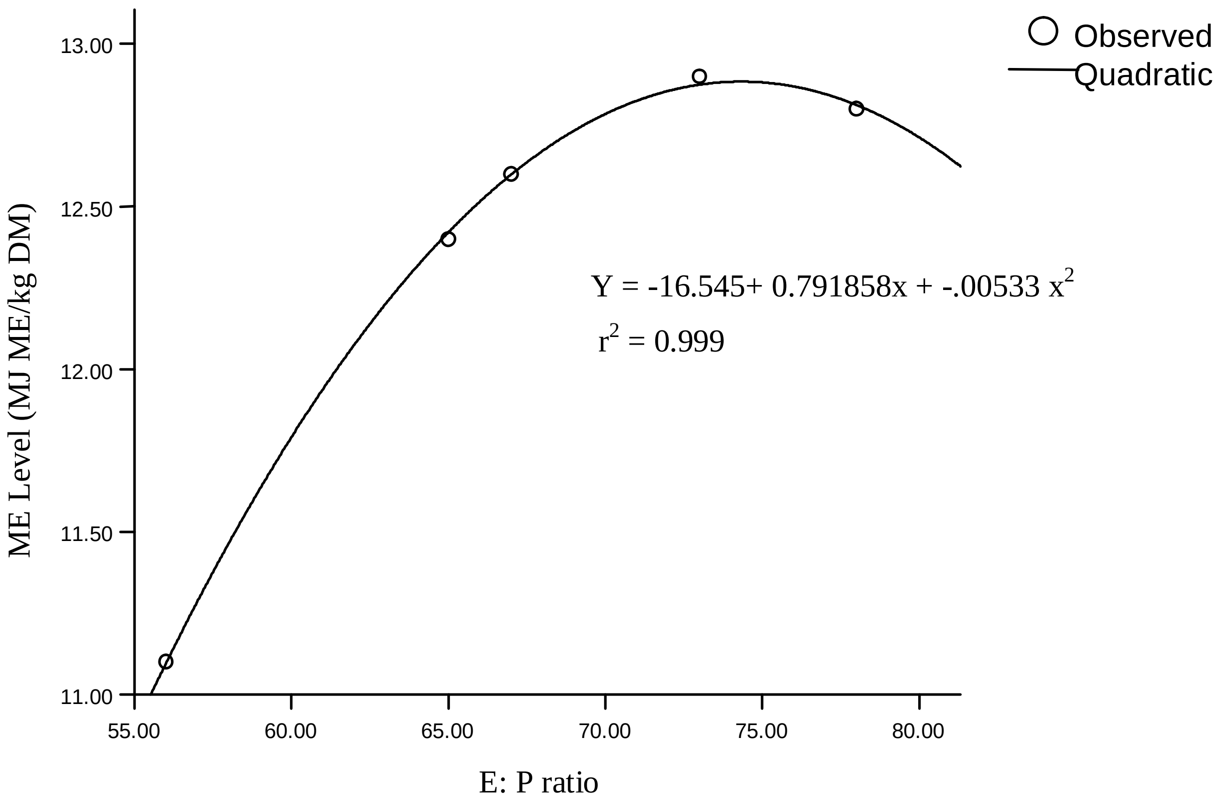

Figure 3.05 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on apparent metabolisable energy level of Venda chickens between one and six weeks old

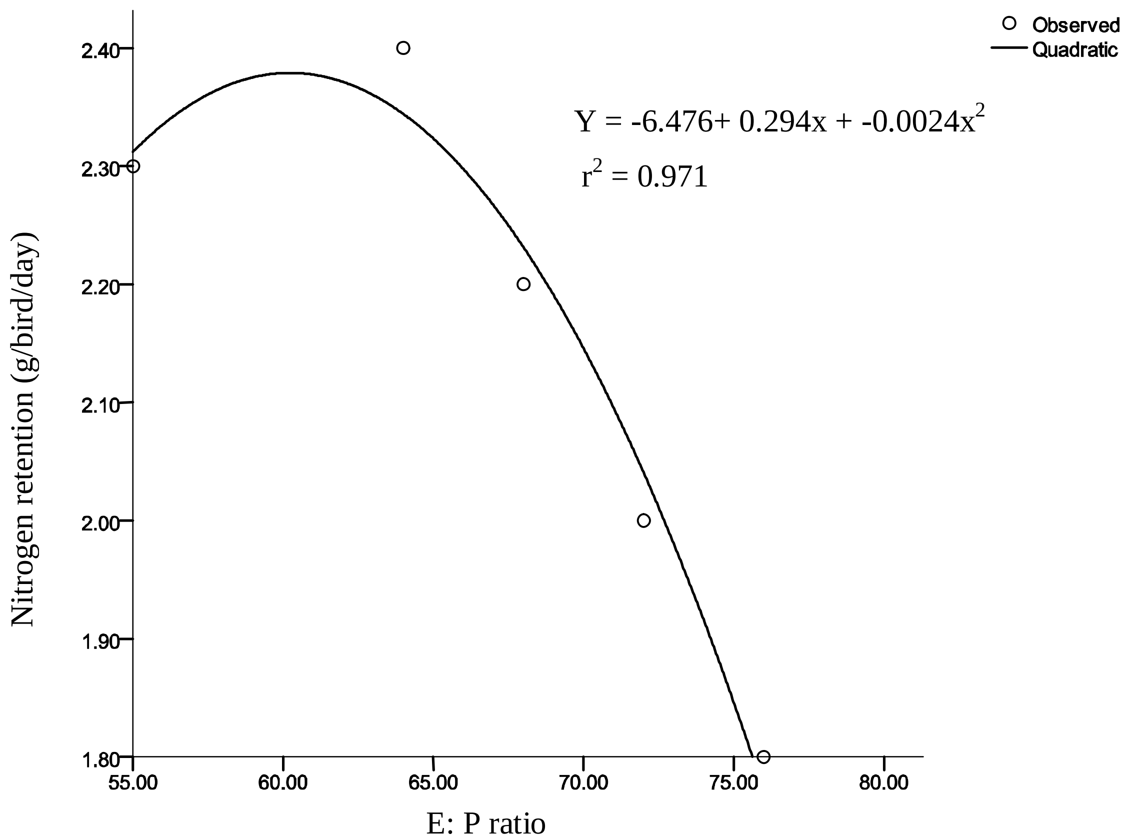

Figure 3.06 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on nitrogen retention of Venda chickens between one and six weeks old

Table 3.08 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) in Venda chickens between one and six weeks old

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y= -16.8613+1.590076x + -0.0128x^2$	62	33	0.441	0.559
Growth	$Y = -33.6343+1.384424x+-0.0111 x^2$	62	10	0.904	0.096
FCR	$Y = 17.430+-0.44595x + 0.003543 x^2$	63	3.4	0.813	0.187
Lwt	$Y = 17.430+-0.44595x + 0.003543 x^2$	63	415	0.958	0.042
ME	$Y = -16.545+ 0.791858x + -.00533 x^2$	74	14.2	0.999	0.610
Nitrogen retention	$Y = -6.476 + 0.294x + -0.0024x^2$	61	2.4	0.971	0.029

FCR :Feed conversion ratio

Lwt :Live weight

ME :Apparent metabolisable energy

P :Probability level

E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)

Y-Value :Optimal Y-Value

3.3.2 Experiment 2

The results of the nutrient composition of the diets in Experiment 2 are presented in Table 3.09.The diets had a similar energy level of 13 MJ ME/kg DM but different protein levels. Protein levels ranged between 160 and 220 g CP/kg DM.

Results of the effect of energy to protein ratio level on feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens from one to six weeks of age, based on a dietary energy level of 13 MJ ME/kg DM, are presented in Table 3.10. Venda chickens offered diets having 59, 68, 72 and 76 MJ ME/kg protein ratios had similar (P>0.05) feed intakes. However, those offered diets having 68 MJ ME/kg protein ate more (P<0.05) than those offered diets having 81 MJ ME/kg protein. Venda chickens offered diets having 68 and 72 MJ ME/kg protein ratios had similar (P>0.05) growth rates. Similarly, Venda chickens offered diets having 59 and 76 MJ ME/kg protein ratios had the same (P>0.05) growth rates. However, those offered a diet having 81 MJ ME/kg protein ratio had a lower (P<0.05) growth rate than those offered diets having 59, 68, 72 and 76 MJ ME/kg protein ratios.

Venda chickens offered diets having 59, 68 72 and 76 MJ ME/kg protein ratios had similar (P>0.05) live weights. However, those offered a diet having 68 MJ ME/kg protein ratio had higher (P<0.05) live weights than those offered a diet having 81 MJ ME/kg protein ratio. Venda chickens offered diets having 59 and 76 MJ ME/kg protein ratios had similar (P>0.05) feed conversion ratios. Similarly, Venda chickens offered diets having 68 and 72 MJ ME/kg protein ratios had the same (P>0.05) feed conversion ratios. However, those offered a diet having 81 MJ ME/kg protein ratio had a poorer (P<0.05) feed conversion ratio than those offered diets having 59, 68, 72 and 76 MJ ME/kg protein ratios. Venda chickens offered diets having 59 and 68 MJ ME/kg protein ratios had similar (P>0.05) ME values. Similarly, Venda chickens offered diets having 76 and 81 MJ ME/kg protein ratios also had the same (P>0.05) ME values. However, those offered a diet having 72 MJ ME/kg protein had a higher (P<0.05) apparent ME value than those offered diets having 59, 68, 76 and 81 MJ ME/kg protein ratios. Venda chickens offered diets having 59, 68, 72, 76 and 81 MJ ME/kg protein ratios had similar ($P>0.05$) nitrogen retentions.

Results of the effect of dietary energy to protein ratio level, based on dietary energy level of 13 MJ ME/kg DM, on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens between one and six weeks old are presented in Figures 3.07 to 3.12 and Table 3.11. Feed intake, growth rate, FCR and nitrogen retention were optimized at dietary energy to protein ratio of 68 MJ ME/kg protein (Figures 3.07, 3.08, 3.10 and 3.12, respectively). Live weight and apparent ME were optimized at dietary energy to protein ratio of 67 MJ ME/kg protein (Figures 3.09 and 3.11, respectively).

Table 3.09 Nutrient composition of diets used in Experiment 2 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed).

	Nutrient					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{13}P_{22}$	928.6	13	220	10.5	12.4	6.6
$E_{13}P_{19}$	928.2	13	190	11.0	12.1	6.4
$E_{13}P_{18}$	928.0	13	185	10.8	11.8	6.0
$E_{13}P_{17}$	928.4	13	170	11.4	11.7	6.2
$E_{13}P_{16}$	928.3	13	160	11.6	12.0	6.1

Table 3.10 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) between one and six weeks of age, live weigh at six weeks old (g/bird) and apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) of Venda chickens between 36 and 42 days of age based on dietary energy level of 13 MJ ME/kg DM*

Variable	Treatment (E:P ratio)					SE
	59	68	72	76	81	
Intake	34^{ab}	36^{a}	34^{ab}	35^{ab}	33^{b}	0.65
Growth	8^{b}	9^{a}	9^{a}	8^{b}	7^{c}	0.00
FCR	4.3^{b}	4.0^{c}	3.8^{c}	4.4^{b}	4.7^{a}	0.08
Live weight	380^{ab}	419^{a}	393^{ab}	370^{ab}	339^{b}	21.46
ME	13.2^{b}	13.5^{b}	14.7^{a}	11.8^{c}	11.7^{c}	0.28
N-retention	1.7	1.3	1.8	1.6	1.2	0.26

abcde :Means in the same row not sharing a common superscript are significantly different ($P < 0.05$).

ME :Apparent metabolisable energy

N-retention :Nitrogen retention

SE :Standard error

* :Dietary ME determined by NIRA (Valdes and Leeson, 1992)

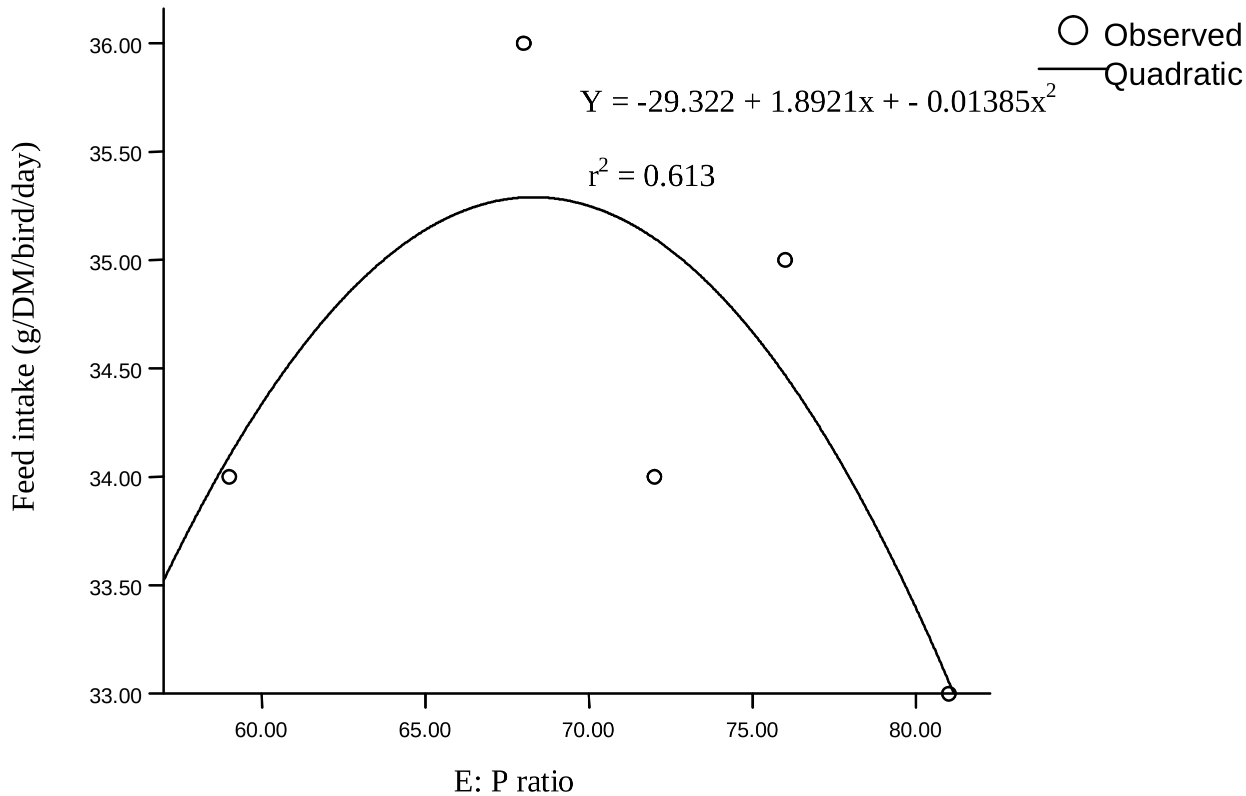

Figure 3.07 Effect of dietary energy to protein ratio level, based on a dietary energy level 13 MJ ME/kg DM, on daily DM feed intake of Venda chickens between one and six weeks old

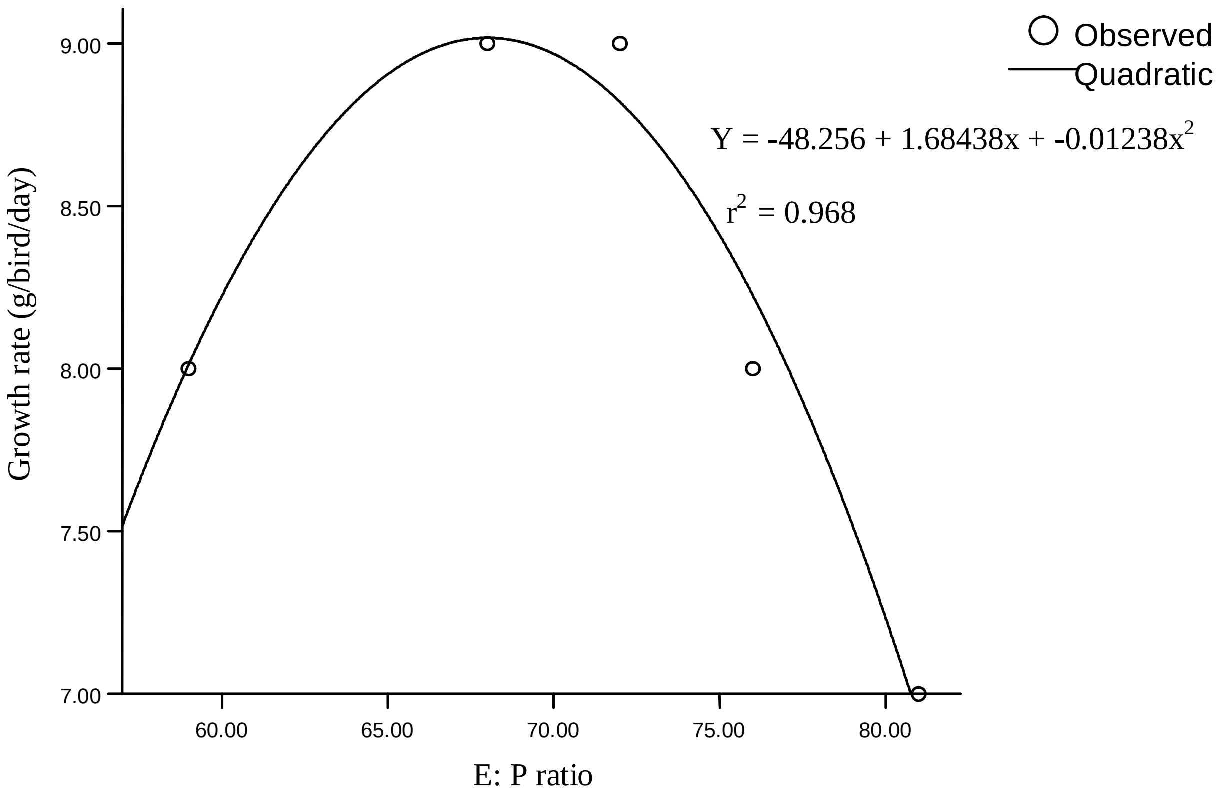

Figure 3.08 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on growth rate of Venda chickens between one and six weeks old

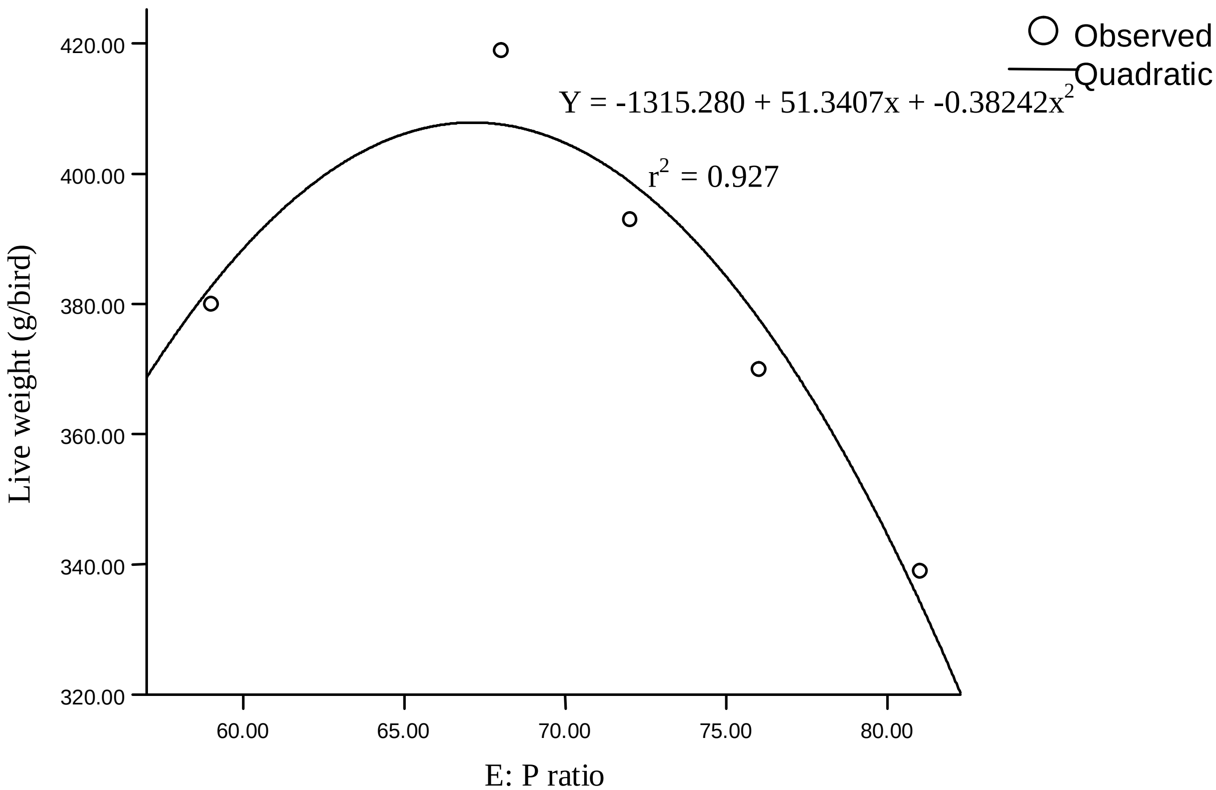

Figure 3.09 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on live weight of Venda chickens at six weeks old

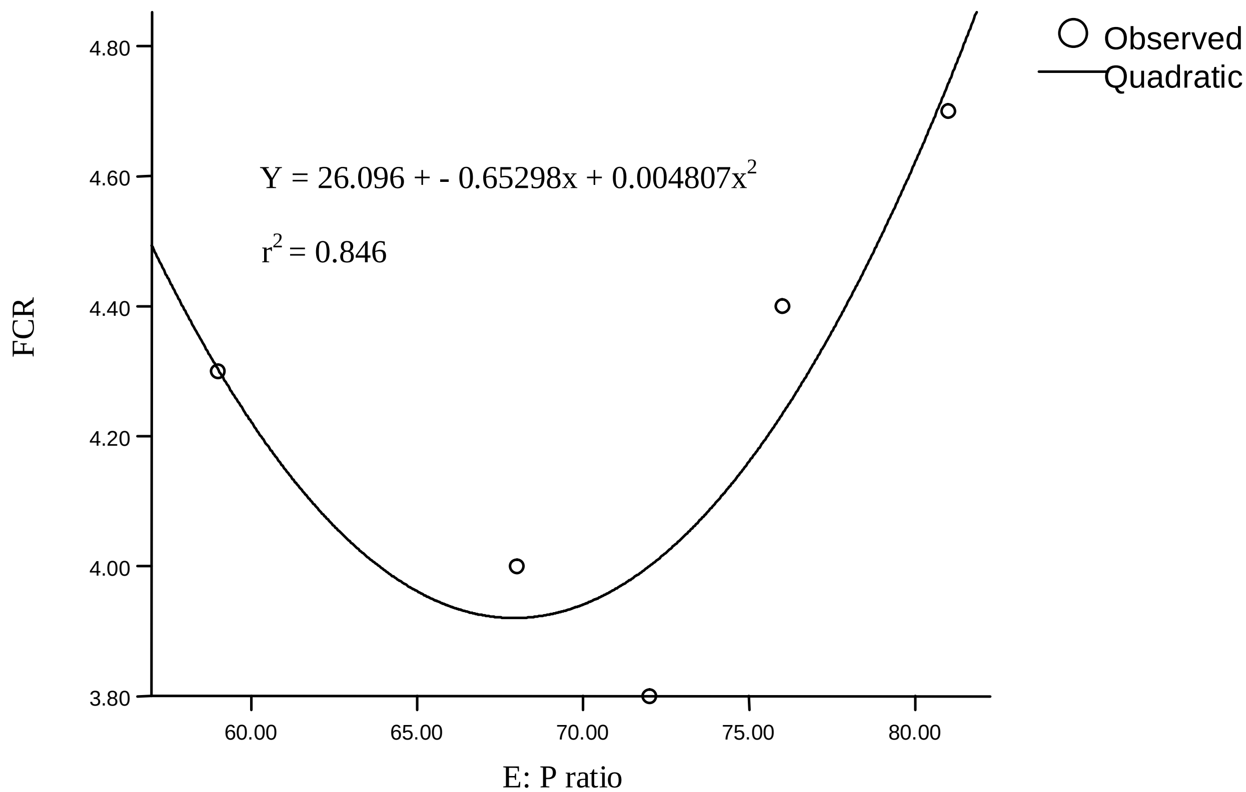

Figure 3.10 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME / kg DM, on FCR of Venda chickens between one and six weeks old

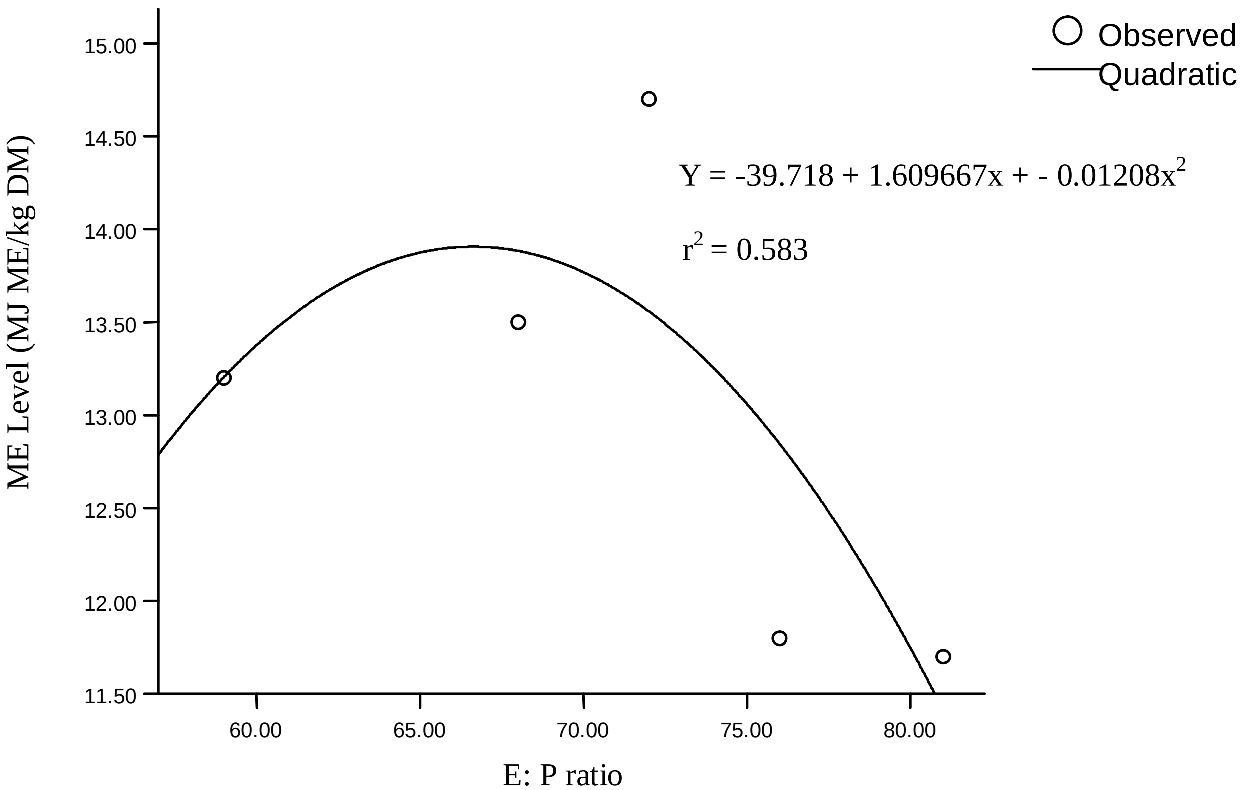

Figure 3.11 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME kg DM, on apparent metabolisable energy level of Venda chickens between one and six weeks old

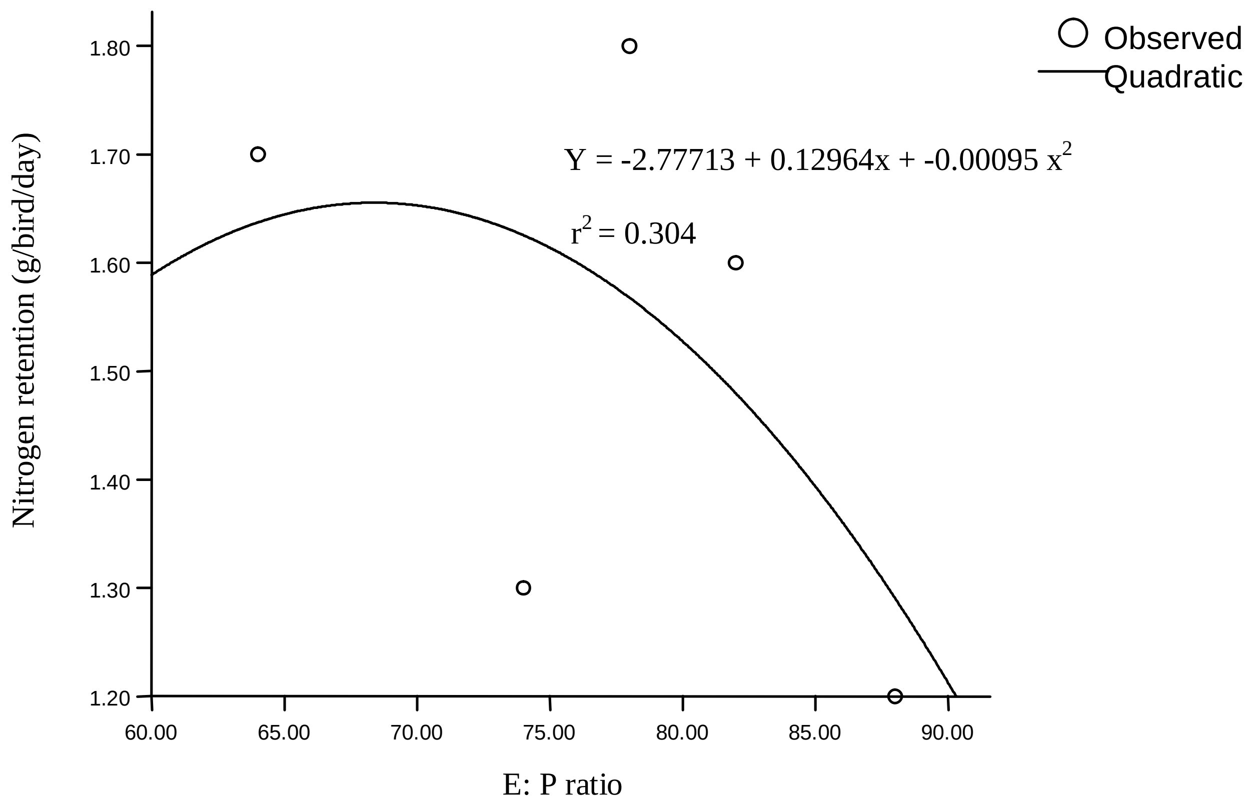

Figure 3.12 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on nitrogen retention of Venda chickens between one and six weeks old

Table 3.11 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) in Venda chickens between one and six weeks old

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y = -29.322+1.8921x + -0.01385x^2$	68	35	0.613	0.387
Growth	$Y = -48.256+1.68438x + -0.01238\ x^2$	68	9	0.968	0.032
FCR	$Y = 26.096+ -0.65298x+ 0.004807\ x^2$	68	3.9	0.846	0.154
Lwt	$Y= -1315.280+51.3407x+ -0.38242x^2$	67	408	0.927	0.073
ME	$Y = -39.718+1.609667x+ -0.01208\ x^2$	67	12.9	0.583	0.417
Nitrogen retention	$Y = -2.77713+0.12964x+ -0.00095\ x^2$	68	1.6	0.304	0.696

FCR :Feed conversion ratio
Lwt :Live weight
ME :Apparent metabolisable energy
P :Probability level
E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)
Y-Value :Optimal Y-Value

3.3.3 Experiment 3

Results of the nutrient composition of the diets used in Experiment 3 are given in Table 3.12. Diets were isocaloric but with different protein levels, ranging from 160 to 220 g CP/kg DM.

Results of the effect of energy to protein ratio level on feed intake, growth rate, feed conversion ratio, live weight, apparent ME and nitrogen retention in Venda chickens from one to six weeks of age, based on a dietary energy level of 13.2 MJ ME/kg DM, are presented in Table 3.13. There were no differences (P>0.05) in feed intake between chickens offered diets having 60, 69, 73, 78 and 83 MJ ME/kg protein ratios. Venda chickens offered diets having 69, 73 and 78 MJ ME/kg protein ratios had similar (P>0.05) growth rates. Similarly, those offered diets having 60 and 83 MJ ME/kg protein ratios had the same (P>0.05) growth rates. However, those offered diets having 69, 73 and 78 MJ ME/kg protein ratios had higher (P<0.05) growth rates than those offered diets having 60 and 83 MJ ME/kg protein ratios. Venda chickens offered diets having 69, 73 and 78 MJ ME/kg protein ratios had similar (P>0.05) live weights. Similarly, chickens offered diets having 60 and 83 MJ ME/kg protein ratios had the same (P>0.05) live weights. However, chickens offered diets having 69, 73 and 78 MJ ME/kg protein ratios had higher (P<0.05) live weights than those offered diets having 60 and 83 MJ ME/kg protein ratios.

Dietary energy to protein ratio had no effect (P>0.05) on feed conversion ratio of Venda chickens. Dietary energy to protein ratio had no effect (P>0.05) on apparent ME of Venda chickens. Venda chickens offered diets having 60, 69 and 73 MJ ME/kg protein ratios had similar (P>0.05) nitrogen retentions. However, Venda chickens offered diets having 78 MJ ME/kg protein ratio had a higher (P<0.05) nitrogen retention value than those offered diets having 60, 69, 73 and 83 MJ ME/kg protein ratios.

Results of the effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens between one and six weeks old are presented in Figures 3.13 to 3.18 and Table 3.14. Feed intake was optimized at a dietary energy to protein ratio of 73 MJ ME/kg protein (Figure 3.13). Growth rate, FCR and live weight were optimized at a dietary energy to protein ratio of 70 MJ ME/kg protein (Figures 3.14, 3.15 and 3.16, respectively). Apparent metabolisable energy and nitrogen retention were optimized at dietary energy to protein ratios of 76 and 69 MJ ME/kg protein, respectively (Figures 3.17 and 3.18, respectively).

Table 3.12 Analysed nutrient composition of diets used in Experiment 3 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed)

	Nutrient					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{13.2}P_{22}$	928.3	13.2	220	10.8	12.7	6.7
$E_{13.2}P_{19}$	927.0	13.2	190	11.0	12.2	5.8
$E_{13.2}P_{18}$	928.1	13.2	185	10.5	11.9	6.0
$E_{13.2}P_{17}$	928.2	13.2	170	11.0	11.6	6.2
$E_{13.2}P_{16}$	928.0	13.2	160	11.3	12.0	6.3

Table 3.13 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) between one and six weeks of age, live weight at six weeks old (g/bird) and apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) of Venda chickens between 36 and 42 days of age, based on a dietary energy level of 13.2 MJ ME/kg DM*

Variable	Treatment (E:P ratio)					SE
	60	69	73	78	83	
Intake	35	38	38	39	37	1.55
Growth	7^{b}	9^{a}	8^{a}	8^{a}	7^{b}	0.01
FCR	5.0	4.2	4.7	4.9	5.3	0.20
Live weight	327^{c}	378^{a}	368^{a}	360^{ab}	335^{bc}	10.18
ME	15.2	12.3	13.6	11.5	13.9	1.12
N-retention	1.3^{b}	1.4^{b}	1.4^{b}	1.7^{a}	0.8^{c}	0.14

^{abcde} :Means in the same row not sharing a common superscript are significantly different ($P < 0.05$).

ME :Apparent metabolisable energy

N-retention :Nitrogen retention

SE :Standard error

* :Dietary ME determined by NIRA (Valdes and Leeson, 1992)

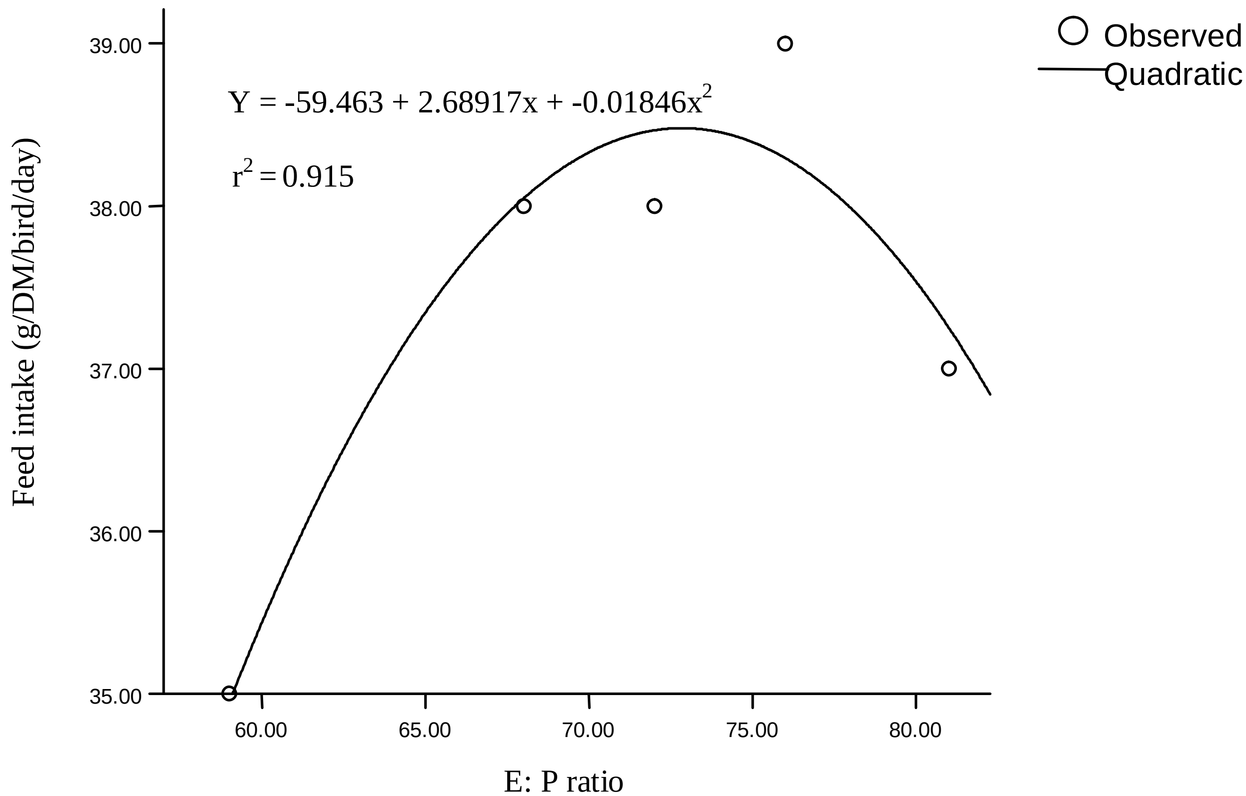

Figure 3.13 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on daily DM feed intake of Venda chickens between one and six weeks old

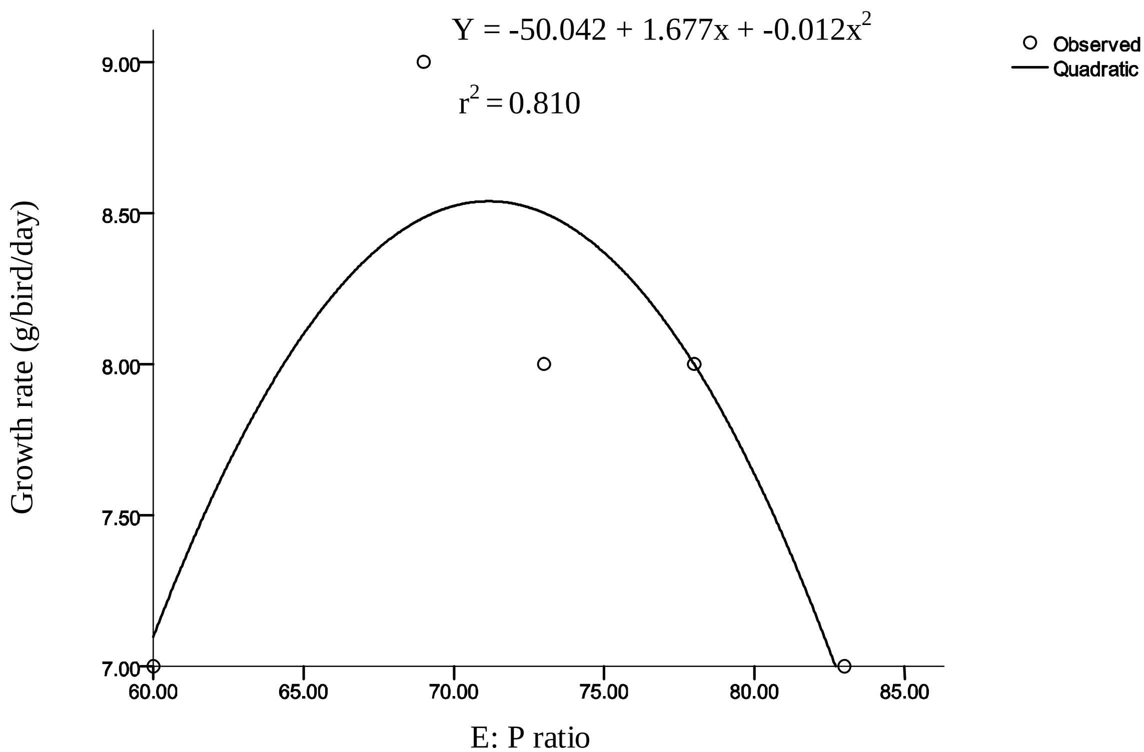

Figure 3.14 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on growth rate of Venda chickens between one and six weeks old

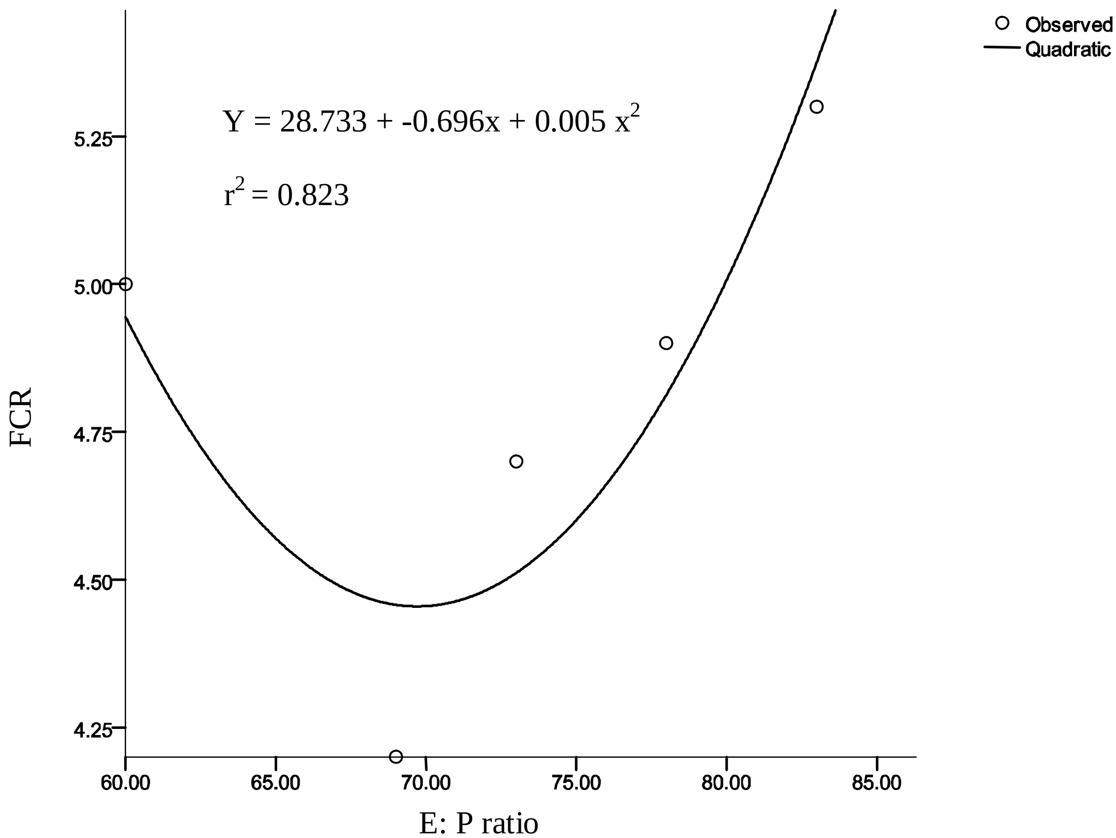

Figure 3.15 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on FCR of Venda chickens between one and six weeks old

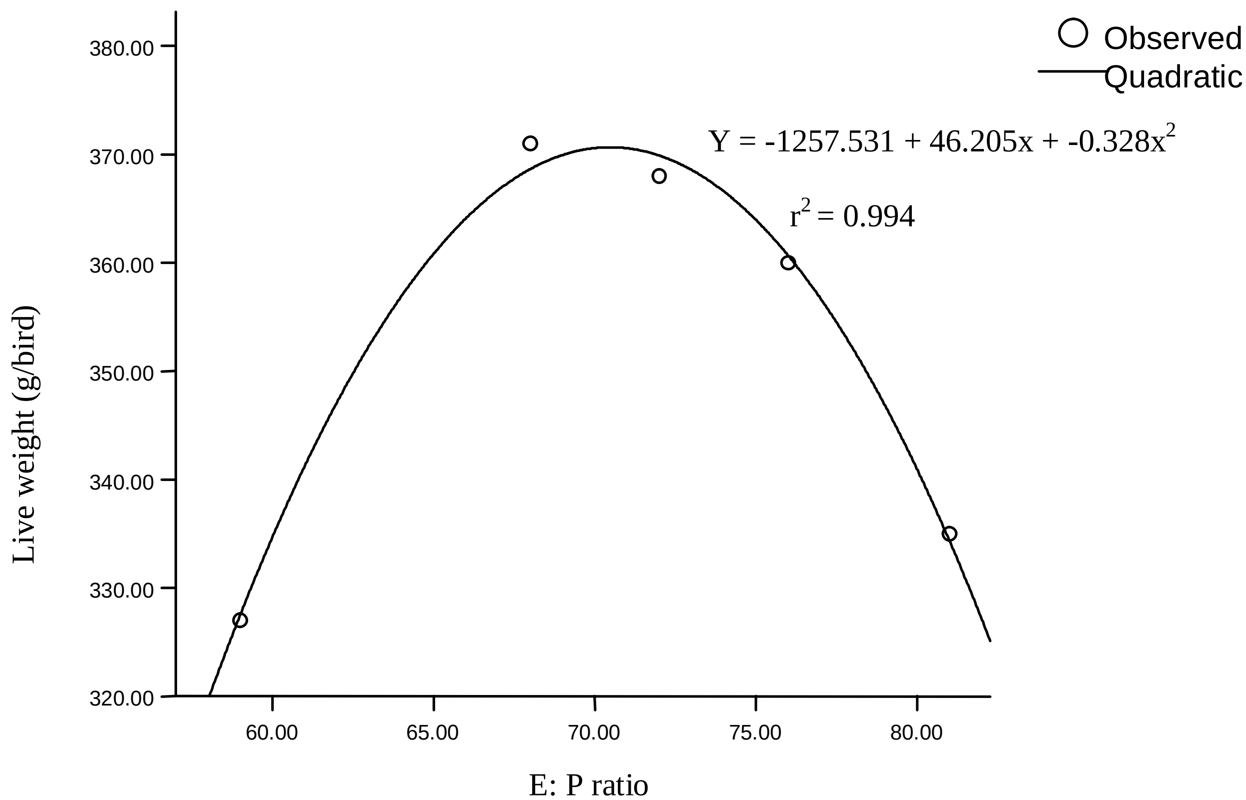

Figure 3.16 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on live weight of Venda chickens at six weeks old

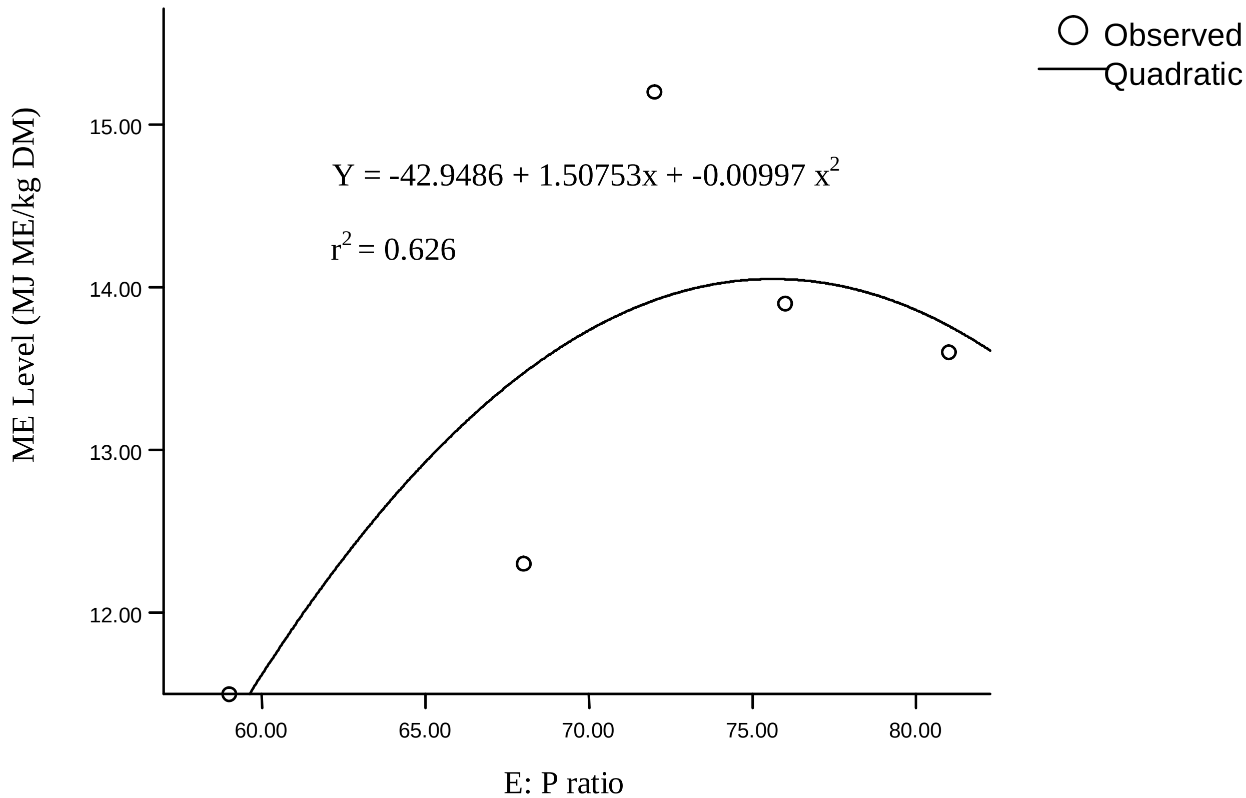

Figure 3.17 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on apparent metabolisable energy level of Venda chickens between one and six weeks old

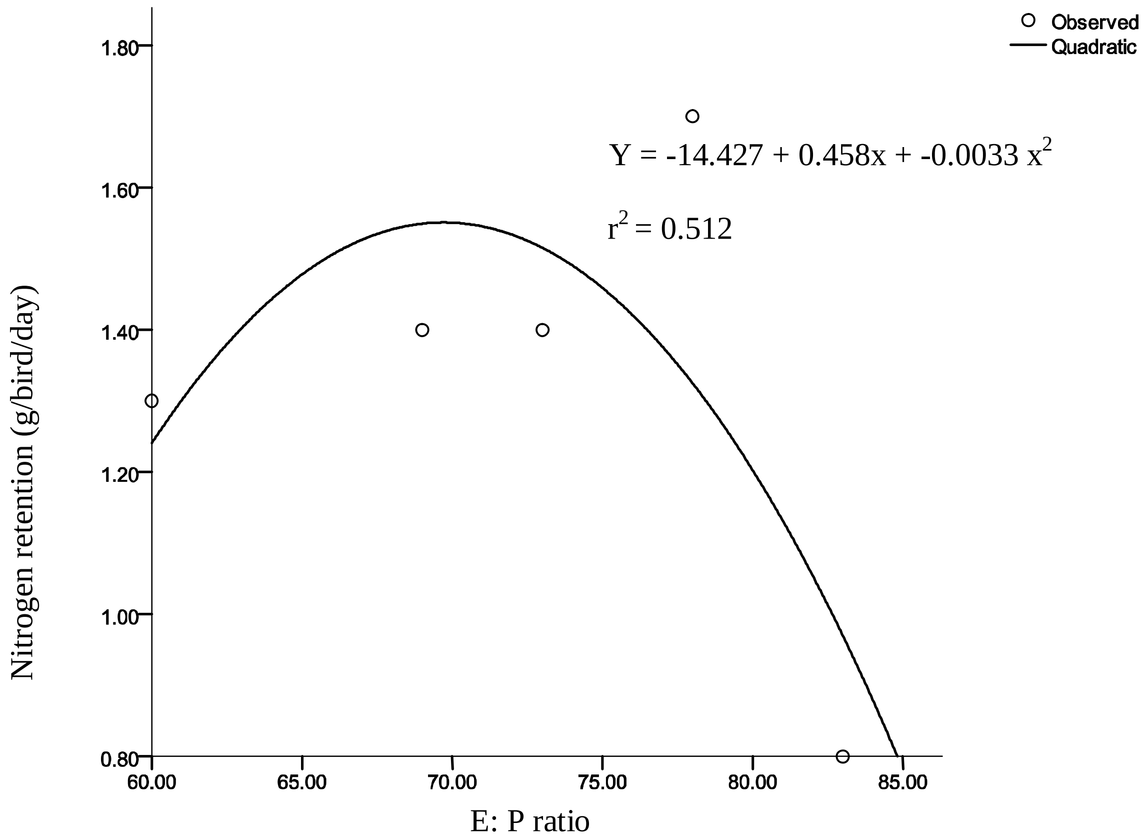

Figure 3.18 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on nitrogen retention of Venda chickens between one and six weeks old

Table 3.14 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) in Venda chickens between one and six weeks old

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y -59.463 + 2.68917x + -0.01846x^2$	73	38	0.915	0.085
Growth	$Y = -50.042 + 1.677x + -0.012 x^2$	70	8.5	0.810	0.190
FCR	$Y = 28.733 + -0.696x + 0.005 x^2$	70	4.5	0.823	0.177
Lwt	$Y = -1257.531 + 46.205x + -0.328x^2$	70	370	0.994	0.006
ME	$Y = - 42.9486+1.50753x+-0.00997 x^2$	76	14.0	0.626	0.374
Nitrogen retention	$Y = -14.427 + 0.458x + -0.0033x^2$	69	1.5	0.512	0.488

FCR :Feed conversion ratio
Lwt :Live weight
ME :Apparent metabolisable energy
P :Probability level
E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)
Y-Value :Y-Value for E: P ratio

3.3.4 Experiment 4

Results of the nutrient composition of the diets used in Experiment 4 are given in Table 3.15. The diets contained a similar energy level of 13.4 MJ ME/kg DM but different protein levels, ranging from 160 to 220 g CP/kg DM.

Results of the effect of energy to protein ratio level on feed intake, growth rate, feed conversion ratio, live weight, apparent ME and nitrogen retention in Venda chickens from one to six weeks of age, based on a dietary energy level of 13.4 MJ ME/kg DM, are presented in Table 3.16. There were no differences (P>0.05) in feed intake and live weight of chickens offered diets having 61, 71, 74, 79 and 84 MJ ME/kg protein ratios. Venda chickens offered diets having 71, 74 and 79 MJ ME/kg protein ratios had similar (P>0.05) growth rates. Similarly, chickens offered diets having 61 and 84 MJ ME/kg protein ratios had the same (P>0.05) growth rates. However, chickens offered diets having 71, 74 and 79 MJ ME/kg protein ratios had higher (P<0.05) growth rates than those offered diets having 61 and 84 MJ ME/kg protein ratios.

Dietary energy to protein ratio had no effect (P>0.05) on FCR and live weight of Venda chickens. Chickens offered a diet having 61 MJ ME/kg protein ratio had a lower (P<0.05) apparent ME than those offered diets having 71, 74, 79 and 84 MJ ME/kg protein ratios. However, those offered diets having 71 and 79 MJ ME/kg protein ratios had similar (P>0.05) apparent ME values. Similarly, chickens offered diets having 74 and 84 MJ ME/kg protein ratios had the same (P>0.05) apparent ME value. Venda chickens offered diets having 61, 71, 74 and 79 MJ ME/kg protein ratios had similar (P>0.05) nitrogen retention values. However, Venda chickens offered diets having 84 MJ ME/kg protein ratio had a lower (P<0.05) nitrogen retention than those offered diets having 61, 71, 74 and 79 MJ ME/kg protein ratios.

Results of the effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens between one and six weeks old are presented in Figures 3.19 to 3.24 and Table 3.17. Feed intake and live weight were optimized at dietary energy to protein ratio of 74 MJ ME/kg protein (Figures 3.19 and 3.21, respectively). Growth rate, FCR, apparent ME and nitrogen retention were optimized at dietary energy to protein ratios of 71, 72, 76 and 70 MJ ME/kg protein, respectively (Figures 3.20, 3.22, 3.23 and 3.24, respectively).

Table 3.15 Nutrient composition of diets used in Experiment 4 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed).

	Nutrient					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{13.4}P_{22}$	923.4	13.4	220	10.9	12.5	6.8
$E_{13.4}P_{19}$	923.1	13.4	190	11.0	12.2	6.4
$E_{13.4}P_{18}$	923.2	13.4	185	11.0	12.4	6.2
$E_{13.4}P_{17}$	923.3	13.4	170	11.4	11.8	6.1
$E_{13.4}P_{16}$	923.0	13.4	160	11.3	12.0	6.0

Table 3.16 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) between one and six weeks of age, live weight at six weeks old (g/bird) and apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) of Venda chickens between 36 and 42 days of age based on a dietary energy level of 13.4 MJ ME/kg DM*

Variable		Treatment	(E:P ratio)			SE
	61	71	74	79	84	
Intake	40	42	44	43	41	2.82
Growth	7^b	9^a	8^a	8^a	7^b	0.01
FCR	5.7	4.7	5.5	5.4	5.9	0.34
Lwt	319	382	365	358	332	26.34
ME	12.1^c	14.4^a	12.9^b	14.0^a	13.3^b	0.20
N-retention	1.2^a	1.2^a	1.5^a	1.4^a	0.8^b	0.12

^{abcde} :Means in the same row not sharing a common superscript are :significantly different ($P < 0.05$).

ME :Apparent metabolisable energy

N-retention :Nitrogen retention

SE :Standard error

***** :Dietary ME determined by NIRA (Valdes and Leeson, 1992)

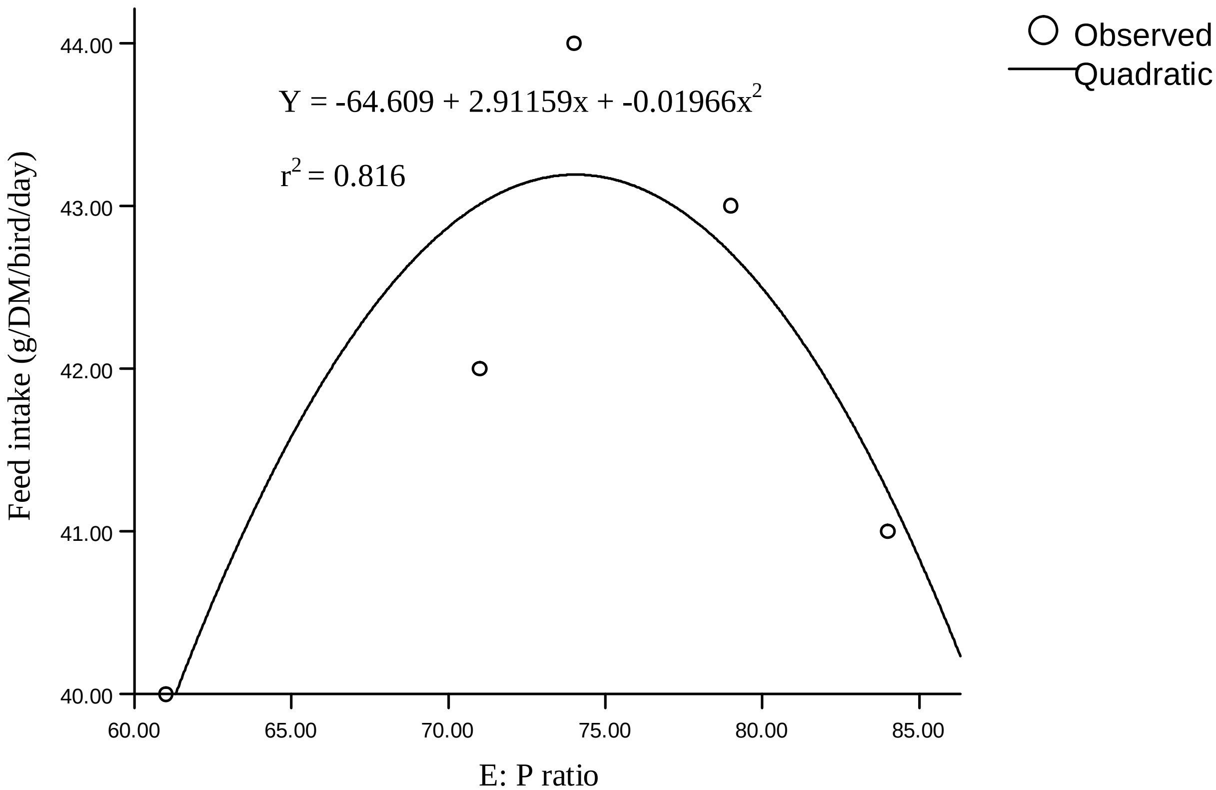

Figure 3.19 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on daily DM feed intake of Venda chickens between one and six weeks old

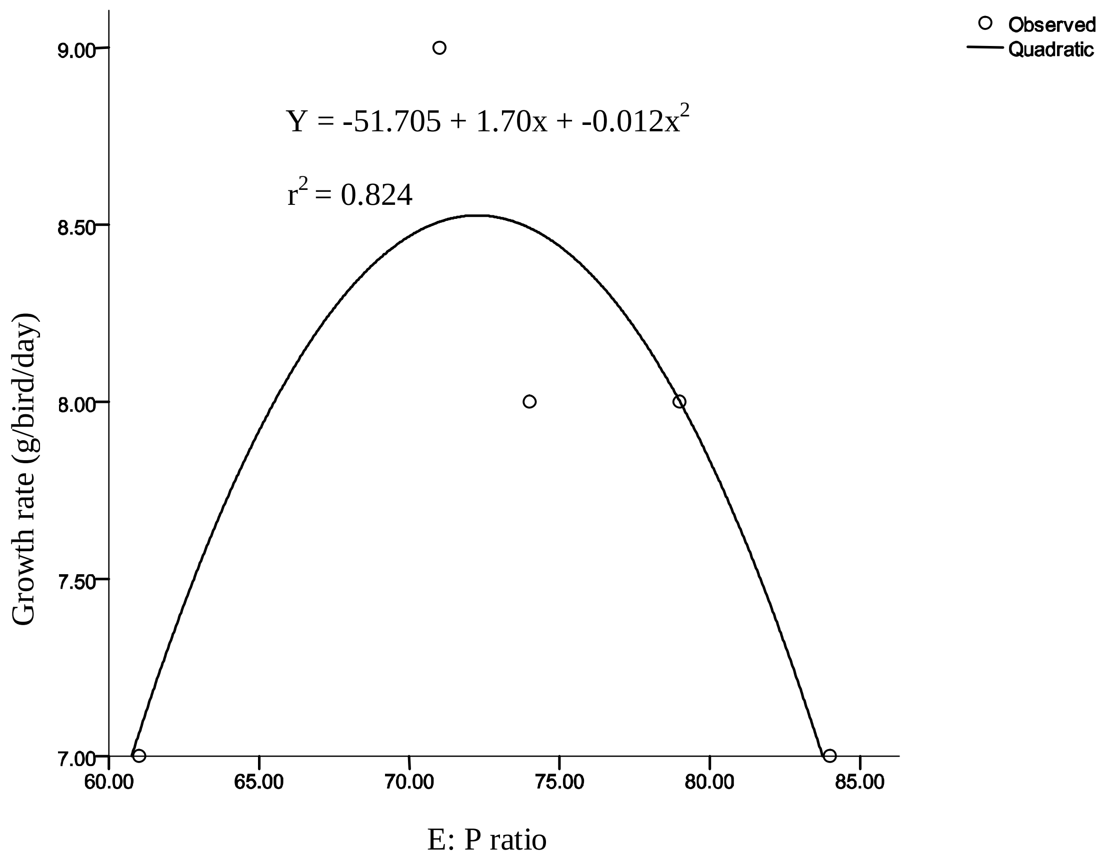

Figure 3.20 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on growth rate of Venda chickens between one and six weeks old

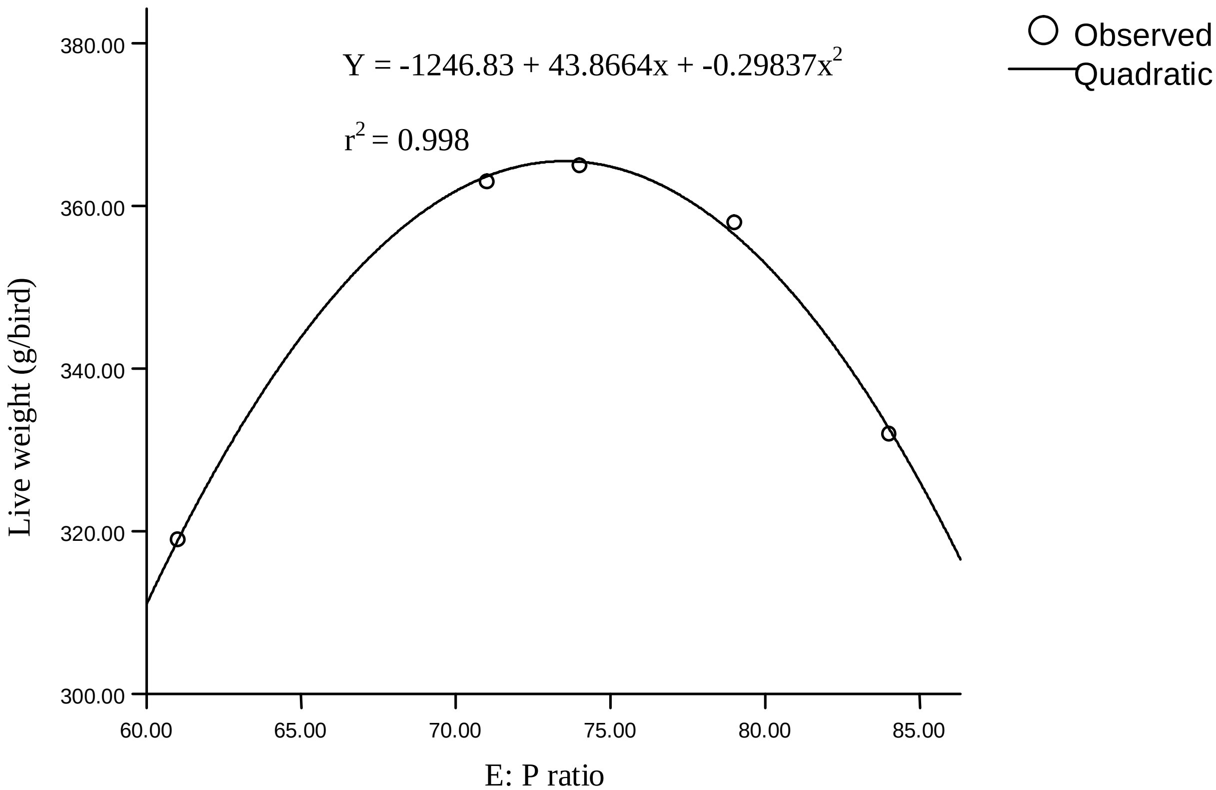

Figure 3.21 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on live weight of Venda chickens at six weeks old

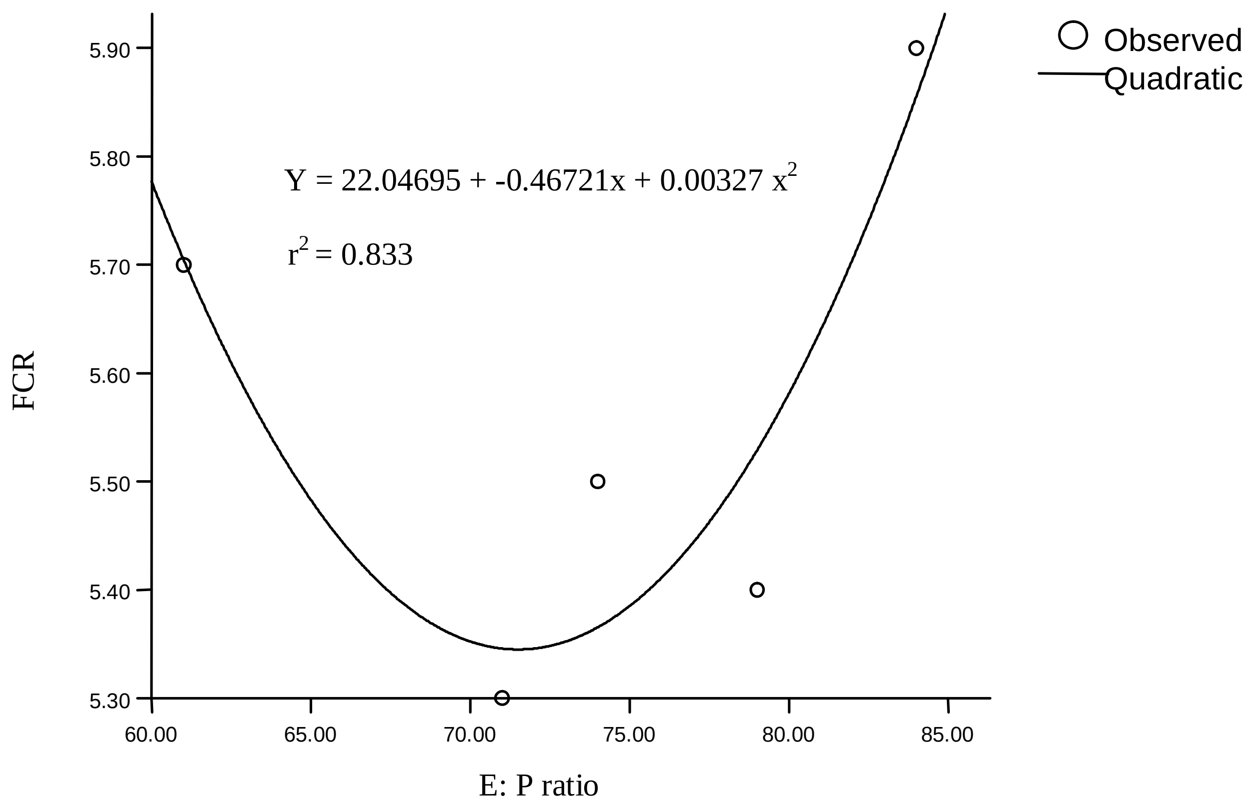

Figure 3.22 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on FCR of Venda chickens between one and six weeks old

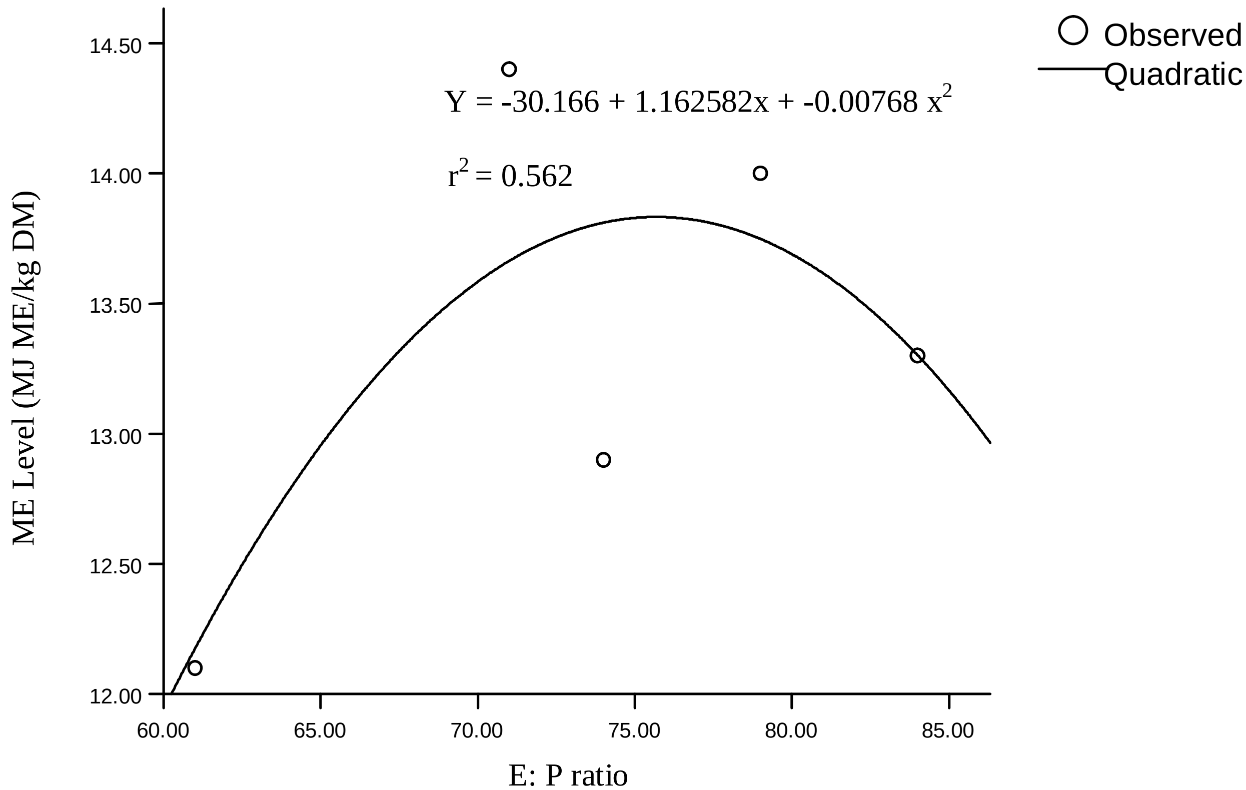

Figure 3.23 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on apparent metabolisable energy level of Venda chickens between one and six weeks old.

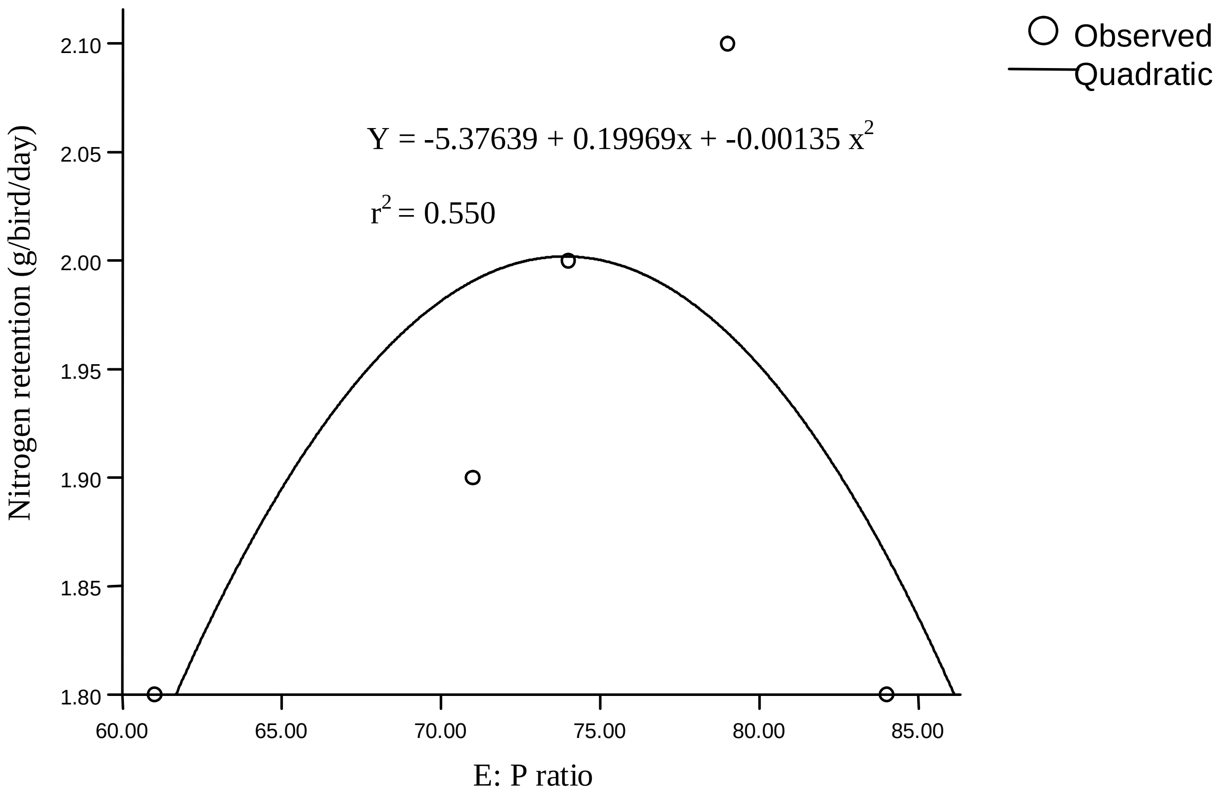

Figure 3.24 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on nitrogen retention of Venda chickens between one and six weeks old

Table 3.17 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) in Venda chickens between one and six weeks old

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y= -64.609 + 2.91159x + -0.01966x^2$	74	43	0.816	0.184
Growth	$Y = -51.705 + 1.70x + -0.012 x^2$	71	8.5	0.824	0.176
FCR	$Y= 22.04695+ -0.46721x+0.00327 x^2$	72	5.3	0.833	0.167
Lwt	$Y= -1246.83+ 43.8664x + -0.29837x^2$	74	365	0.998	0.002
ME	$Y= -30.166+1.162582x + -0.00768 x^2$	76	13.8	0.562	0.438
Nitrogen retention	$Y= -5.37639+0.19969x + -0.00135 x^2$	70	1.4	0.550	0.450

FCR :Feed conversion ratio
Lwt :Live weight
ME :Apparent metabolisable energy
P :Probability level
E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)
Y-Value :Optimal Y-Value

3.3.5 Experiment 5

Results of the nutrient composition of the diets used in Experiment 5 are given in Table 3.18. The diets had a similar energy level of 14 MJ ME/kg DM but different protein concentrations, ranging between 160 to 220 g CP/kg DM.

Results of the effect of energy to protein ratio level on feed intake, growth rate, feed conversion ratio, live weight, apparent ME and nitrogen retention of Venda chickens from one to six weeks of age, based on a dietary energy level of 14 MJ ME/kg DM, are presented in Table 3.19. There were no differences (P>0.05) in feed intake between chickens offered diets having 64, 74, 78, 82 and 88 MJ ME/kg protein ratios. Venda chickens offered a diet having 64 MJ ME/kg protein ratio had a lower (P<0.05) growth rate than those offered diets having 74, 78, 82 and 88 MJ ME/kg protein ratios. However, those offered diets having 74, 78, 82 and 88 MJ ME/kg protein ratios had the same (P>0.05) growth rates.

Venda chickens offered a diet having 64 MJ ME/kg protein ratio had a lower (P<0.05) live weight than those offered diets having 74, 78, 82 and 88 MJ ME/kg protein ratios. However, those offered diets having 74, 78, 82 and 88 MJ ME/kg protein ratio had similar (P>0.05) live weights. Venda chickens offered a diet having 64 MJ ME/kg protein ratio had a poorer (P<0.05) feed conversion ratio than those offered diets having 78 and 82 MJ ME/kg protein ratios. However, those offered diets having 64, 74 and 88 MJ ME/kg protein ratios had similar (P>0.05) feed conversion ratios. Similarly, those offered diets having 78 and 82 MJ ME/kg protein ratios also had the same (P>0.05) feed conversion ratios. Venda chickens offered a diet having 78 MJ ME/kg protein ratio had a higher (P<0.05) apparent ME than those offered diets having 64, 74, 82 and 82 MJ ME/kg protein ratios. However, those offered diets having 64, 74, 82 and 88 MJ ME/kg protein ratios had similar (P>0.05) apparent ME. Venda chickens offered a diet having 82 MJ ME/kg protein ratio had a higher (P<0.05) nitrogen retention than those offered diets having 64, 74, 78 and 88 MJ ME/kg protein ratios, while those offered diets having 74 and 78 MJ ME/kg protein ratios had similar

(P>0.05) nitrogen retentions and those offered diets having 64 and 88 MJ ME/kg protein ratios had the same (P>0.05) nitrogen retentions.

Results of the effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy and nitrogen retention in Venda chickens between one and six weeks old are presented in Figures 3.25 to 3.30 and Table 3.20. Feed intake, growth rate and live weight were optimized at dietary energy to protein ratios of 76, 79 and 78 MJ ME/kg protein, respectively (Figures 3.25, 3.26 and 3.27, respectively). Feed conversion ratio, apparent ME and nitrogen retention were optimized at dietary energy to protein ratios of 82, 74 and 77 MJ ME/kg protein, respectively (Figures 3.28, 3.29 and 3.30, respectively).

Table 3.18 Nutrient composition of the diets used in Experiment 5 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed).

	Nutrient					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{14}P_{22}$	926.5	14	220	10.9	12.6	6.6
$E_{14}P_{19}$	926.4	14	190	11.0	12.3	6.4
$E_{14}P_{18}$	926.2	14	185	11.0	12.2	6.5
$E_{14}P_{17}$	926.3	14	170	11.4	12.4	6.4
$E_{14}P_{16}$	926.2	14	160	11.3	12.5	6.3

Table 3.19 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) between one and six weeks of age, live weight at six weeks old (g/bird) and apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) of Venda chickens between 36 and 42 days of age based on a dietary energy level of 14 MJ ME/kg DM*

Variable	Treatment (E:P ratio)					SE
	64	74	78	82	88	
Intake	42	45	45	44	42	1.87
Growth	6^{b}	7^{ab}	8^{a}	8^{a}	7^{ab}	0.54
FCR	7.0^{a}	6.4^{ab}	5.6^{b}	5.5^{b}	6.0^{ab}	0.44
Live weight	291^{b}	330^{ab}	354^{a}	340^{ab}	310^{ab}	18.28
ME	13.8^{b}	13.9^{b}	14.8^{a}	13.6^{b}	13.5^{b}	0.18
N-retention	0.8^{dc}	0.6^{b}	1.3^{b}	2.2^{a}	1.1^{bc}	0.11

^{abcde} :Means in the same row not sharing a common superscript are significantly different ($P < 0.05$).

ME :Apparent metabolisable energy

N-retention :Nitrogen retention

SE :Standard error

* :Dietary ME determined by NIRA (Valdes and Leeson, 1992)

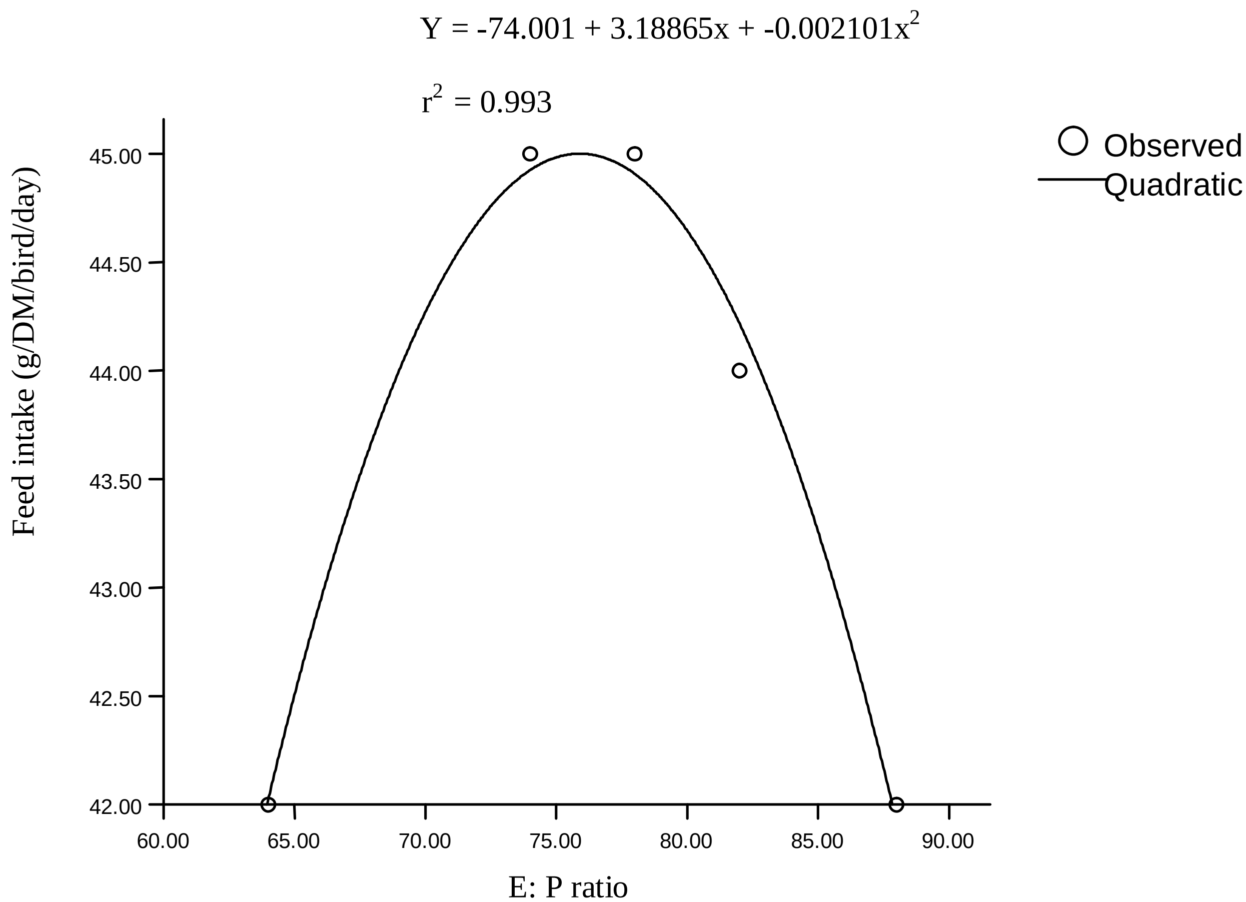

Figure 3.25 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on daily DM feed intake of Venda chickens between one and six weeks old

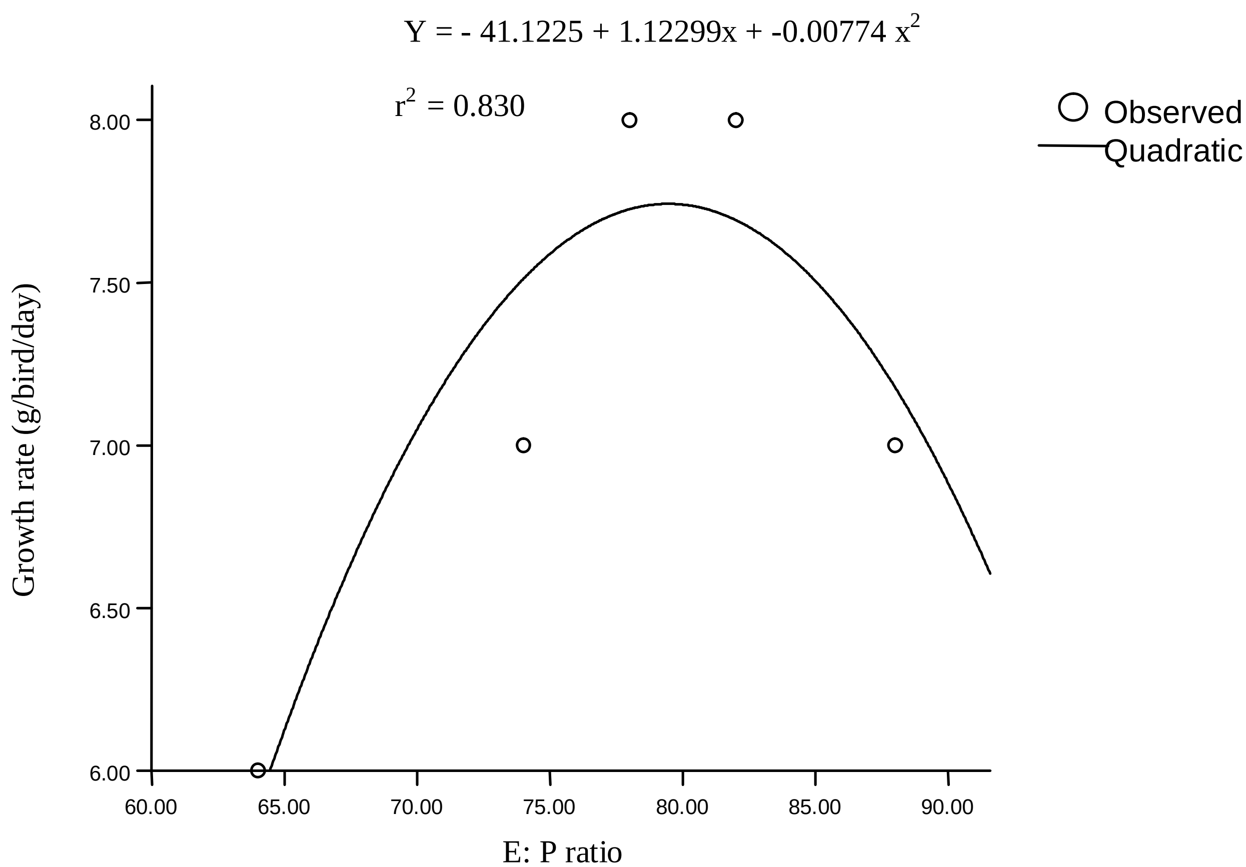

Figure 3.26 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on growth rate of Venda chickens between one and six weeks old

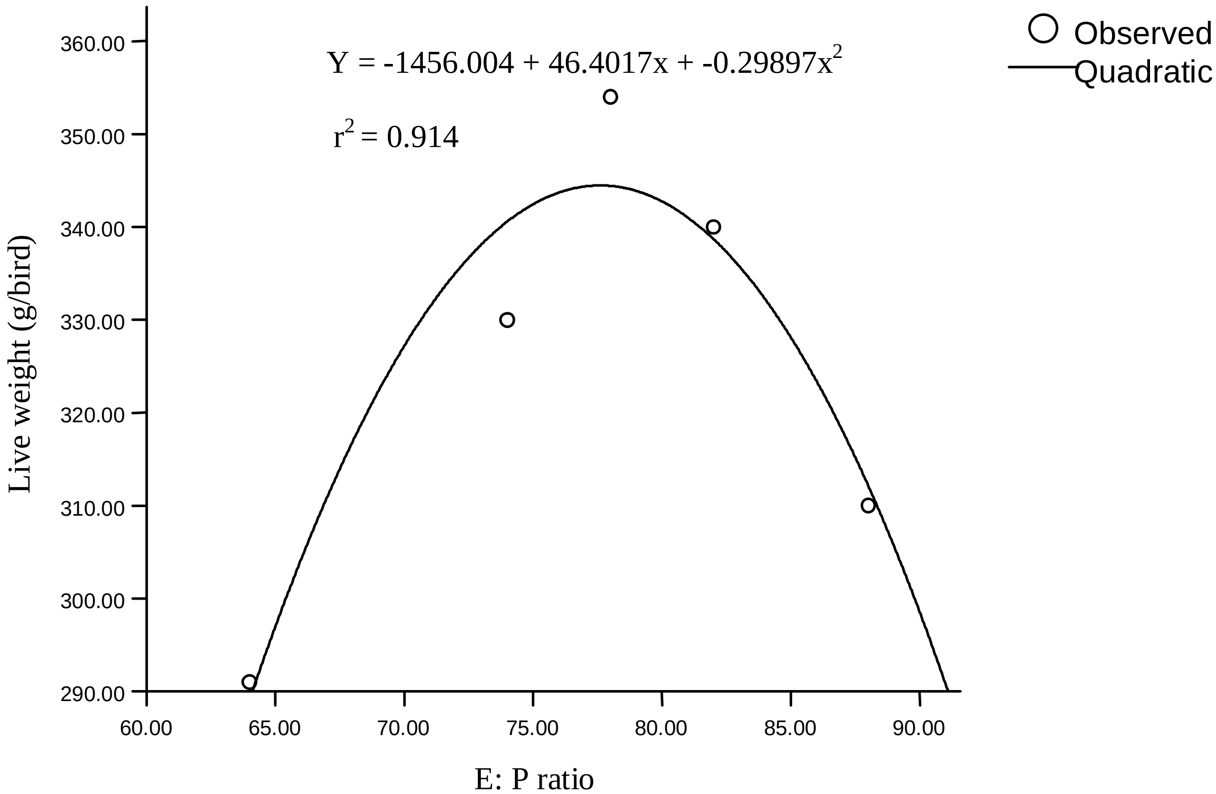

Figure 3.27 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on live weight of Venda chickens at six weeks old

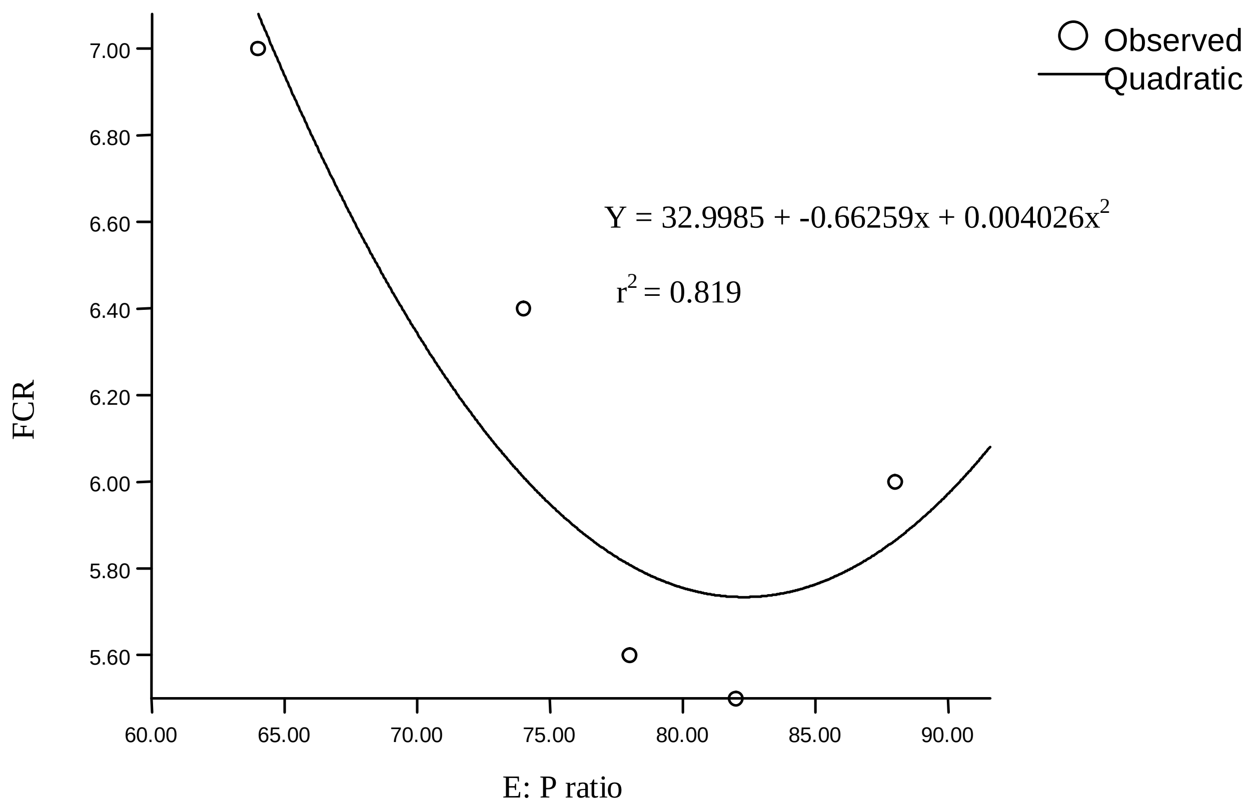

Figure 3.28 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM on FCR of Venda chickens between one and six weeks old

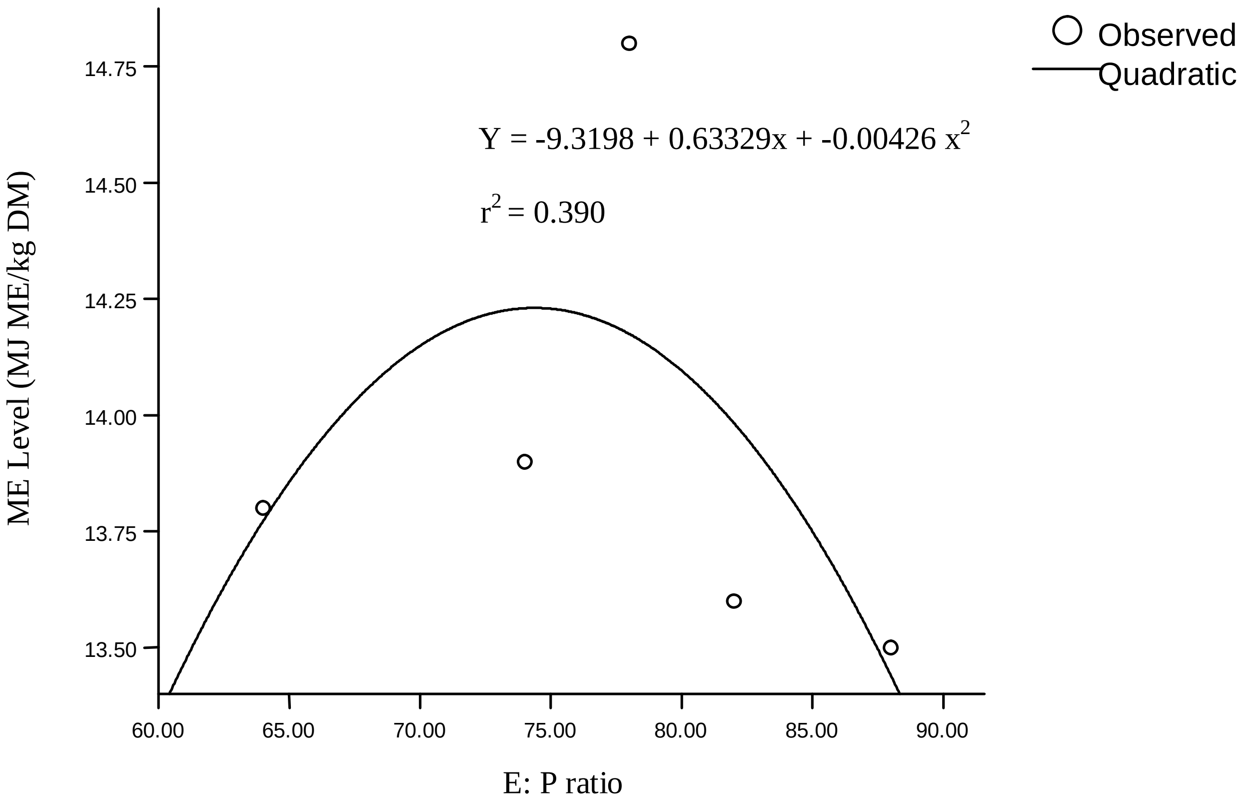

Figure 3.29 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on apparent metabolisable energy level of Venda chickens between one and six weeks old

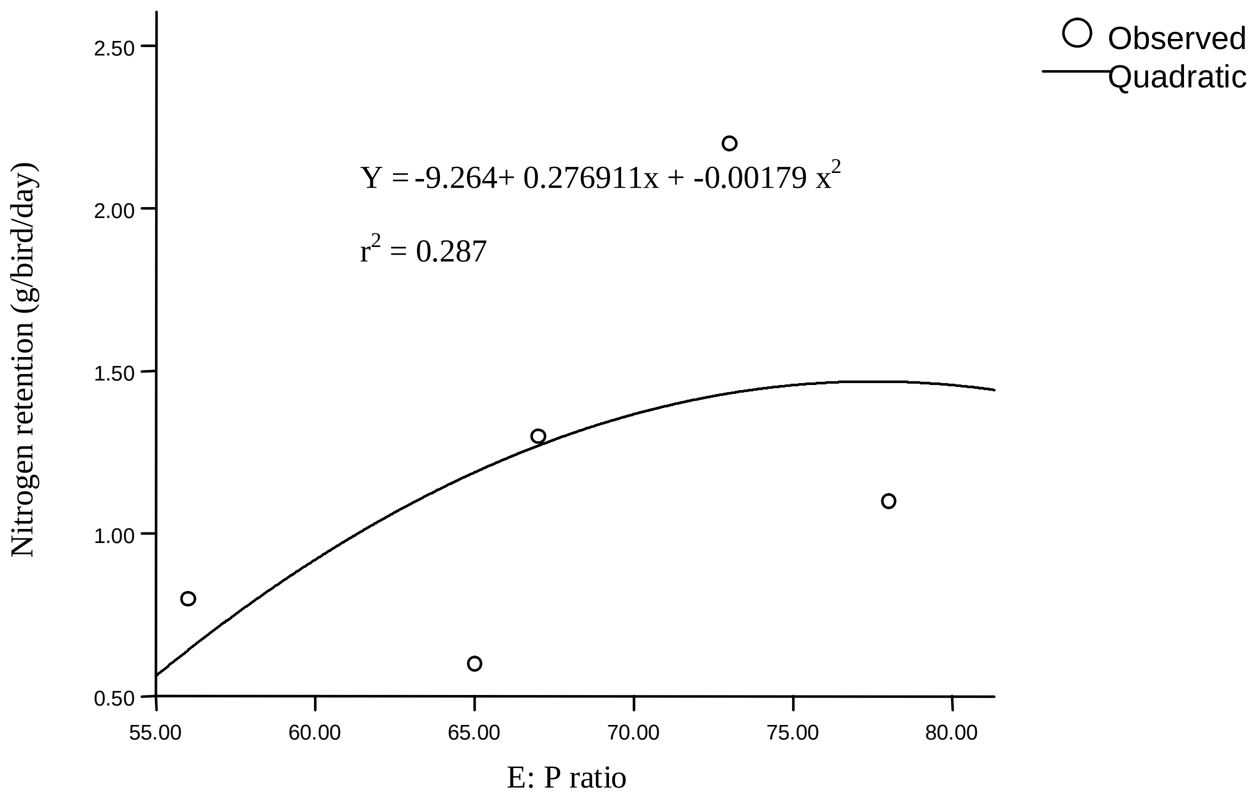

Figure 3.30 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on nitrogen retention of Venda chickens between one and six weeks old

Table 3.20 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM) and nitrogen retention (g/bird/day) in Venda chickens between one and six weeks old

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y = -74.001 + 3.18865x + -0.002101x^2$	76	45	0.993	0.007
Growth	$Y = -41.1225 + 1.12299x + -0.00774x^2$	79	8	0.830	0.170
FCR	$Y = 32.9985 + -0.66259x + 0.004026x^2$	82	5.7	0.819	0.181
Lwt	$Y = -1456.004 + 46.4017x + -0.29897x^2$	78	344	0.914	0.086
ME	$Y = -16.545 + 0.791858x + -0.00533x^2$	74	13.9	0.999	0.001
Nitrogen retention	$Y = -9.264 + 0.276911x + -0.00179x^2$	77	1.4	0.287	0.713

FCR :Feed conversion ratio
Lwt :Live weight
ME :Apparent metabolisable energy
P :Probability level
E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)
Y-Value :Optimal Y-Value

3.3.6 Optimal responses

Results of the effect of dietary energy to protein ratio level on optimal responses of Venda chickens between one and six weeks of age, based on all the dietary energy levels, are presented in Table 3.21. Optimal feed intake (r^2= 0.837), feed conversion ratio (r^2= 0.769) and apparent metabolisable energy (r^2= 0.928) tended to increase with increasing dietary energy to protein ratio level (Figures 3.31, 3.32 and 3.33). However, Optimal live weight (r^2= 0.923), growth rate (r^2= 0.888) and nitrogen retention (r^2= 0.726) tended to decrease with increasing dietary energy to protein ratio levels (Figures 3.34, 3.35 and 3.36, respectively).

Table 3.21 Effect of energy to protein ratio level (MJ ME/kg protein), based on different dietary energy levels, on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy (ME) and nitrogen retention in Venda chickens between one and six weeks of age

Variable	Dietary energy level (MJME/kg DM)				
	12.2	13	13.2	13.4	14
Optimum intake (g/bird/day)	33	35	38	43	45
E:P ratio level	62	68	73	74	76
Diet CP level (g/kg)	197	191	181	181	184
Optimum growth (g/bird/day)	10	9	8.5	8.5	8
E:P ratio level	62	68	70	71	79
Diet CP level (g/kg)	197	191	189	189	177
Optimum FCR	3.4	3.9	4.5	5.3	5.7
E:P ratio level	63	68	70	72	82
Diet CP level (g/kg)	194	191	189	186	171
Live weight at 6 weeks (g/bird/)	415	408	370	365	344
E:P ratio level	63	67	70	74	78
Diet CP level (g/kg)	194	194	189	181	179
Optimum apparent ME (MJ ME/kg DM)	14	13	14	14	14
E:P ratio level	74	67	76	76	74
Diet CP level (g/kg)	165	194	174	176	189
Optimum N-retention (g/bird/day)	2.4	1.6	1.5	1.4	1.4
E:P ratio level	61	68	69	70	77
Diet CP level (g/kg)	200	191	191	191	181

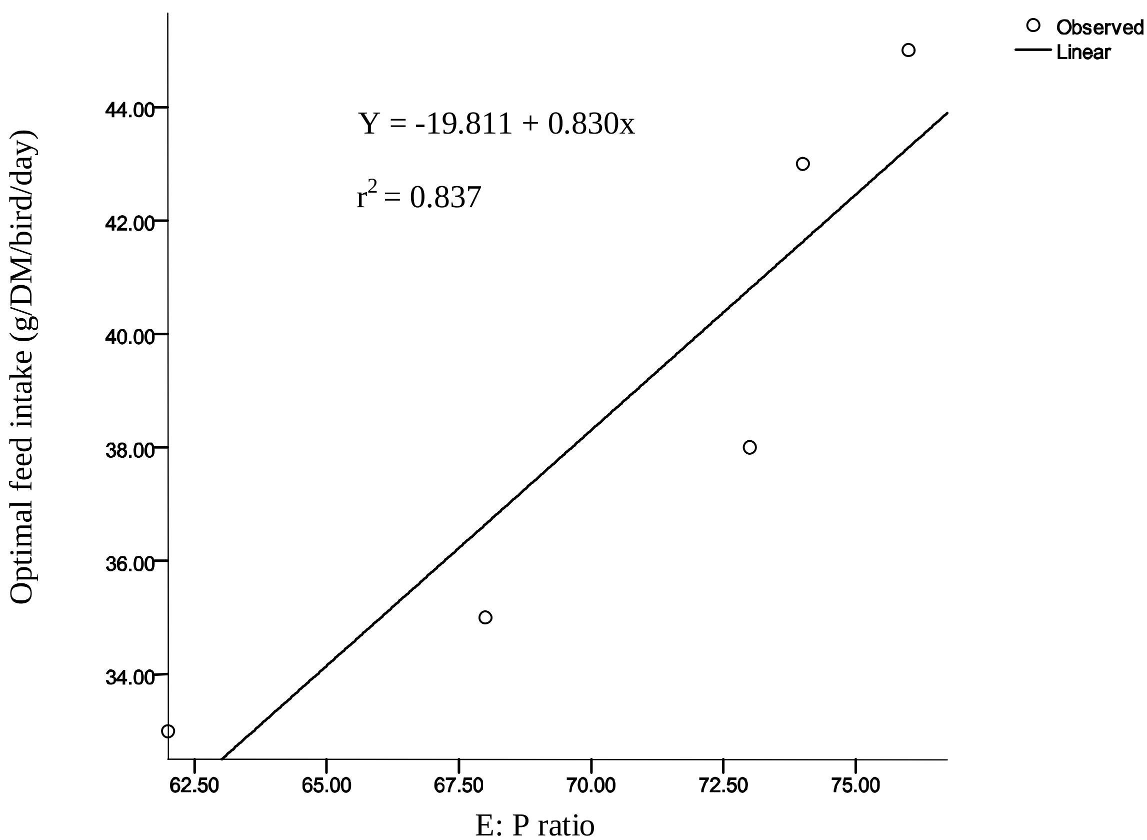

Figure 3.31 Relationship between optimal dietary energy to protein ratio and optimal feed intake of unsexed Venda chickens based on different dietary energy levels between one and six weeks of age.

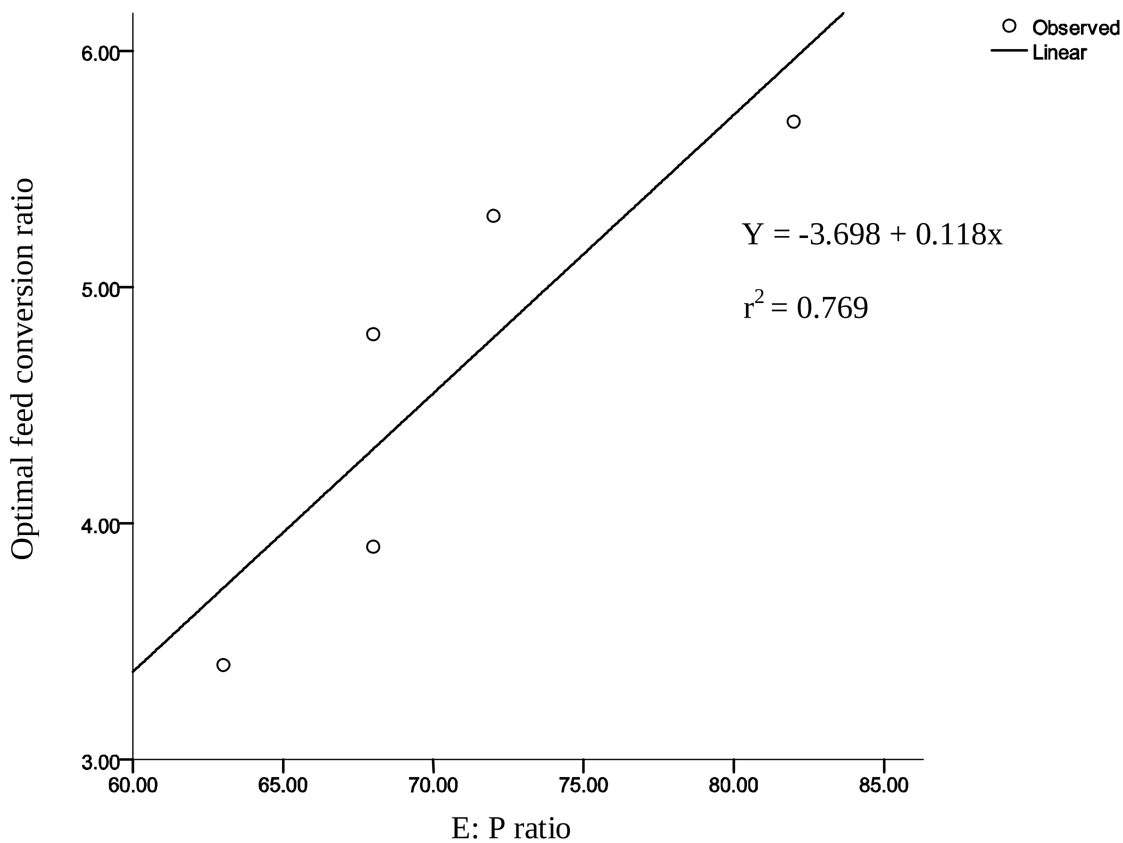

Figure 3.32 Relationship between optimal dietary energy to protein ratio and optimal feed conversion ratio of unsexed Venda chickens based on different dietary energy levels between one and six weeks of age.

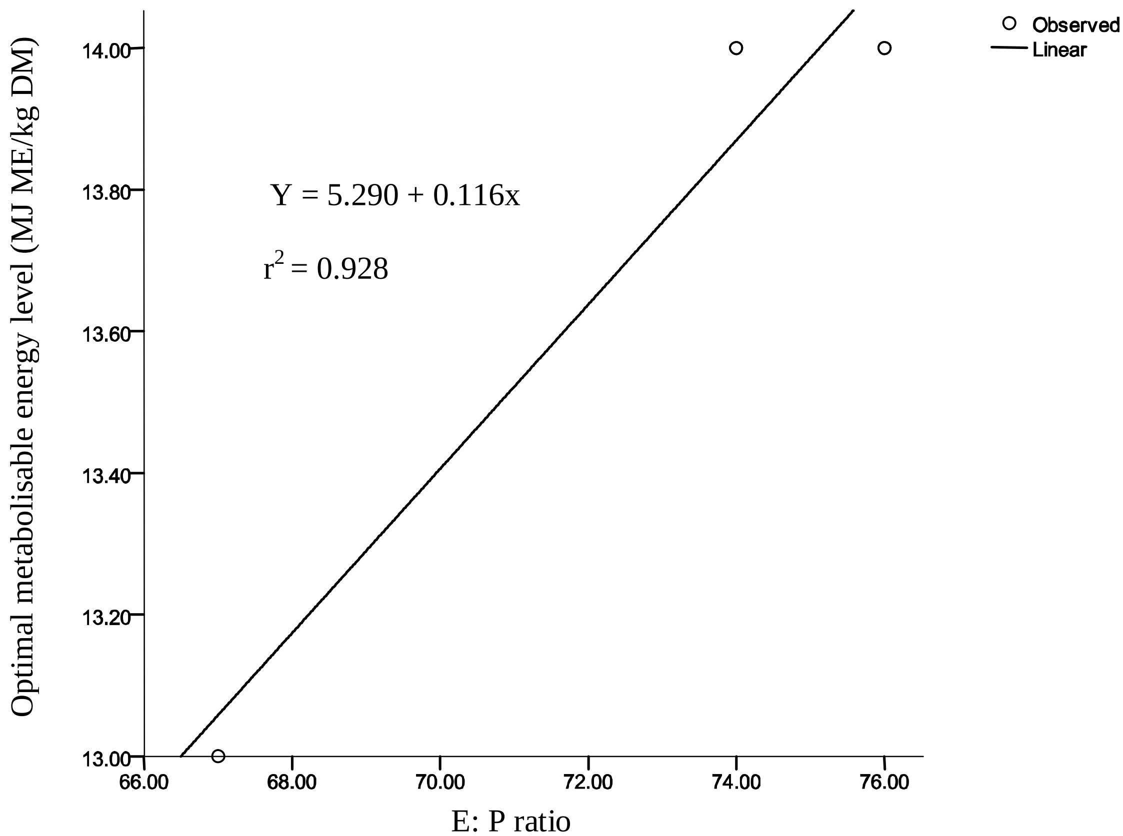

Figure 3.33 Relationship between optimal dietary energy to protein ratio and optimal metabolisable energy level of unsexed Venda chickens based on different dietary energy levels between one and six weeks of age.

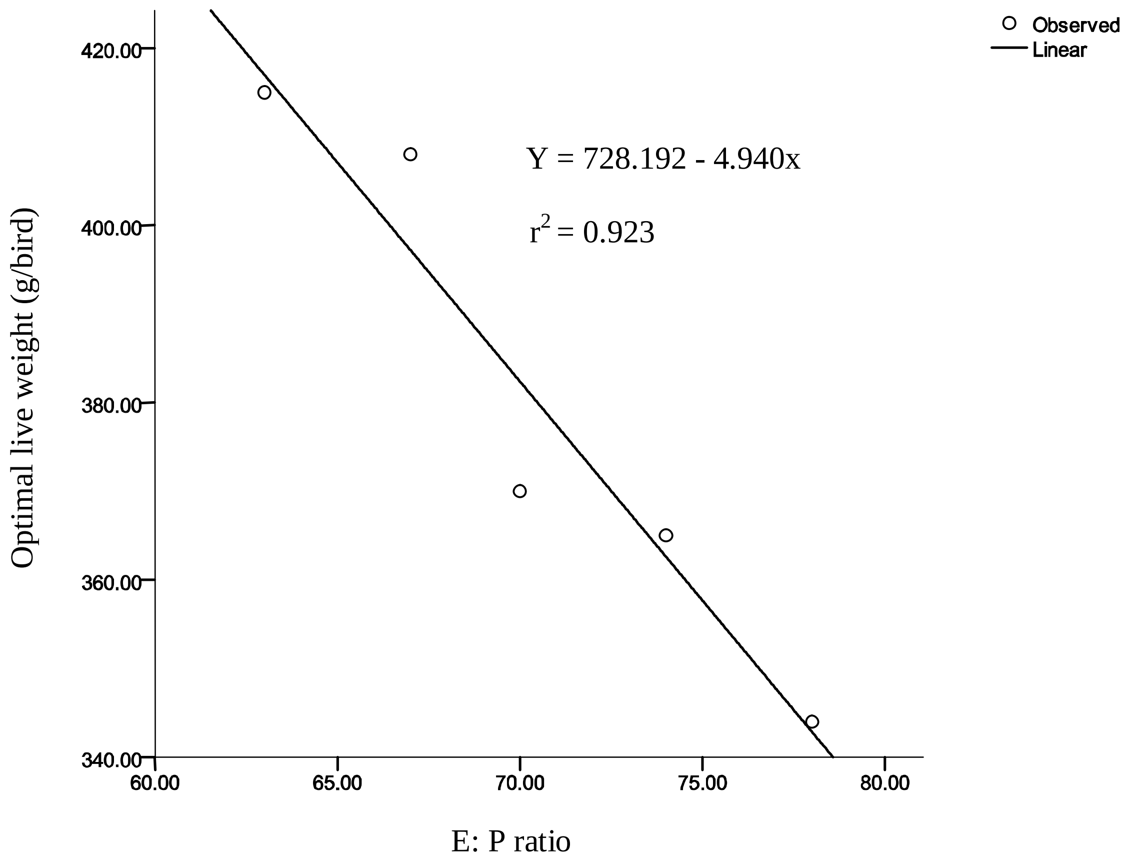

Figure 3.34 Relationship between optimal dietary energy to protein ratio and optimal live weight of unsexed Venda chickens based on different dietary energy levels between one and six weeks of age.

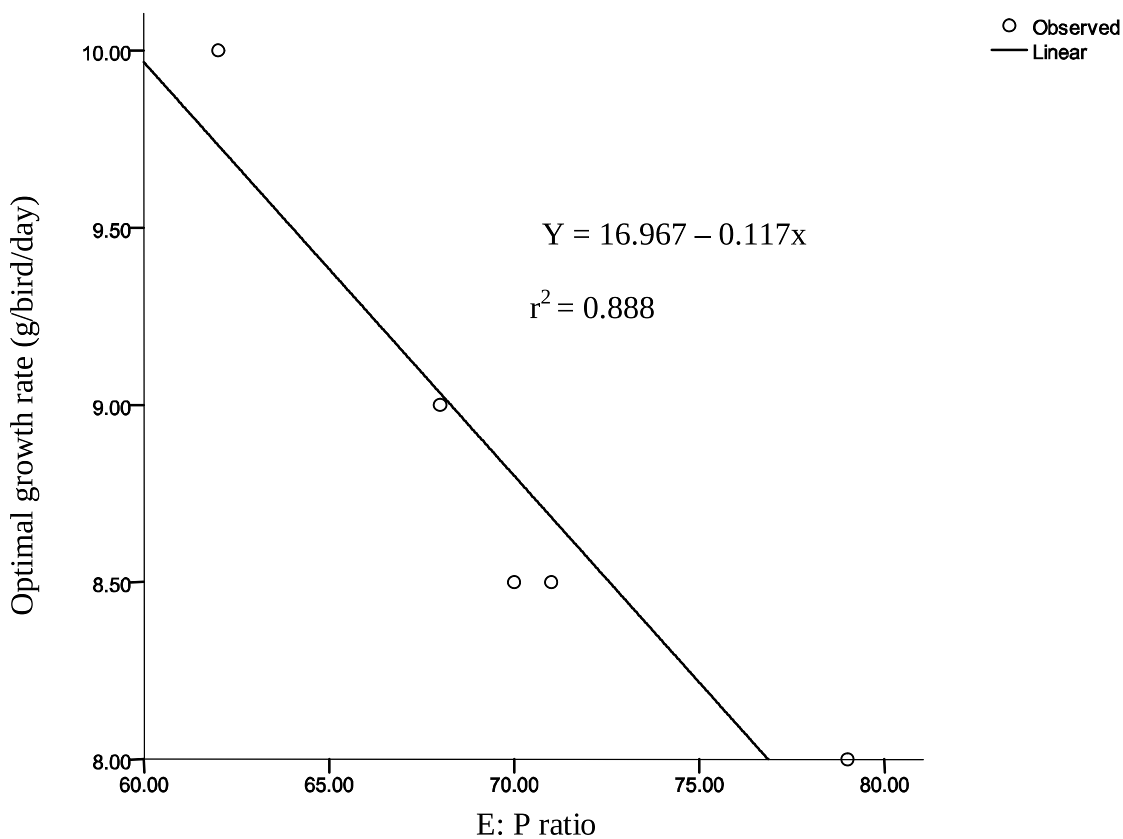

Figure 3.35 Relationship between optimal dietary energy to protein ratio and optimal growth rate of unsexed Venda chickens based on different dietary energy levels between one and six weeks of age.

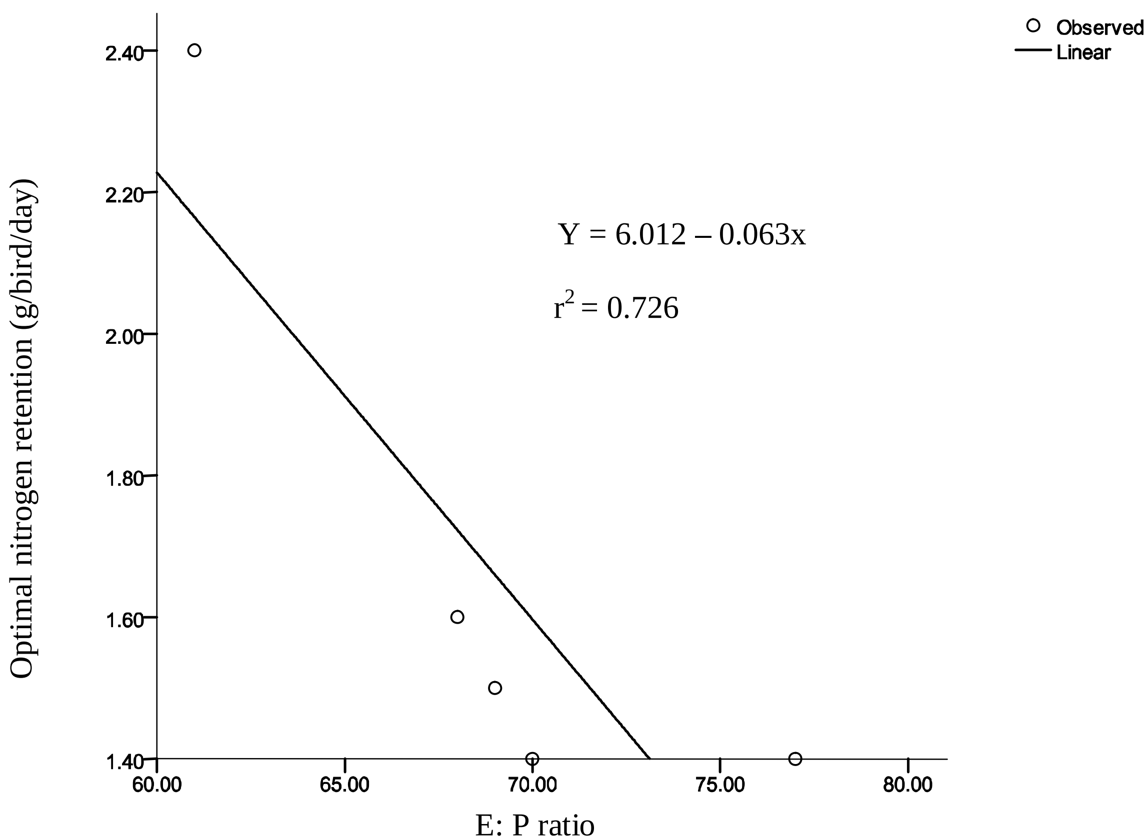

Figure 3.36 Relationship between optimal dietary energy to protein ratio and optimal nitrogen retention of unsexed Venda chickens based on different dietary energy levels between one and six weeks of age.

3.3.7 Efficiency of dietary protein and energy utilization

Results of the effect of dietary energy to protein ratio level on efficiency of dietary protein and energy utilization for optimal growth rate in Venda chickens between one and six weeks of age, based on all the dietary energy levels, are presented in Table 3.22 and Figures 3.37 to 3.38. Efficiency of crude protein utilization decreased with increasing dietary energy to protein ratio (Figure 3.37) (r^2= 0.855) However, efficiency of apparent metabolisable energy utilization increased with increasing dietary energy to protein ratio (Figure 3.38) (r^2= 0.726).

Table 3.22 Effect of dietary energy to protein ratio levels (MJ ME/kg protein), based on all the dietary energy levels, on efficiency of dietary protein and energy utilization for optimal growth rate (g/bird/day) in Venda chickens between one and six weeks

Variable	Dietary energy level (MJ ME/kgDM)				
	12.2	13	13.2	13.4	14
Optimum growth (g/bird/day)	10	9	8.5	8.5	8
E:P ratio level	62	68	70	71	79
Diet CP level (g/kg)	197	191	189	189	177
Efficiency of utilization of diet CP	0.19	0.19	0.18	0.18	0.17
Efficiency of utilization of diet energy	12.0	12.2	12.9	12.9	13.7

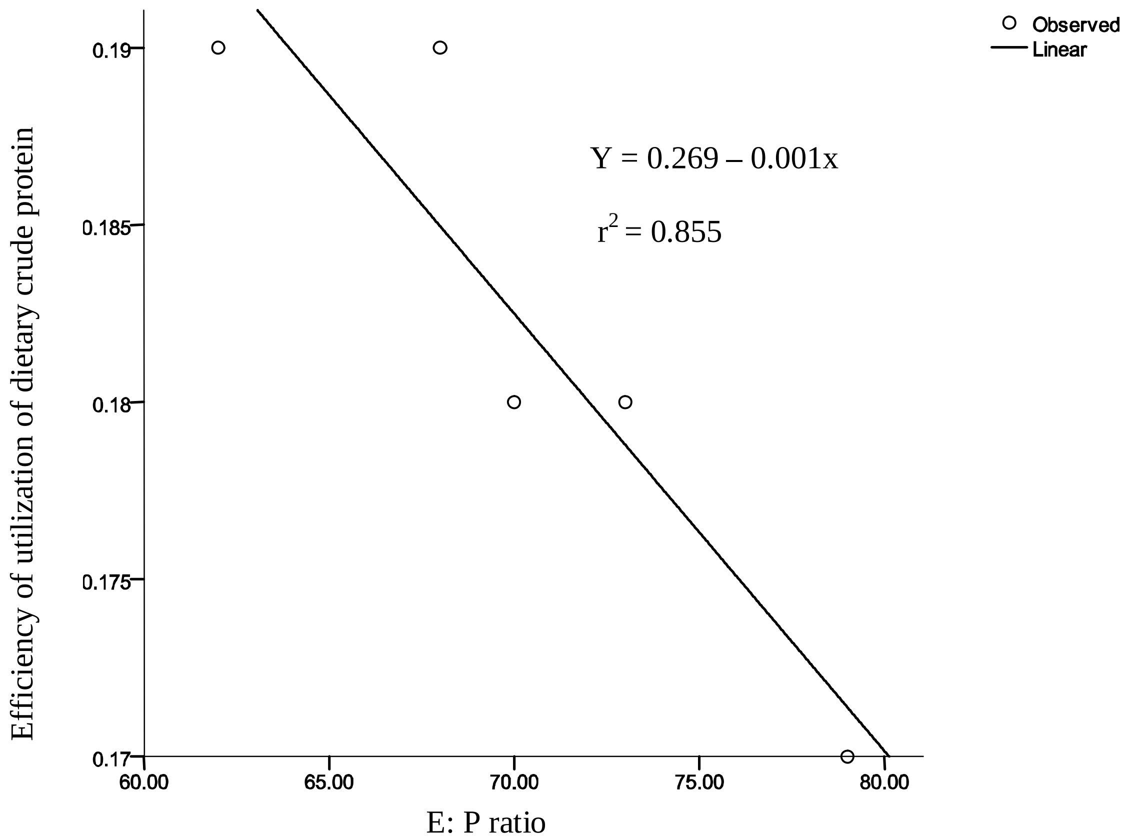

Figure 3.37 Relationship between optimal dietary energy to protein ratio and efficiency of utilization of dietary crude protein, based on different dietary energy levels, in unsexed Venda chickens between one and six weeks of age

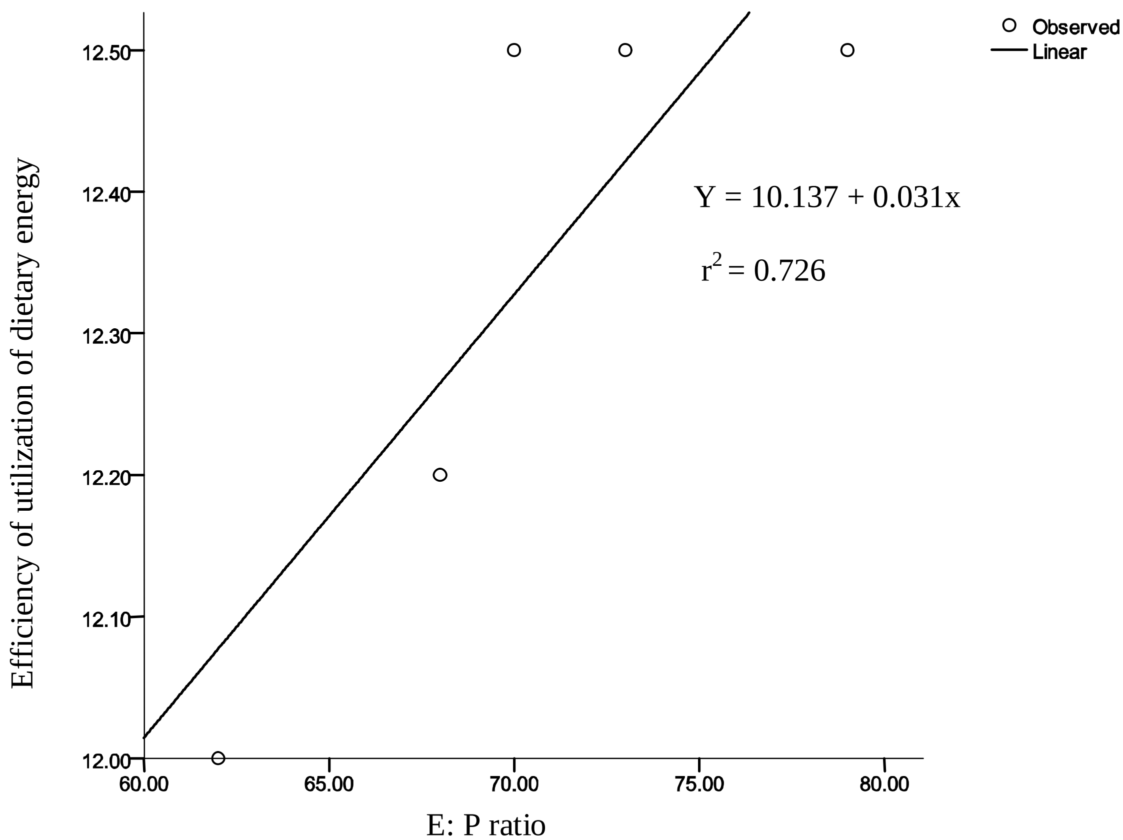

Figure 3.38 Relationship between optimal dietary energy to protein ratio and efficiency of utilization of dietary energy, based on different dietary energy levels, in unsexed Venda chickens between one and six weeks of age.

3.3.8 Optimal dietary crude protein level and energy utilization

Results of the relationship between optimal dietary crude protein level and optimal dietary energy utilization for feed intake and growth rate of Venda chickens between one and six weeks of age, based on all the dietary energy levels, are presented in Table 3.23 and Figures 3.39 to 3.40. Quadratic calculations indicate that protein requirements for optimal energy utilization to maximize feed intake is generally higher than that for maximizing growth rate.

Table 3.23 Relationship between optimal dietary crude protein level (g/kg DM) and optimal dietary energy utilization for feed intake (g/bird/day) and growth rate (g/bird/day) in Venda chickens between one and six weeks of age, based on all the dietary energy levels

Trait	Formula	Optimal protein	Y-Value	r^2	P
Intake	$Y = -364.190 + 4.078x + -0.011x^2$	185	13.76	0.835	0.165
Growth	$Y = -101.433 + 1.307x + -0.0037x^2$	178	14.00	0.986	0.014

P :Probability level

Optimal protein :Optimal protein level (g/kg DM)

Y-Value :Energy value for optimal protein level (MJ ME/kg DM)

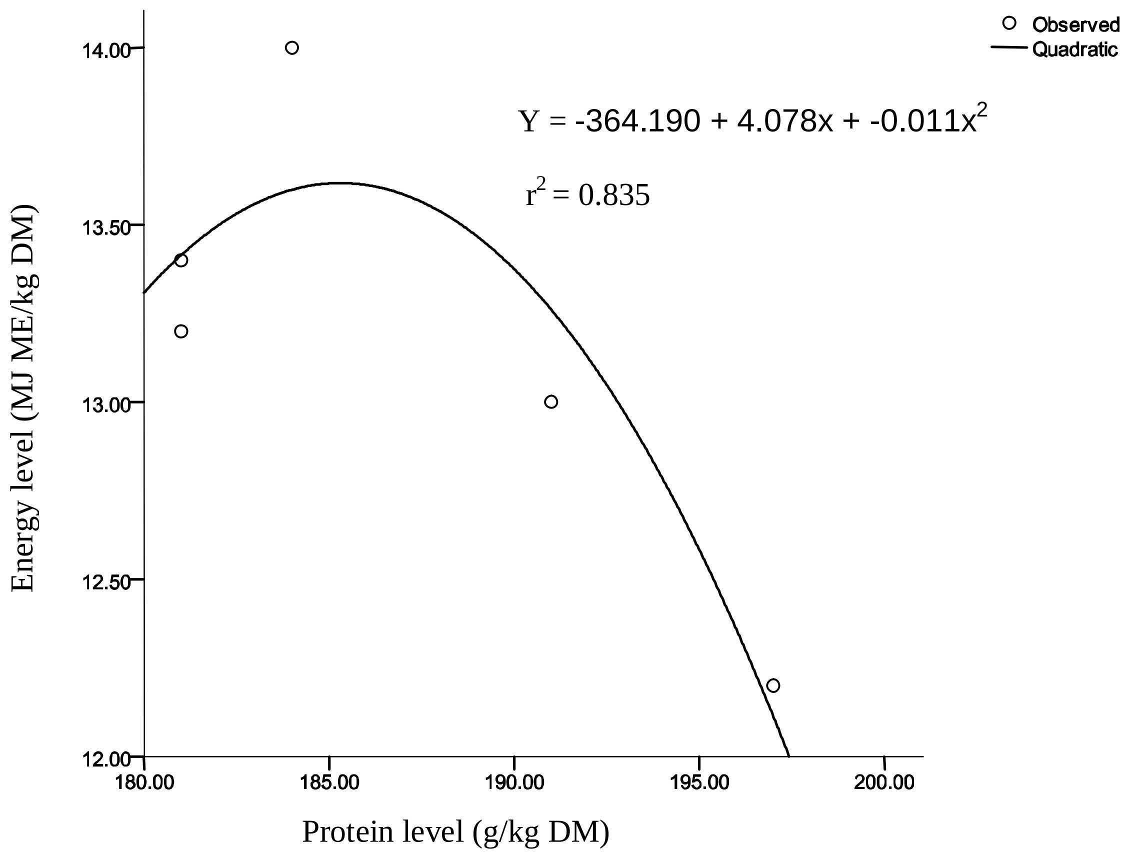

Figure 3.39 Relationship between optimal dietary crude protein level and optimal dietary energy utilization for feed intake in Venda chickens between one and six weeks of age

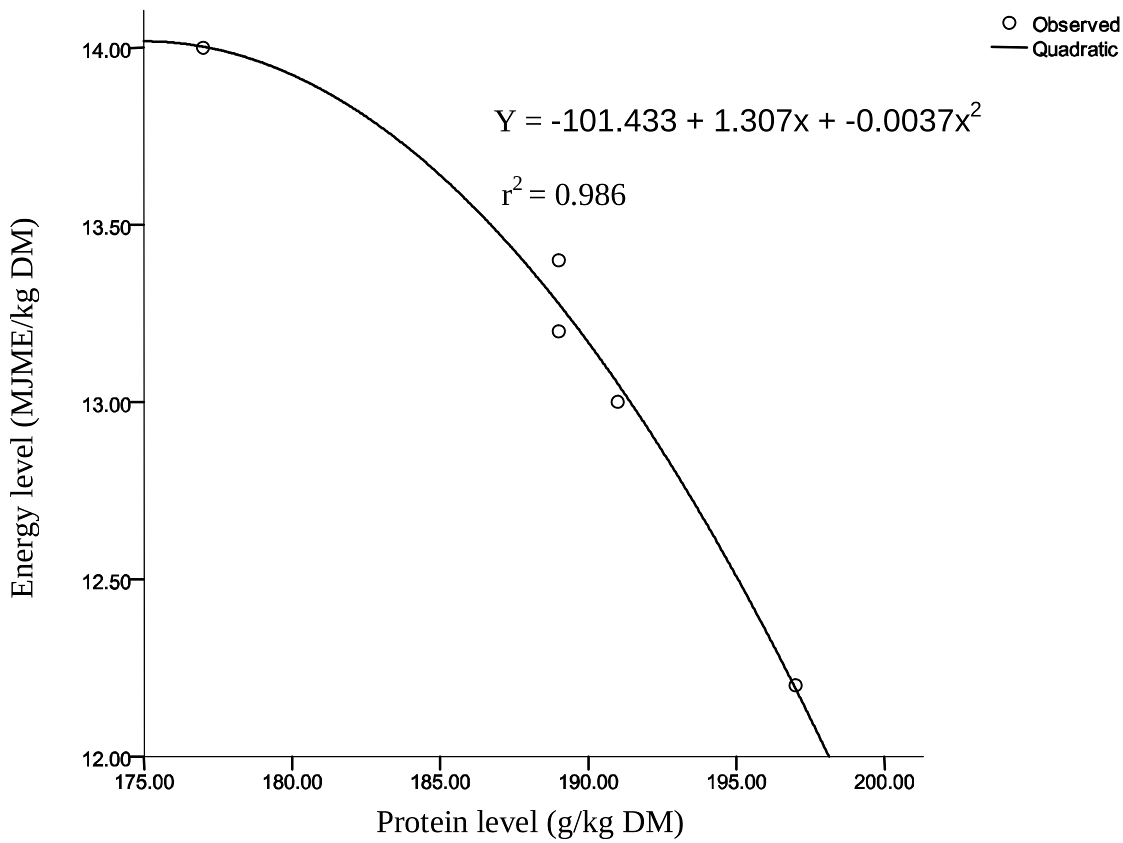

Figure 3.40 Relationship between optimal dietary crude protein level and optimal dietary energy utilization for growth rate in Venda chickens between one and six weeks of age

3.4 DISSCUSION

3.4.1 Experiment 1

The diets used in this study were formulated to provide high and low dietary energy to protein ratio levels. The laboratory analyzed experimental diets were isocaloric but with different levels of protein, thus ending up with different dietary energy to protein ratio levels. Dietary energy to protein ratio levels varied across all the diets, ranging from 55 to 76 MJ ME/kg protein. These cover both low and high ratios. The diets contained similar levels of other nutrients which met the recommended chickens' requirements (NRC, 1994).

Results of the present study indicate that dietary energy to protein ratio level had a significant effect on feed intake, growth rate, feed conversion ratio and live weight of Venda chickens during the starter phase. These differences in performance variables were expected. This is because alterations in dietary energy to protein ratio either by increasing or decreasing the ratio by means of changing the energy content, protein content or both will result in differences in animal performance (Buyse *et al.,* 1992) and hence feeds of different dietary energy to protein ratios will give different performance responses. Similar results were obtained by Lin *et al.* (1980) and Jones and Smith (1986) who found that feed intake, growth rate, body weight gain, feed efficiency and live weight of meat-type broiler chickens change with alterations in dietary energy to protein ratio levels. However, these observations are contrary to the findings of Ndegwa *et al.* (2001) in Kenya who found no differences in performance variables of indigenous growing chickens when dietary energy to protein ratio of the feed was changed by increasing the diet crude protein content from 17 to 23 %.

Dietary energy to protein ratio level had no effect on apparent metabolisable energy intake and nitrogen retention. This is similar to the findings of Ndegwa *et al.* (2001). It is possible that the dietary energy to protein ratio levels required for apparent metabolisable energy intake and nitrogen retention were lower than or equal to ratios used in the present study. Thus, changing the ratio level did not have any effect on ME intake and nitrogen retention.

The results of the present study showed that during the starter phase, based on feed energy level of 12.2 MJ ME/kg DM, a single dietary energy to protein ratio of 62 MJ ME/kg protein optimized both feed intake and growth rate in Venda chickens. Data on ideal dietary energy to protein ratio levels for optimal variable responses in Venda chickens are scarce.
A single dietary energy to protein ratio of 53.27 MJ ME/kg protein calculated from the data of Nawaz *et al.* (2006) also optimized both feed intake and growth rate in broiler chickens during the starter period. However, the ratio of 62 MJ ME/kg protein for optimum feed intake and growth rate obtained in the present study is higher than the ratio of 53.27 estimated from the data of Nawaz *et al.* (2006) for optimum feed intake and growth rate in broiler chickens during the starter period. This may indicate differences in energy and protein requirements for optimum feed intake and growth rate between the indigenous Venda chickens and broiler chickens as similarly observed by Tadelle and Ogle (2000). Also, this may indicate higher protein requirements for broiler chickens than Venda chickens. Such discrepant variations in requirements may be due to genetic differences.

On the other hand, optimum dietary energy to protein ratio of 63 MJ ME/kg protein optimized both feed conversion ratio and live weight. The ratio of 63 MJ ME/kg protein is higher than the 55.22 MJ ME/kg protein value of Kamran *et al.* (2008), 57.30 MJ ME/Kg protein value of Nascimento *et al.* (2007) and 58.17 MJ ME/Kg protein value of the NRC (1994), for optimal productivity of all production variables in broiler chickens during the entire starter period. Metabolisable energy and nitrogen retention were optimized at different dietary energy to protein ratios of 74 and 61 MJ ME/kg protein, respectively. However, the ratio of 61 MJ ME/kg protein for optimizing nitrogen retention is lower than ratios for optimum feed intake, growth rate, feed conversion ratio, live weight and metabolisable energy. This may imply that an alteration of tissues takes place, particularly muscle and fat deposits, which may differ in nutrient contents (Moran and Bilgili, 1990). It can be concluded that not a single energy to protein ratio optimized feed intake, growth rate, live weight, feed conversion ratio, metabolisable energy and nitrogen retention in Venda chickens. This may imply that the nutrient requirements of unsexed indigenous Venda chickens during the growing phase are dynamic and are dependant on the particular production variable in question. This should be taken into consideration when formulating rations for indigenous Venda chickens. Thus, the feeding program for indigenous Venda chickens should consider the primary objective of the producer since the desired outcomes may differ for different operations. This has implications on ration formulation for Venda chickens.

3.4.2 Experiment 2

This experiment was designed to provide a higher dietary energy level than that provided in Experiment 1. Thus, dietary energy to protein ratio levels ranged from 59 to 81 MJ ME/kg protein. The diets contained similar levels of other nutrients which met the chicken's requirements as recommended by the NRC (1994).

Results of Experiment 2 indicate that dietary energy to protein ratio level had significant effects on all production parameters studied except for nitrogen retention. It is possible that the dietary energy to protein ratio levels required for nitrogen retention were lower than or equal to the ratios used in the present study. In such cases, energy to protein ratio would not be expected to have any effect on nitrogen retention. On the other hand, a single dietary energy to protein ratio of 68 MJ ME/kg protein optimized feed intake, growth rate, feed conversion ratio and nitrogen retention in Venda chickens. Similarly, a single dietary energy to protein ratio of 67 MJ ME/kg protein optimized live weight and metabolisable energy. Thus, it seems likely that a single dietary energy to protein ratio optimizes feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy and nitrogen retention in Venda chickens on a diet having 13 MJ ME/kg DM. This is similar to the findings of NRC (1994) and Swatson *et* *al.* (2002a), who estimated single ratios of 58.17 and 61.12 MJ ME/kg protein, respectively, for all production variables in broiler chickens during the entire starter period.

However, the optimum values of 67 and 68 MJ ME/kg protein observed in the present study are higher than the single ratios of 58.17 and 61.12 MJ ME/kg protein estimated by NRC (1994) and Swatson *et al.* (2002a), respectively, for broiler chickens during the entire starter period. The higher energy to protein ratios for optimum productivity in the present study may be indicative of lower protein requirements for Venda chickens as compared to protein requirements for broiler chickens (Kingori *et al*., 2003).

3.4.3 Experiment 3

The diets in Experiment 3 had a similar energy value of 13.2 MJ ME/kg DM. Thus, dietary energy to protein ratio values were higher than those used in Experiments 1 and 2, ranging from 60 to 83 MJ ME/kg protein. The diets were formulated to satisfy the chicken's other nutritional requirements as estimated by the NRC (1994).

Dietary energy to protein ratio level had no effect on feed intake, feed conversion ratio and metabolisable energy of Venda chickens. Rosa *et al.* (1997), Yung *et al*. (2001) and Wu *et al*. (2005) found similar results. These authors reported that dietary energy to protein ratio level had no effect on feed intake and feed conversion ratio in commercial breeder pullets at the growing phase. However, in the present study, dietary energy to protein ratio level had significant effects on growth rate, live weight and nitrogen retention of Venda chickens. These results could not be explained in terms of similarities in feed intakes, feed conversion ratio and metabolisable energy intakes. Contrary to the present results, Han *et al.* (1992) and Ndegwa *et al.* (2001) found no differences in growth rate of broiler chickens offered isocaloric diets with varying crude protein levels.

A single dietary energy to protein ratio of 70 MJ ME/kg protein optimized growth rate, feed conversion ratio and live weight in Venda chickens for the feed energy level of 13.2 MJ ME/kg DM. The ratio of 70 MJ ME/kg protein is lower than the ratios of 73 and 76 MJ ME/kg protein for optimum feed intake and metabolisable energy but higher than the ratio of 69 MJ ME/kg protein for optimum nitrogen retention for this feed energy level. This may indicate that the dietary energy to protein ratio for optimal responses in Venda chickens offered an isocaloric diet is relative and may depend on the variable in question and the dietary energy level. However, these results are different from the findings of NRC (1994) and Swatson *et al.* (2002a) who estimated single ratios of 58.17 and 61.12 MJ ME/kg protein, respectively, for all production variables in broiler chickens during the entire starter period.

3.4.4 Experiment 4

Experiment 4 was formulated to be isocaloric but with different crude protein levels, thus ending up with different dietary energy to protein ratio values, ranging from 61 to 84 MJ ME/kg protein.

Dietary energy to protein ratio level had an effect on growth rate, metabolisable energy intake and nitrogen retention in Venda chickens during the starter phase. These results are similar to the findings of Hussein *et al*. (1996) who found differences in growth rate of white Leghorn chicks when offered diets differing in dietary energy to protein ratio levels. The physiological explanation for this effect is not clear and merits further investigation. However, it is possible that there were differences in rate of nutrient utilization among the chickens offered the different dietary regimes (Hussein *et al*.,1996).

The present experimental results indicate that dietary energy to protein ratio of 74 MJ ME/kg protein optimized both feed intake and live weight in Venda chickens. However, contrary to the present findings, NRC (1994) and Swatson *et* *al.* (2002a) estimated single ratios of 58.17 and 61.12 MJ ME/kg protein, respectively, for all production variables in broiler chickens during the entire starter period. The ratio of 74 MJ ME/kg protein is higher than the ratios of 70, 71 and 72 MJ ME/kg protein for optimum nitrogen retention, growth rate and feed conversion ratio, respectively, but lower than the ratio of 76 MJ ME/kg protein for optimum metabolisable energy level. Thus, there seems to be no single dietary energy to protein ratio level for all the production variables studied. Similar results have been reported elsewhere (Gonzalez-a and Pesti, 1993).

3.4.5 Experiment 5

In this experiment, diets contained a similar energy value of 14 MJ ME/kg DM with different dietary energy to protein ratio levels, ranging from 64 to 88 MJ ME/kg protein. Dietary energy to protein ratio level had significant effects on growth rate, live weight, feed conversion ratio, metabolisable energy level and nitrogen retention, with the exception of feed intake, in Venda chickens during the starter period. Similar results have been reported elsewhere (Lin *et al.,*1980; Jones and Smith,1986). These authors found that growth rate, body weight gain, feed efficiency and live weight of meat-type broiler chickens change with alterations in dietary energy to protein ratio levels. The present findings are contrary to the findings of Holsheimer and Veerkamp (1992) who found that feed intake was affected by energy and protein content of the feed.

Increasing the feed energy level to 14 MJ ME/kg DM optimized metabolisable energy, feed intake, nitrogen retention, live weight, growth rate and feed conversion ratio at different dietary energy to protein ratios of 74, 76, 77, 78, 79 and 82 MJ ME/kg protein, respectively. These results are different from the findings of NRC (1994) and Swatson *et al.* (2002a) who estimated single ratios of 58.17 and 61.12 MJ ME/kg protein, respectively, for all production variables in broiler chickens during the entire starter period. This may indicate that the dietary energy to protein ratio for optimal responses in Venda chickens offered isocaloric diets is relative and may depend on the variable in question and the dietary energy level. This may be indicative of an alteration of tissues taking place, particularly in muscle and fat deposits, which may differ in nutrient contents (Moran and Bilgili, 1990).

3.4.6 Optimal responses

Optimal feed intake in Venda chickens increased with increasing feed energy. Thus, feed intake increased with increase in feed energy level and with decrease in feed protein content. This is contrary to the observation that broiler chickens eat to satisfy their energy requirements (Leeson, 2000; Nahashon *et al.,* 2005; 2006; Veldkamp *et al.,* 2005), or that broiler chickens will eat less of a feed higher in energy content than the one having a lower energy value (Plavik *et al.,* 1997; Nahashon *et al.,* 2006; Veldkamp *et al.,* 2005). These findings together suggest that feed intake of broiler chickens is, first and foremost, closely linked to the feed energy level and hence birds attempt, as a priority, to adjust their feed intakes according to the energy level of the diet.

Indigenous Venda chickens however, tended to behave differently in this respect. Tadelle *et al.* (2000a) suggested that genetic limitation influences indigenous chicken growth responses because it affects their nutritional requirements. Thus, one possible consequence of the intrinsic genetic limitations of indigenous Venda chickens might be the loss of sensitivity to regulate feed intake according to dietary energy level as observed in the present study.

The physiological explanation for the present observation in indigenous Venda chickens is not clear and merits further investigation. However, it has been shown that chickens will increase their feed intake in response to marginal levels of first limiting feed nutrient, independent of the diet energy level (Boarman, 1979) since appetite is assumed to be dependent on the nutrient requirements of the animal and the contents of those nutrients in the feed (Emmans and Fisher, 1986). As such, optimal feed intake in the present study may have increased regardless of the energy value of the feed. Thus, Venda chickens ate more feed in an attempt to obtain more of the limiting protein.

The present observation is similar to the results obtained with broiler chickens by Burnham *et al.* (1992) and with laying hens by Gous *et al.* (1987). These authors observed that chickens increased their feed intake as the limiting nutrient in the feed decreased in an attempt to obtain more of the limiting nutrient to satisfy their requirements for that nutrient. Thus, in the present study, birds ate to meet their protein requirements, which were limiting with decreasing dietary crude protein levels. Contrary to results of the present findings, Kemp *et al*. (2005) and Berhe and Gous (2005) observed that the Ross 308 strain of broiler chickens does not apparently conform to the theory that birds attempt to consume sufficient of a feed to meet their requirement for the first limiting nutrient in the feed as proposed by Boarman (1979) and supported by the work of Emmans and Fisher (1986). These authors observed that instead of increasing food intake, the Ross 308 broiler chicken strains decreased their feed intake as dietary energy was increased and dietary protein content reduced, resulting in a lower growth rate than in the Cobb 500 strain. They concluded that Ross 308 broiler chickens have been selected for improved growth and feed efficiency using high protein feeds.

The authors went further to emphasize the point that such selection results in heavier carcasses (Pym and Solvens, 1979) and perhaps a reduced ability to fatten when faced with feeds marginally deficient in protein. Harper and Rogers (1965) suggested that when there is a dietary protein deficit, the free amino acid patterns of both muscle and plasma become imbalanced and consequently trigger the appetite regulating system to reduce feed intake. This may be the scenario when Ross 308 broiler chickens receive feeds marginally deficient in protein unlike the Venda chickens.

Apparently, genetic potential may influence the Ross 308 broiler chickens' feeding behaviour as it affects their nutritional requirements (Gous et al., 1999). Ross 308 broiler chickens have a pronounced genetic advantage for fast growth using high protein feed compared to Venda chickens and this might explain the differences in feed intake response patterns to marginally limiting feed protein content. In addition, the increase in feed intake to increasing feed energy density level in the present study and the associated increase in the dietary metabolisable energy intake of the chickens may indicate that energy was not limiting and hence it did not play a limiting factor in the amount of feed the chickens consumed. The present results support the revised thinking of the NRC (1994) that some chicken strains do not adjust their feed intake to changes in the dietary metabolisable energy density and, as a result, may be prone to over-consuming metabolisable energy in an attempt to obtain sufficiency of the limiting nutrient when offered diets high in energy. It is, therefore, concluded that optimal feed intake responses in growing Venda chickens offered diets differing in optimal dietary energy to protein ratio levels were influenced by the level of the limiting protein content in the feed rather than the feed energy level per se. This observation on limitations in feed intake in effect challenges the strongly held theory that all chickens will consume diets to meet their energy requirements and thereby achieve their genetic potential for growth. However, because of the important implications of these differences, both the energy and protein levels of the diet should be taken into account when formulating diets aimed at achieving optimal feed intake in growing indigenous Venda chickens.

Optimal live weight of Venda chickens at six weeks of age decreased with increasing dietary energy to protein ratio levels. This was expected since optimal growth rate of the birds also decreased with increasing dietary energy to protein ratio levels. This means that both live weight and growth rate decreased with increase in feed energy level and with decrease in feed protein content. This is similar to the results of Leeson *et al.* (1996) who found that high energy and low protein diets depressed growth of broiler chickens.

The results of the present study contradicts the findings of Han *et al.* (1992) who observed no differences in body weight gain or growth rate of broiler chickens fed differing protein diets. However, the increase in feed intake to decreasing protein content may indicate an attempt by the chickens to obtain more of the low protein diets to satisfy their protein requirements for growth.

This was not unexpected as the early growth phase of birds is characterized by a high and increasing growth rate; the self-accelerating phase described by Brody (1945). There is, therefore, a high demand for protein in the early growth phase and, hence the observed increase in feed intake of the birds as dietary protein content in the feed is reduced in order to meet their protein requirements, irrespective of the feed energy level. However, this increase in feed intake with low protein diets was achieved with decreasing growth rate in the chickens offered these diets. This may imply that their protein requirements were not met, irrespective of the increased feed intake. Thus, it is possible that this was the most likely cause for the decreasing growth rate observed with feeds low in protein content. A marginally reduced dietary crude protein level has been shown to depress growth in broiler chickens (Rosebriugh and Steele, 1985; Carew and Alster, 1997). Similarly, D'Mello and Lewis (1970) have also reported that an imbalance of protein in the diets of broiler chickens leads to growth depression. Thus, the present results have shown that optimal live weight and growth rate decreased with increase in dietary energy content and energy to protein ratio.

Optimal feed conversion ratio, in the present study, increased with increasing feed energy level and decreasing feed protein content. This means that feed conversion ratio deteriorated with increasing feed energy level and decreasing feed protein content. This may probably be due to low protein intakes. Similar results have been reported elsewhere (Bautista 1986; Sedgwick, 1979). The present results also support the findings of Jackson *et al.* (1982) who reported that feed conversion ratio in broiler chickens increased with increasing feed energy level. Similar results were also reported by Ferguson *et al.* (1998) who observed increased feed conversion ratio with decreasing protein content in broiler chickens. Si *et al.* (2004) also reported a significant negative effect of dietary crude protein content on feed conversion ratio. However, the results of the present study are contrary to the findings of Lesson *et al.* (1996) who reported improved feed conversion ratio with increasing feed energy level.

Optimal nitrogen retention decreased with increase in dietary energy content. This was expected since nitrogen retention and utilization by the growing animal are known to be influenced by both the level of energy intake and diet protein content (Breirem and Homb, 1972; Black, 1974). On the other hand, optimal metabolisable energy level increased with increasing dietary energy to protein ratio, indicating excessive energy intake as similarly observed by NRC (1994). Thus, poor optimal growth rate and deteriorating optimal feed conversion ratio with increasing dietary energy to protein ratio levels negatively affected live weight of the chickens at six weeks of age.

Correlation analysis also demonstrated that dietary energy to protein ratio levels affected optimal responses. Optimal feed intake, feed conversion ratio and metabolisable energy level were positively and strongly correlated with dietary energy to protein ratio levels. In contrast, optimal live weight, growth rate and nitrogen retention were negatively and strongly correlated with dietary energy to protein ratio levels.

The positive correlation of feed intake, feed conversion ratio and metabolisable energy level with dietary energy to protein ratio levels without any reduction in feed intake further substantiates that birds ate to meet their protein requirements which were limiting with decreasing dietary crude protein levels and suggest over-consumption of metabolisable energy with increasing dietary energy to protein ratio levels. Similar results have been reported elsewhere (NRC, 1994). However, this over-consumption of energy did not translate into weight gain, indicating poor utilization of dietary energy and this support the positive and strong correlation obtained between feed conversion ratio with increasing energy to protein ratio level.

On the other hand, the strong but negative correlation values obtained between live weight, growth rate and nitrogen retention and dietary energy to protein ratio level support the earlier observation that protein limitations for tissue synthesis with decreasing dietary crude protein level resulted in poor optimal growth rate and negatively affected live weight of the chickens. This is similar to the findings of D'Mello and Lewis (1970) who found that an imbalance of protein in the diets of broiler chickens leads to growth depression.

In spite of lower nitrogen retention values observed with increasing feed energy level and decreasing feed protein content, the efficiency of utilization of dietary protein appears to have improved. As energy was not limiting, an efficient conversion of the consumed protein to growth was expected and observed. Similar results have been reported elsewhere (Ward *et al.,* 2003). However, as suggested by Hewitt (1992), at low protein content, improved protein efficiency may be the product of reduced protein catabolism rather than increased tissue synthesis alone. Thus, applying this to the present result may explain the improved protein efficiency, but poor growth rate observed with increasing feed energy level and decreasing feed protein content. On the other hand, the converse applies to efficiency of utilization of metabolisable energy. Apparently, metabolisable energy utilization deteriorated with increasing dietary energy to protein ratio level. This was expected since increasing dietary energy to protein ratio level in the present study promoted excessive energy intake.

Results of the present study indicate that protein requirements for optimal energy utilization to maximize feed intake is generally higher than that for maximizing growth rate. This may be an indication of high digestive losses in these chickens (Mbajiorgu, 2007). The present study has shown that a diet containing a crude protein level of 178 g/kg DM and an energy level of 14 MJ ME/kg DM allowed for optimal utilization of absorbed protein and energy for growth in unsexed indigenous Venda chickens aged between one and six weeks old. NRC (1994) recommended a diet containing 230 g/kg DM crude protein and a 13.38 MJ

ME/kg DM for broiler chickens during the starter period of growth. No similar study in indigenous chickens on this subject were found.

CHAPTER 4

EFFECT OF DIETARY ENERGY TO PROTEIN RATIO LEVEL ON GROWTH AND CARCASS CHARACTERISTICS OF MALE INDIGENOUS VENDA CHICKENS RAISED IN CLOSED CONFINEMENT FROM SEVEN UP TO THIRTEEN WEEKS OF AGE

4.1 Introduction

No studies on energy to protein ratio for optimal feed intake, growth, feed conversion ratio, live weight, digestibility and carcass characteristics of indigenous male Venda chickens aged between seven and thirteen weeks and raised in closed confinement were found in the literature. Determination of the dietary energy to protein ratio level that will optimize growth and carcass characteristics of indigenous male Venda chickens is important. Furthermore, extensive data on fat deposition in these chickens is also not available. Excessive fat in chickens is one of the problems faced by the poultry industry since it reduces carcass quality and feed efficiency (Oyedeji and Atteh, 2005). Coronary heart diseases and arteriosclerosis are strongly related to high dietary intake of cholesterol and saturated fatty acids, and are among the most important causes of human mortalities (Sacks, 2002).

Energy to protein ratio value of a diet could be of importance in determining fat content in poultry meat. Summers and Leeson (1979) reported that chickens with widely differing amounts of carcass fat could be produced by manipulation of the dietary energy to protein ratio value. However, the effects of dietary energy to protein ratio value on fat deposition in indigenous Venda chickens are not known. The objective of this study was, therefore, to determine energy to protein ratios for optimal feed intake, digestibility, growth, feed conversion ratio, live weight and carcass characteristics of seven to thirteen weeks old male Venda chickens raised in closed confinement.

4.2 Materials and methods

4.2.1 Study site

This study was also done at the University of Limpopo Experimental farm as described in Chapter 3, Section 3.2.1

4.2.2 Experimental procedures, dietary treatments and design

Five experiments designated as Experiments 6, 7, 8, 9 and 10 were conducted. The layouts, treatments, design and execution were similar to those described for Experiments 1 to 5 except that Experiments 6 to 10 were for older male indigenous Venda birds. These chickens were different from the ones used in Experiments 1 to 5. Each experiment commenced with 100 seven weeks old male Venda chickens with an initial live weight of 320 ± 2 g per bird. In each experiment, the chickens were randomly assigned to five treatments (Tables 4.01 to 4.05) with four replications, each having five birds. Thus, 20 floor pens (1.5 m^2/pen) were used in total for each experiment. A complete randomized design (SAS, 2008) was used for each experiment. The formulated experimental diets were purchased from Zet_B Feeds, Louis Trichardt, South Africa. All the five experiments were carried out around the same time and for a period of seven weeks. The experiments were terminated when the birds were 13 weeks old. Light was provided 24 hours daily while feed and water were provided *ad-libitum* throughout the experiments.

Table 4.01 Dietary treatments for Experiment 6*

Diet	Diet description	E:P ratio (MJ ME/kg protein)
$E_{12.2}P_{22}$	Diet containing12.2 MJ ME/kg DM feed and 22 % crude protein	55
$E_{12.2}P_{19}$	Diet containing12.2 MJ ME/kg DM feed and 19 % crude protein	64
$E_{12.2}P_{18}$	Diet containing12.2 MJ ME/kg DM feed and 18 % crude protein	68
$E_{12.2}P_{17}$	Diet containing12.2 MJ ME/kg DM feed and 17 % crude protein	72
$E_{12.2}P_{16}$	Diet containing12.2 MJ ME/kg DM feed and 16 % crude protein	76

* Laboratory determined ME (NIRA) and CP

Table 4.02 Dietary treatments for Experiment 7*

Diet	Diet description	E:P ratio (MJ ME/kg protein)
$E_{13}P_{22}$	Diet containing13 MJ ME/kg DM feed and 22 % crude protein	59
$E_{13}P_{19}$	Diet containing13 MJ ME/kg DM feed and 19 % crude protein	68
$E_{13}P_{18}$	Diet containing13 MJ ME/kg DM feed and 18 % crude protein	72
$E_{13}P_{17}$	Diet containing13 MJ ME/kg DM feed and 17 % crude protein	76
$E_{13}P_{16}$	Diet containing13 MJ ME/kg DM feed and 16 % crude protein	81

* Laboratory determined ME (NIRA) and CP

Table 4.03 Dietary treatments for Experiment 8*

Diet	Diet description	E:P ratio (MJ ME/kg protein)
$E_{13.2}P_{22}$	Diet containing13.2 MJ ME/kg DM feed and 22 % crude protein	60
$E_{13.2}P_{19}$	Diet containing13.2 MJ ME/kg DM feed and 19 % crude protein	69
$E_{13.2}P_{18}$	Diet containing13.2 MJ ME/kg DM feed and 18 % crude protein	73
$E_{13.2}P_{17}$	Diet containing13.2 MJ ME/kg DM feed and 17 % crude protein	78
$E_{13.2}P_{16}$	Diet containing13.2 MJ ME/kg DM feed and 16 % crude protein	83

* Laboratory determined ME (NIRA) and CP

Table 4.04 Dietary treatments for Experiment 9*

Diet	Diet description	E:P ratio (MJ ME/kg protein)
$E_{13.4}P_{22}$	Diet containing13.4 MJ ME/kg DM feed and 22 % crude protein	61
$E_{13.4}P_{19}$	Diet containing13.4 MJ ME/kg DM feed and 19 % crude protein	71
$E_{13.4}P_{18}$	Diet containing13.4 MJ ME/kg DM feed and 18 % crude protein	74
$E_{13.4}P_{17}$	Diet containing13.4 MJ ME/kg DM feed and 17 % crude protein	79
$E_{13.4}P_{16}$	Diet containing13.4 MJ ME/kg DM feed and 16 % crude protein	84

* Laboratory determined ME (NIRA) and CP

Table 4.05 Dietary treatments for Experiment 10*

Diet	Diet description	E:P ratio (MJ ME/kg protein)
$E_{14}P_{22}$	Diet containing14 MJ ME/kg DM feed and 22 % crude protein	64
$E_{14}P_{19}$	Diet containing14 MJ ME/kg DM feed and 19 % crude protein	74
$E_{14}P_{18}$	Diet containing14 MJ ME/kg DM feed and 18 % crude protein	78
$E_{14}P_{17}$	Diet containing14 MJ ME/kg DM feed and 17 % crude protein	82
$E_{14}P_{16}$	Diet containing14 MJ ME/kg DM feed and 16 % crude protein	88

* Laboratory determined ME (NIRA) and CP

4.2.3 Data collection

The initial live weights of the chickens were taken at the commencement of each experiment. Thereafter, average live weight per bird was measured at weekly intervals. These live weights were used to calculate the growth rate. Weekly mean feed intakes were determined until termination of the experiment. Daily mean live weights and feed intakes were calculated from the weekly measurements. Daily mean growth rates and feed conversion ratios were also calculated from the above measurements. Digestibility was measured when the chickens were between 85 and 91 days old. Digestibility was conducted in specially designed metabolic cages having separated watering and feeding troughs. Two birds were randomly selected from each replicate and transferred to metabolic cages for measurement of apparent digestibility. The procedure followed was as described in Chapter 3, Section 3.2.3. At 91 days of age all remaining male Venda chickens per pen in each experiment were slaughtered by cervical dislocation to determine carcass characteristics. 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 the end of each slaughtering, meat samples from each breast part of the slaughtered bird were taken and stored in the refrigerator until analyzed for dry matter and nitrogen content.

4.2.4 Chemical analysis

Dry matter of the feeds, faeces and feed refusals from each experiment were determined by drying the samples in the oven for 48 hours at a temperature of 105 ^{0}C. Ash content of the feeds, feed refusals and faeces were analyzed by ashing a sample at 600 ^{0}C in a muffle furnace overnight. Nitrogen contents were determined by the Kjedahl method (AOAC, 2002). Gross energy values for feeds and faeces were determined using an adiabatic bomb calorimeter (University of Limpopo laboratory, South Africa). However, metabolisable energy levels of the diets were determined in the laboratory using the method of Near Infra-Red Reflectance Analysis (NIRA), as described by Valdes and Leeson (1992). The apparent metabolisable energy contents of the diets from each experiment were determined. Apparent metabolisable energy was equal to energy in the feed consumed minus energy excreted in the faeces (AOAC, 2002).

4.2.5 Data analysis

Data on feed intake, digestibility, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention and carcass characteristics for all the five experiments were analyzed by one-way analysis of variance (SAS, 2008). Where there was a significant F-test ($P<0.05$), the 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 energy to crude protein ratio were modelled using the quadratic equation (SAS, 2008) as described in Chapter 3, Section 3.2.5

The relationship between optimal responses in feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention or carcass characteristics across the five experiments and dietary energy to protein ratio levels were modeled using a linear regression equation (SAS, 2008) as described in Chapter 3, Section 3.2.5

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

4.3 RESULTS

4.3.1 Experiment 6

Results of the nutrient composition of the diets used in Experiment 6 are presented in Table 4.06. These are similar to the results for diets in Experiment 1, Chapter 3, Section 3.3.1.

Data on the effect of energy to protein ratio level on feed intake, dry matter digestibility, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight of male Venda chickens from seven to 13 weeks of age, based on a dietary energy level of 12.2 MJ ME/kg DM, are presented in Table 4.07. Male Venda chickens offered a diet having 64 MJ ME/kg protein ratio ate more ($P<0.05$) feed than those offered diets having 72 and 76 MJ ME/kg protein ratios. However, male Venda chickens offered diets having 55, 64 and 68 MJ ME/kg protein ratios had similar ($P>0.05$) feed intakes. Similarly, chickens offered diets having 55, 68, 72 and 76 MJ ME/kg protein ratios had same ($P>0.05$) feed intakes.

Male Venda chickens offered diets having 64 MJ ME/kg protein ratio had higher ($P<0.05$) growth rate than those offered diets having 72 and 76 MJ ME/kg protein ratios. However, chickens offered diets having 55, 64 and 68 MJ ME/kg protein ratios had similar ($P>0.05$) growth rates. Male Venda chickens offered a diet having 64 MJ ME/kg protein ratios had a higher ($P<0.05$) live weight than those offered diets having 72 and 76 MJ ME/kg protein ratios. However, chickens offered diets having 72 and 76 MJ ME/kg protein ratios had similar ($P>0.05$) live weights. Similarly, chickens offered diets having 55, 64 and 68 MJ ME/kg protein ratios had similar ($P>0.05$) live weights. Male Venda chickens on a diet having 64 MJ ME/kg protein ratio had a better ($P<0.05$) feed conversion ratio than those on diets having 55, 68, 72 and 76 MJ ME/kg protein ratios. Male Venda chickens offered diets having 64, 68 and 72 MJ ME/kg protein ratios had similar ($P>0.05$) apparent ME values, and those offered diets having 55 and 76 MJ ME/kg protein ratios also had the same ($P>0.05$) apparent ME values. Male Venda chickens offered diets having 55, 64, 68 and 76 MJ ME/kg protein ratios had higher ($P<0.05$) nitrogen retentions than those offered diets having a 72 MJ ME/kg protein ratio. However, those offered diets having 55, 64, 68 and 76 MJ ME/kg protein ratios had similar ($P>0.05$) nitrogen retentions. Male Venda chickens offered a diet having a 76 MJ ME/kg protein ratio had lower ($P<0.05$) carcass weight than those offered a diet having 64 MJ ME/kg protein ratios. However, chickens offered diets having 55, 64, 68 and 72 MJ ME/kg protein ratios had similar ($P>0.05$) carcass weights. Similarly, chickens offered diets having 55, 68, 72 and 76 MJ ME/kg protein ratios had similar ($P>0.05$) carcass weights. Male Venda chickens offered diets having 68 and 76 MJ ME/kg protein ratios had lower ($P<0.05$) breast meat yield than those offered a diet having a 64 MJ ME/kg protein ratio. However, chickens offered diets having 55, 64 and 72 MJ ME/kg protein ratios had similar ($P>0.05$) breast meat yields. Similarly, chickens offered diets having 55, 68, 72 and 76 MJ ME/kg protein ratios had similar ($P>0.05$) breast meat yields. There were no differences ($P>0.05$) in fat pad weights and digestibility values between male Venda chickens offered diets having 55, 64, 68, 72 and 76 MJ ME/kg protein ratios.

Results of the effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent ME, nitrogen retention, carcass weight, breast meat yield and fat pad weight in male Venda chickens between seven and 13 weeks old are presented in Figures 4.01 to 4.09 and Table 4.08. Feed intake was optimized at a dietary energy to protein ratio of 62 MJ ME/kg protein (Figure 4.01). Growth rate, feed conversion ratio, live weight, carcass weight and breast meat yield were optimized at a single dietary energy to protein ratio of 60 MJ ME/kg protein (Figures 4.02, 4.03, 4.04, 4.07 and 4.08, respectively) while apparent ME and nitrogen retention were optimized at dietary energy to protein ratios of 65 and 63 MJ ME/kg protein, respectively (Figures 4.05 and 4.06, respectively). Minimum fat pad weight was achieved at a dietary energy to protein ratio of 70 MJ ME/kg protein (Figure 4.09). However, quadratic analysis indicated no optimal digestibility response to dietary energy to protein ratio levels used in this experiment.

Table 4.06 Nutrient composition of diets used in Experiment 6 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed)

	Nutrient					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{12.2}P_{22}$	931.4	12.2	220	11.0	10.8	5.5
$E_{12.2}P_{19}$	931.0	12.2	190	10.9	10.6	5.0
$E_{12.2}P_{18}$	931.6	12.2	185	10.8	10.7	5.3
$E_{12.2}P_{17}$	931.4	12.2	170	11.1	10.1	5.2
$E_{12.2}P_{16}$	931.8	12.2	160	11.2	10.2	5.0

Table 4.07 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day) and feed conversion ratio (FCR) between seven and thirteen weeks of age, live weight at thirteen weeks old (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day) and dry matter digestibility (decimal) between 85 and 91 days of age, and carcass weight (g/bird), breast meat yield (g/bird) and fat pad weight (g/bird) of male Venda chickens based on a dietary energy level of 12.2 MJ ME/kg DM*

Variable		Treament	(E:P ratio)			SE
	55	64	68	72	76	
Intake	84^{ab}	93^{a}	83^{ab}	78^{b}	73^{b}	3.59
Growth rate	16^{ab}	19^{a}	14^{ab}	10^{b}	10^{b}	2.28
FCR	5.3^{d}	4.8^{e}	5.9^{c}	7.8^{a}	7.3^{b}	1.62
Live weight	1115^{ab}	1240^{a}	1006^{ab}	830^{b}	813^{b}	124.8
ME	12.7^{bc}	14.2^{a}	13.7^{ab}	13.7^{ab}	12.3^{c}	0.32
N-retention	2.1^{a}	2.3^{a}	2.7^{a}	1.5^{b}	2.2^{a}	0.17
Carcass weight	893^{ab}	992^{a}	713^{ab}	695^{ab}	676^{b}	63.53
Breast meat yield	158^{ab}	168^{a}	121^{b}	132^{ab}	107^{b}	10.21
Fat pad weight	1.3	0.6	0.4	0.3	0.5	0.65
DM Digestibility	0.9	0.9	0.9	0.9	0.9	0.02

^{abcde} :Means in the same row not sharing a common superscript are significantly different (P<0.05).

ME :Apparent metabolisable energy

N-retention :Nitrogen retention

SE: :Standard error

DM Digestibility :Dry matter digestibility

* :Dietary ME determined by NIRA(Valdes and Leeson, 1992)

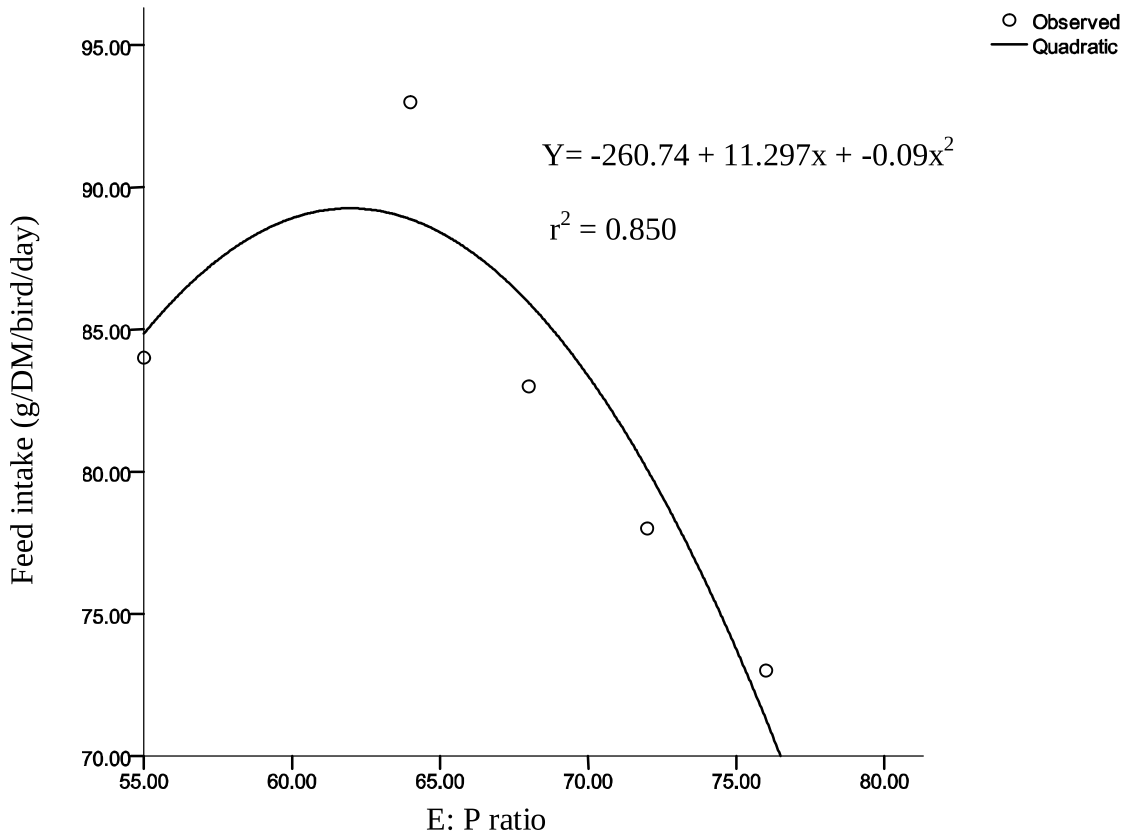

Figure 4.01 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on daily DM feed intake of male Venda chickens between seven and 13 weeks old

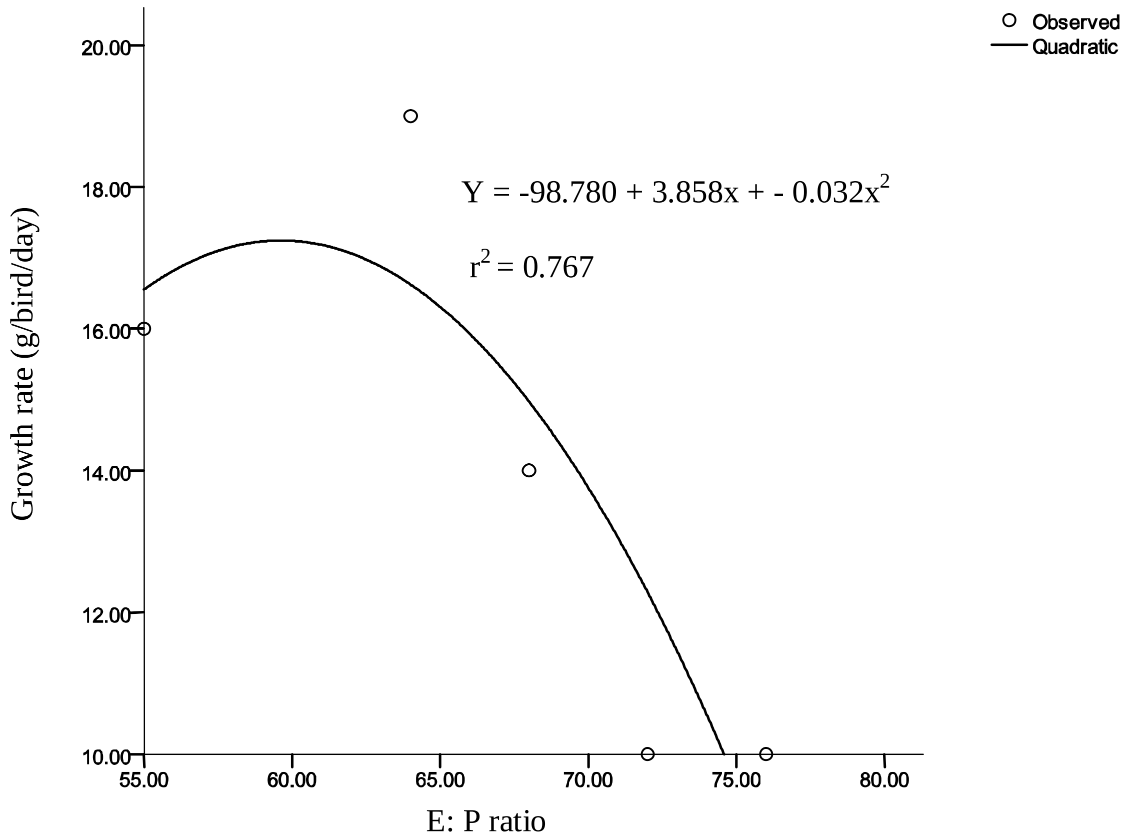

Figure 4.02 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on growth rate of male Venda chickens between seven and 13 weeks old

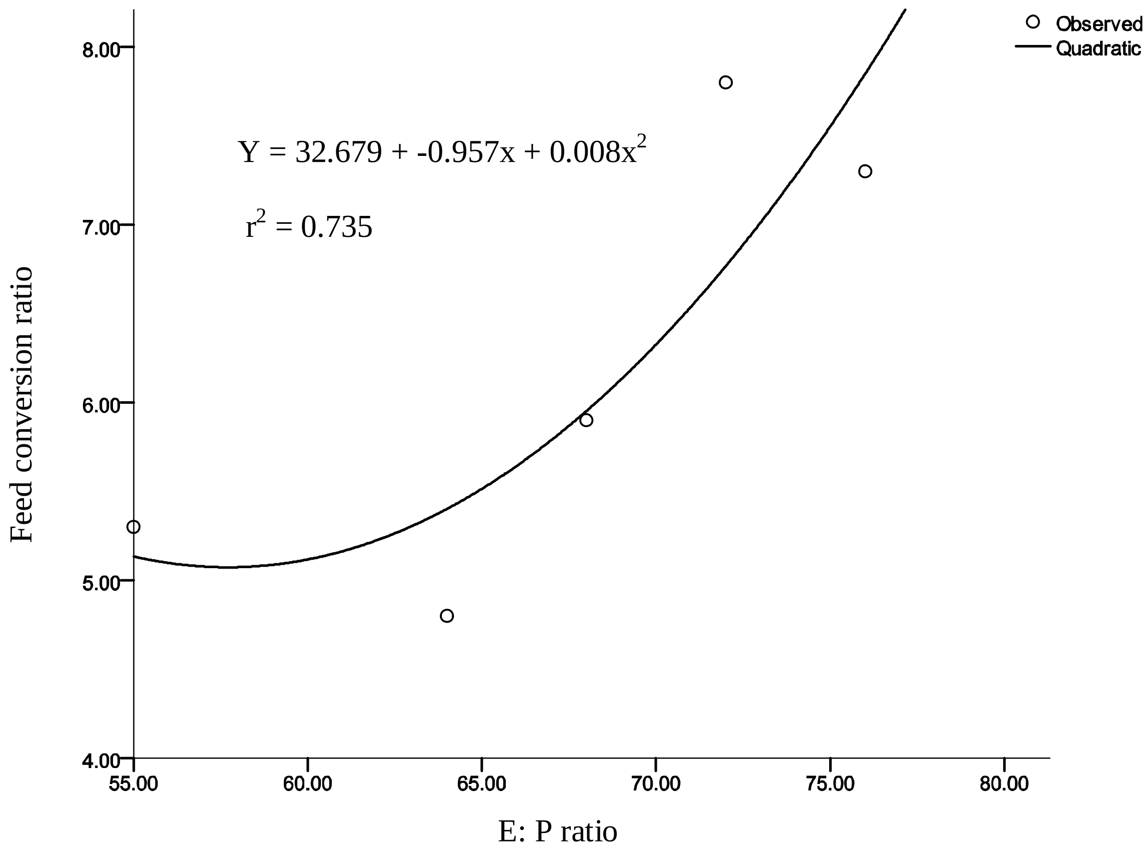

Figure 4.03 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on feed conversion ratio of male Venda chickens between seven and 13 weeks old

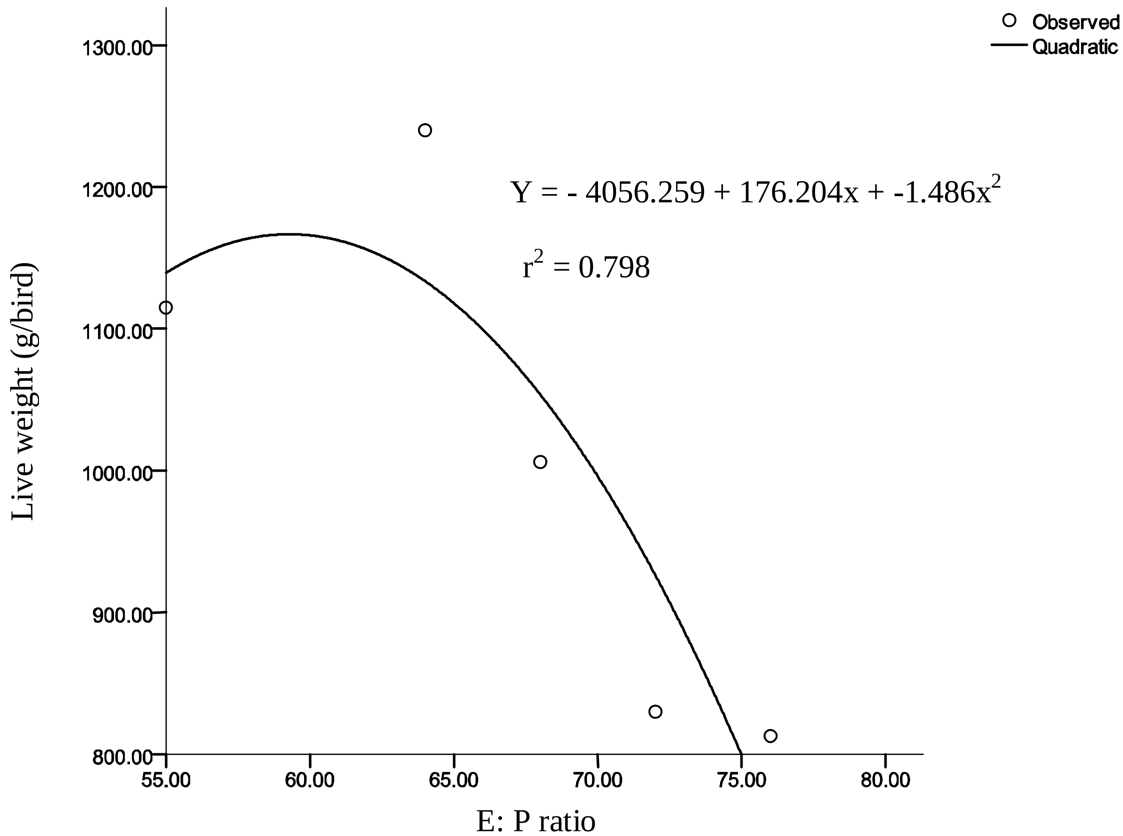

Figure 4.04 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on live weight of male Venda chickens at 13 weeks old

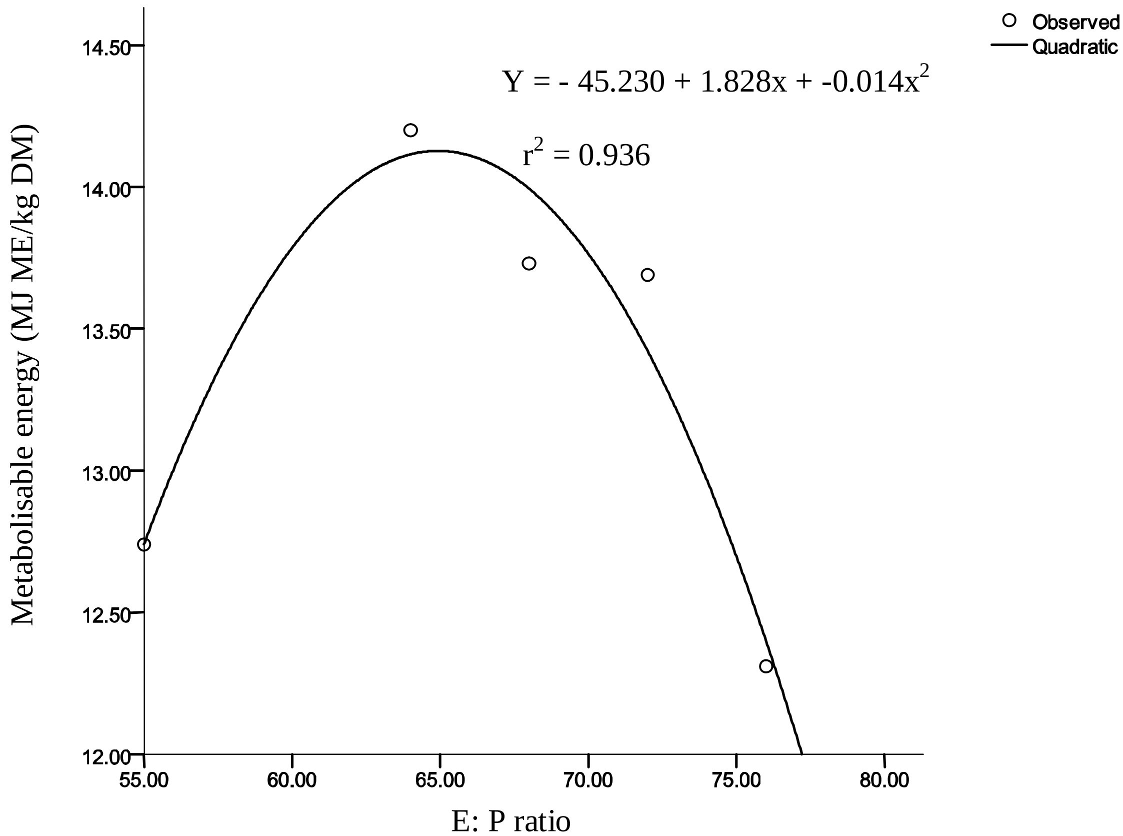

Figure 4.05 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on apparent metabolisable energy level of male Venda chickens between seven and 13 weeks old

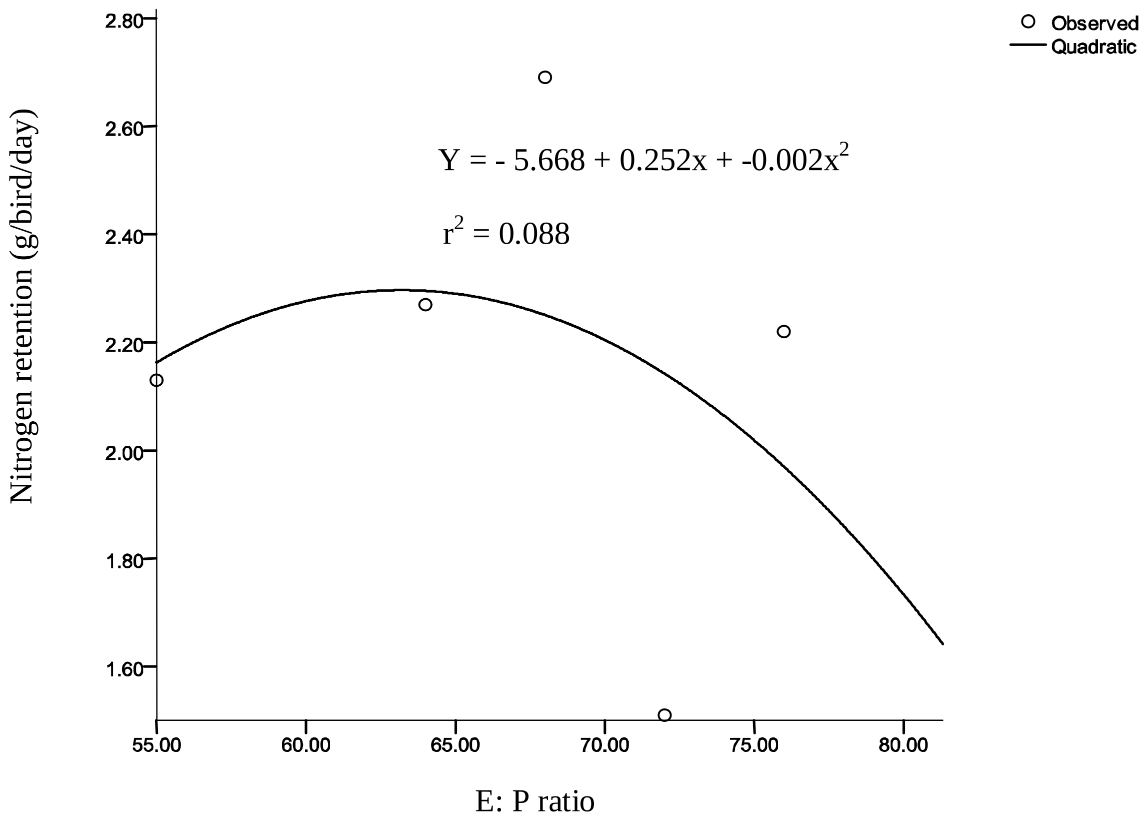

Figure 4.06 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on nitrogen retention of male Venda chickens between seven and 13 weeks old

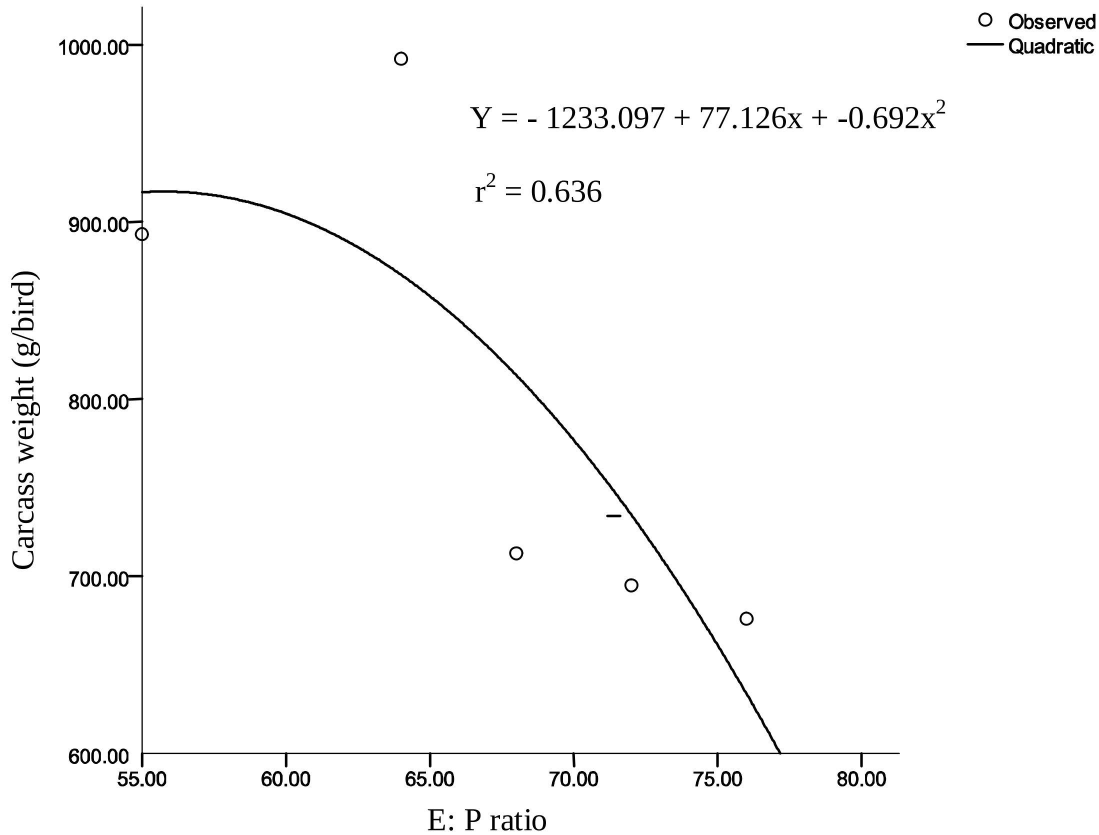

Figure 4.07 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on optimal carcass weight of male Venda chickens between seven and 13 weeks old

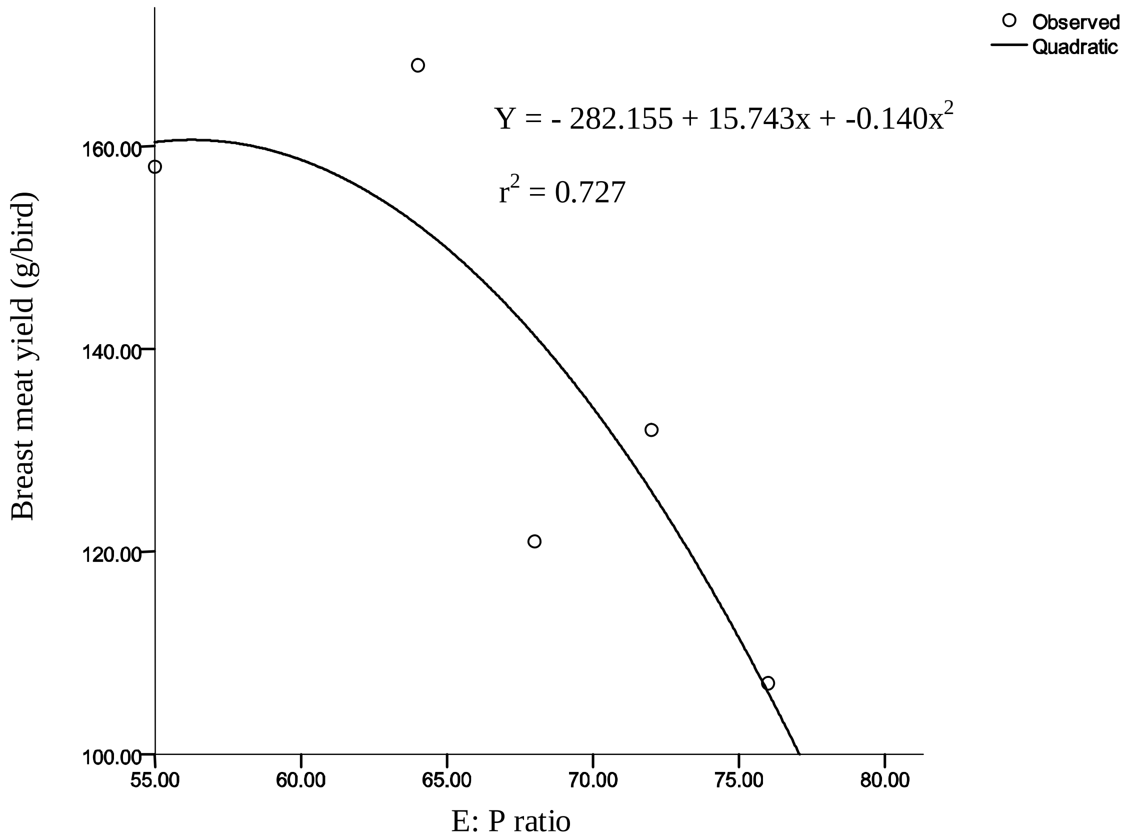

Figure 4.08 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on optimal breast meat yield of male Venda chickens between seven and 13 weeks old

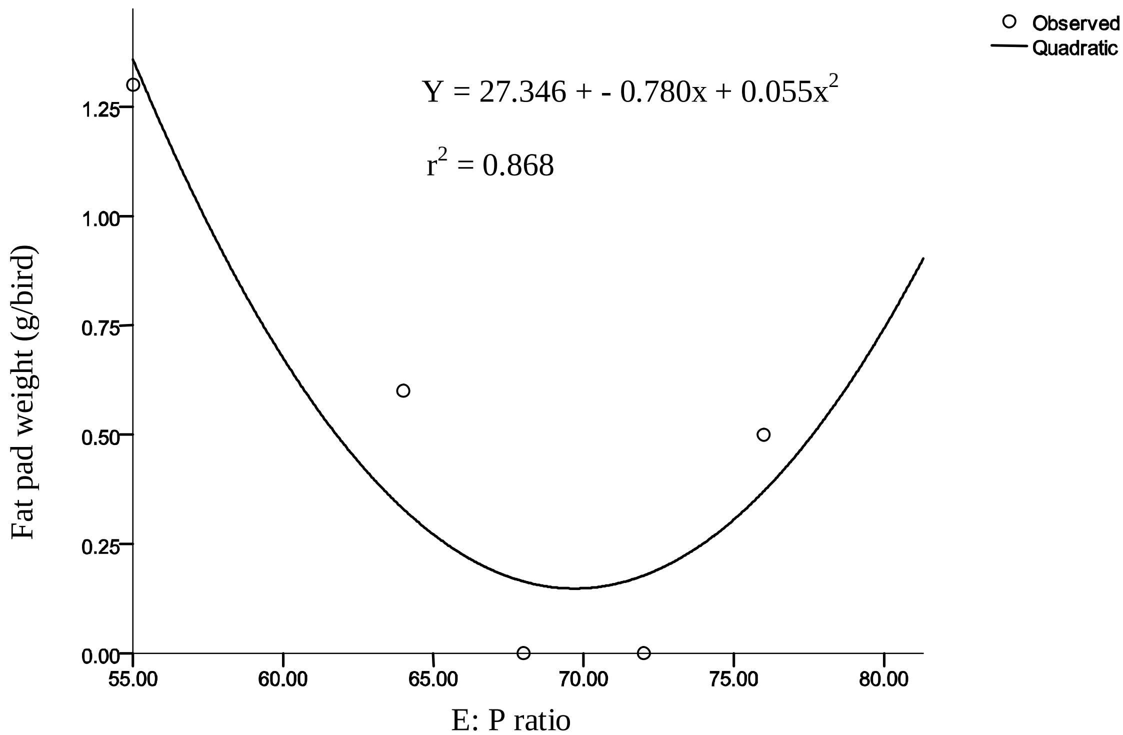

Figure 4.09 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on optimal fat pad weight of male Venda chickens between seven and 13 weeks old

Table 4.08 Effect of dietary energy to protein ratio level, based on a dietary energy level of 12.2 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day), carcass weight (g/bird), breast meat yield (g/bird) and fat pad weight (g/bird) in male Venda chickens between seven and 13 weeks old

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y = -260.74 + 11.297x + -0.091x^2$	62	89	0.850	0.150
Growth	$Y = -98.780 + 3.858x + -0.032x^2$	60	16	0.767	0.233
FCR	$Y = 32.679 + -0.957x + 0.008x^2$	60	5.5	0.735	0.265
Lwt	$Y=-4056.259+176.204x +-1.486x^2$	60	1167	0.798	0.202
ME	$Y = -45.230 + 1.828x + -0.0014x^2$	65	14.4	0.936	0.064
N-retention	$Y = -5.668 + 0.252x + -0.002x^2$	63	2.3	0.088	0.912
Carcass wt	$Y =-1233.097+ 77.126x+ -0.692x^2$	60	916	0.636	0.364
Breast	$Y = -282.155 + 15.743x+ -0.140x^2$	60	160	0.727	0.273
Fat pad	$Y = 27.346 + -0.780x + 0.055x^2$	70	0.24	0.868	0.132

FCR :Feed conversion ratio
Lwt :Live weight
ME :Apparent metabolisable energy
P :Probability level
E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)
Y-Value Optimal Y-Value
N-retention :Nitrogen retention
Carcass wt :carcass weight
Breast :Breast meat yield

4.3.2 Experiment 7

Results of the nutrient composition of the diets used in Experiment 7 are presented in Table 4.09. The diets had a similar energy level of 13 MJ ME/kg DM but different protein concentrations, ranging between 160 and 220 g CP/kg DM.

Results of the effect of energy to protein ratio level on feed intake, dry matter digestibility, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight of male Venda chickens from seven to 13 weeks of age, based on a dietary energy level of 13 MJ ME/kg DM, are presented in Table 4.10. Male Venda chickens offered a diet having 76 MJ ME/kg protein ratio had lower (P<0.05) feed intake than those offered diets having 68 and 72 MJ ME/kg protein ratios. However, the chickens offered diets having 59, 68, 72 and 81 MJ ME/kg protein ratios had similar (P>0.05) feed intakes. Similarly, birds offered diets having 59, 76 and 81 MJ ME/kg protein ratios had the same (P>0.05) feed intakes.

There were no differences (P>0.05) in growth rates between chickens offered diets having 59, 68, 72, 76 and 81 MJ ME/kg protein ratios. There were no differences (P>0.05) in live weights between male Venda chickens offered diets having 59, 68, 72, 76 and 81 MJ ME/kg protein ratios. Venda chickens offered a diet having 68 MJ ME/kg protein ratio had a better (P<0.05) feed conversion ratio than those on diets having 59 and 76 MJ ME/kg protein ratios. However, the chickens offered diets having 59, 72, 76 and 81 MJ ME/kg protein ratios had similar (P>0.05) feed conversion ratios. Male Venda chickens offered a diet having 68 MJ ME/kg protein ratio had a higher (P<0.05) apparent metabolisable energy value than those offered diets having 59, 72, 76 and 81 MJ ME/kg protein ratios. However, those offered diets having 59, 72, 76 and 81 MJ ME/kg protein ratios had similar (P>0.05) apparent ME values. Male Venda chickens offered a diet having 68 MJ ME/kg protein ratio had a higher (P<0.05) nitrogen retention than those offered diets having 59, 72, 76 and 81 MJ ME/kg protein ratios.

However, those offered diets having 59 and 81 MJ ME/kg protein ratios had the same (P>0.05) nitrogen retentions. Similarly, male Venda chickens offered diets having 72 and 76 MJ ME/kg protein ratios had similar (P>0.05) nitrogen retention values. There were no differences (P>0.05) in carcass weight, breast meat yield, fat pad weights and digestibility values between Venda chickens offered diets having 59, 68, 72, 76 and 81 MJ ME/kg protein ratios.

Results of the effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight in male Venda chickens between seven and 13 weeks old are presented in Figures 4.10 to 4.18 and Table 4.11. Feed intake was optimized at a dietary energy to protein ratio of 66 MJ ME/kg protein (Figure 4.10). Growth rate, live weight, carcass weight and fat pad weight were optimized at a single dietary energy to protein ratio of 71 MJ ME/kg protein (Figures 4.11, 4.13, 4.16 and 4.18, respectively) while feed conversion ratio, apparent ME, nitrogen retention and breast meat yield were optimized at dietary energy to protein ratios of 75, 70, 64 and 81 MJ ME/kg protein, respectively (Figures 4.12, 4.14, 4.15 and 4.17, respectively). However, regression analysis indicated no optimal digestibility response to dietary energy to protein ratio levels used in this experiment.

Table 4.09 Nutrient composition of diets used in Experiment 7 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed).

	Nutrient					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{13}P_{22}$	928.6	13	220	10.5	10.6	5.8
$E_{13}P_{19}$	928.2	13	190	11.0	10.4	5.7
$E_{13}P_{18}$	928.0	13	185	10.8	10.0	5.1
$E_{13}P_{17}$	928.4	13	170	11.4	10.2	5.4
$E_{13}P_{16}$	928.3	13	160	11.6	10.1	5.5

Table 4.10 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day) and feed conversion ratio (FCR) between seven and thirteen weeks of age, live weight at thirteen weeks old (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day) and dry matter digestibility (decimal) between 85 and 91 days of age, and carcass weight (g/bird), breast meat yield (g/bird) and fat pad weight (g/bird) of male Venda chickens based on a dietary energy level of 13 MJ ME/kg DM*

Variable	Treatment (E:P ratio)					SE
	59	68	72	76	81	
Intake	80^{ab}	82^{a}	84^{a}	74^{b}	78^{ab}	2.25
Growth rate	11	14	13	10	13	1.86
FCR	7.3^{a}	5.8^{b}	6.4^{ab}	7.4^{a}	6.0^{ab}	0.91
Live weight	865	1030	960	805	973	90.9
ME	13.6^{b}	15.8^{a}	13.4^{b}	13.3^{b}	14.4^{b}	0.34
N-retention	2.2^{b}	3.4^{a}	1.8^{c}	1.5^{c}	2.1^{b}	0.06
Carcass weight	704	895	800	688	812	69.97
Breast meat yield	132	165	146	117	162	15.63
Fat pad weight	0.7	0.3	0.5	0.8	0.6	0.37
Feed dry Matter Digestibility	0.9	0.9	0.9	0.9	0.9	0.02

^{abcde} :Means in the same row not sharing a common superscript are significantly different ($P<0.05$).

ME :Metabolisable energy

N-retention :Nitrogen retention

SE :Standard error

* :Dietary ME determined by NIRA(Valdes and Leeson, 1992)

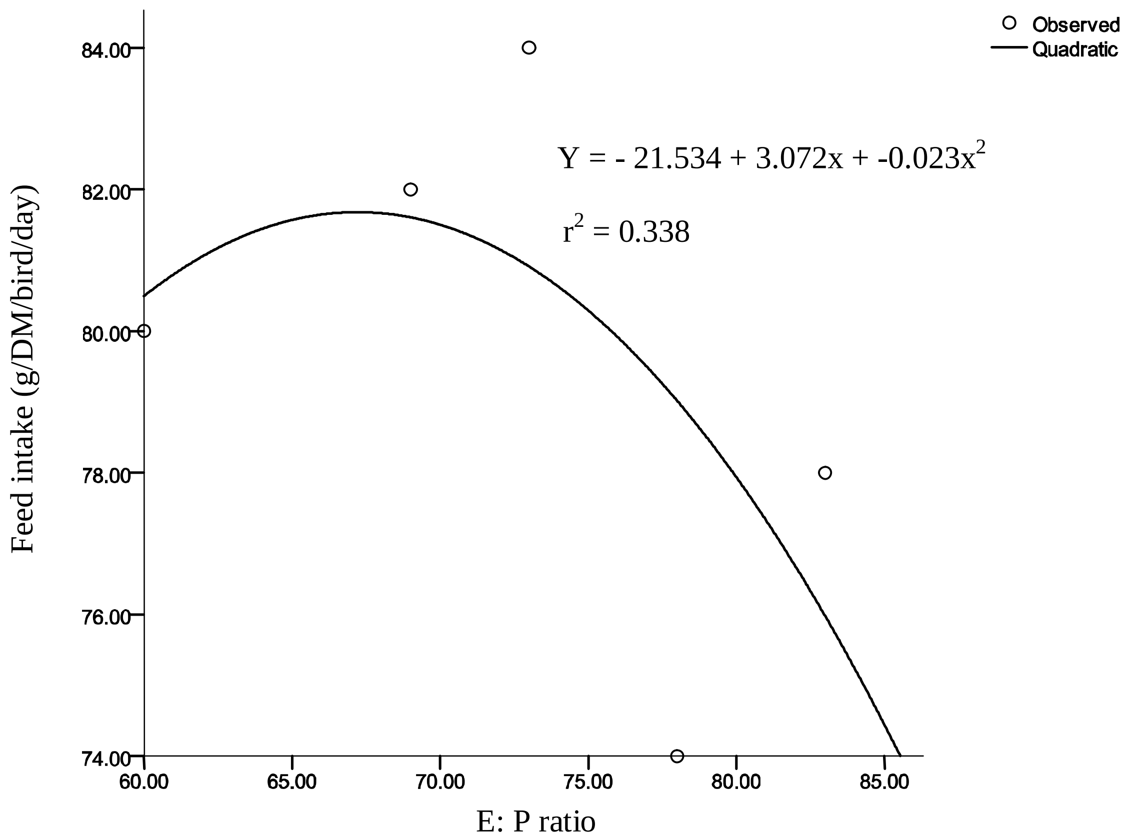

Figure 4.10 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on daily DM feed intake of male Venda chickens between seven and 13 weeks old

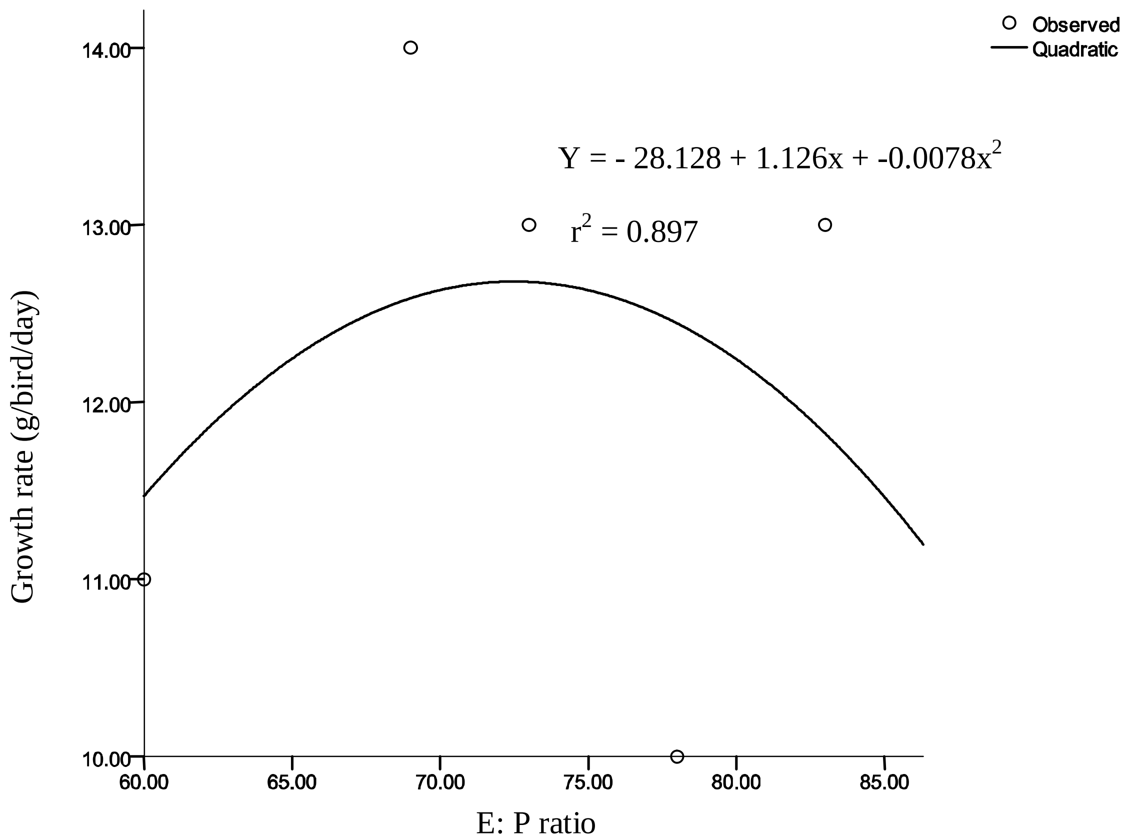

Figure 4.11 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on growth rate of male Venda chickens between seven and 13 weeks old

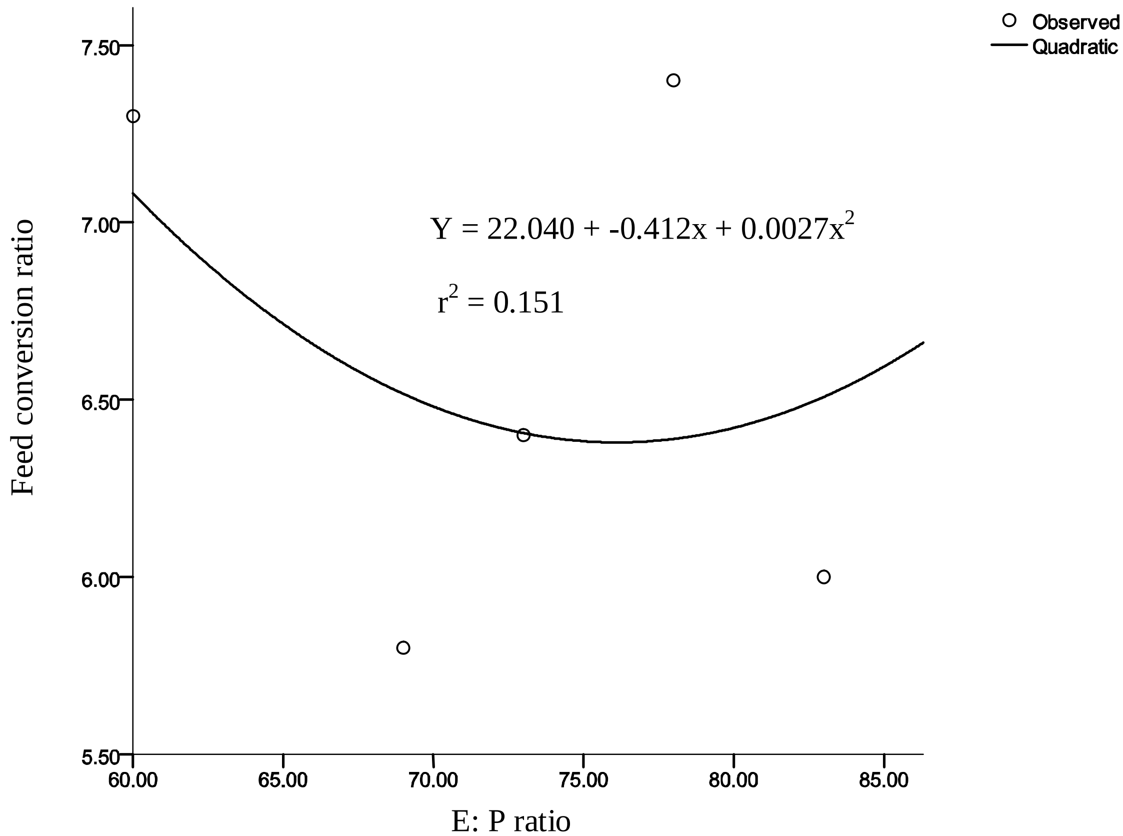

Figure 4.12 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on feed conversion ratio of male Venda chickens between seven and 13 weeks of age

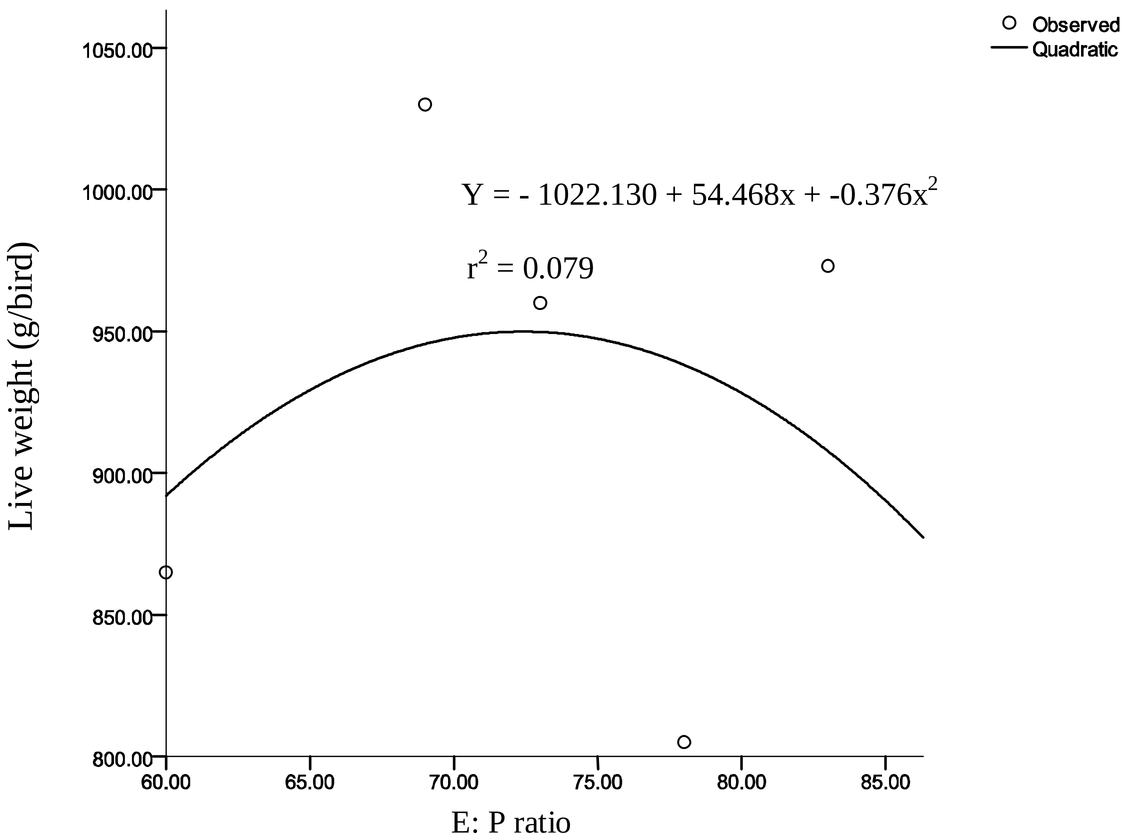

Figure 4.13 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on live weight of male Venda chickens at 13 weeks old

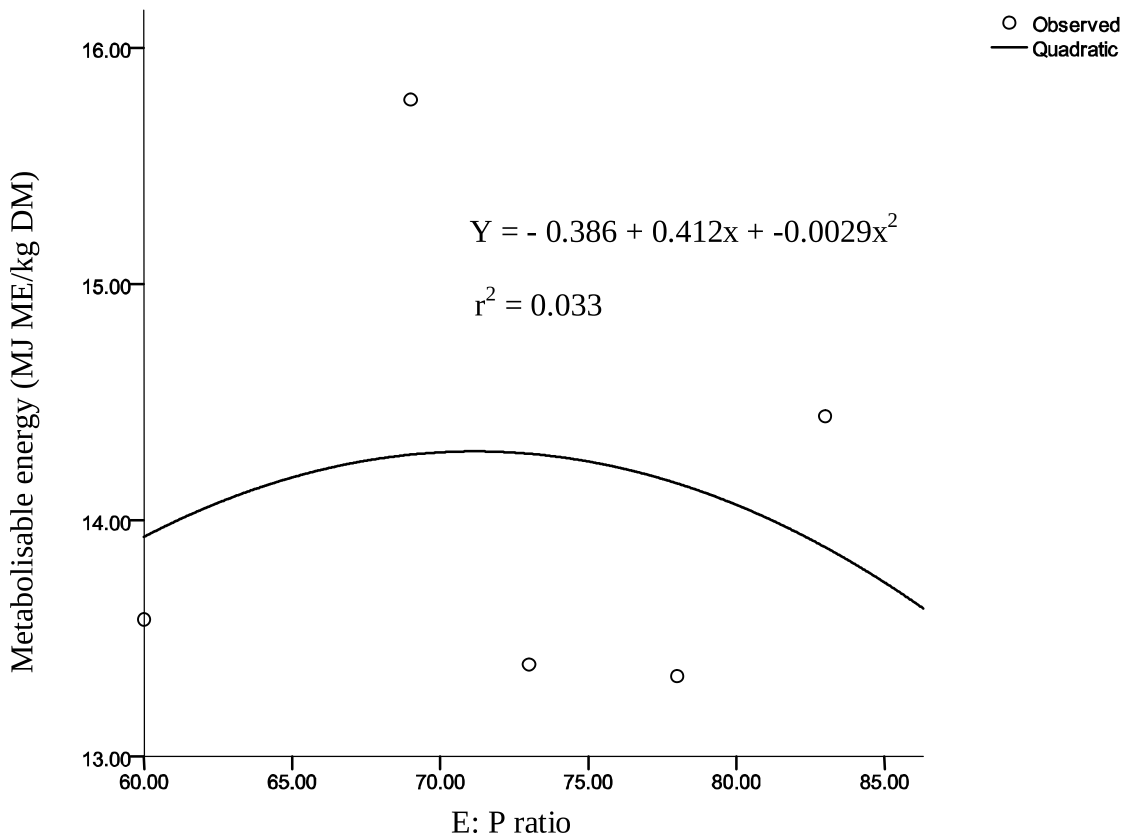

Figure 4.14 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on apparent metabolisable energy level of male Venda chickens between seven and 13 weeks old

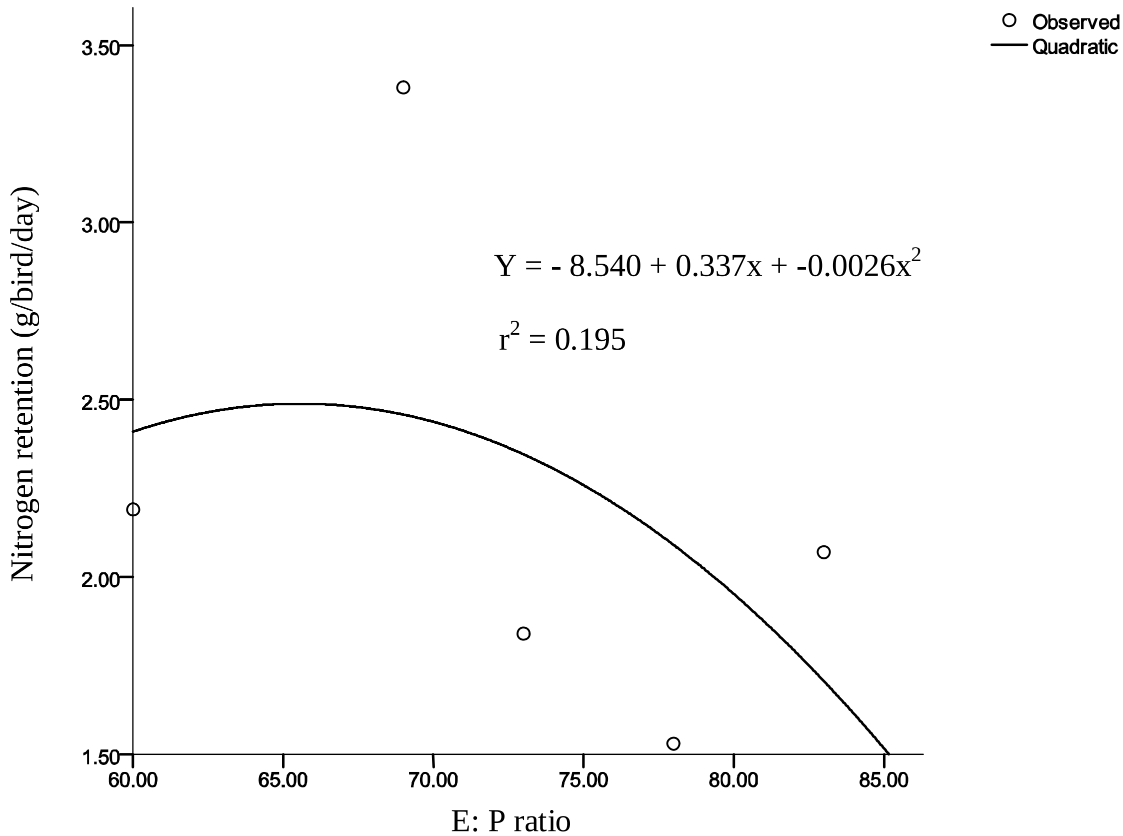

Figure 4.15 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on nitrogen retention of male Venda chickens between seven and 13 weeks old

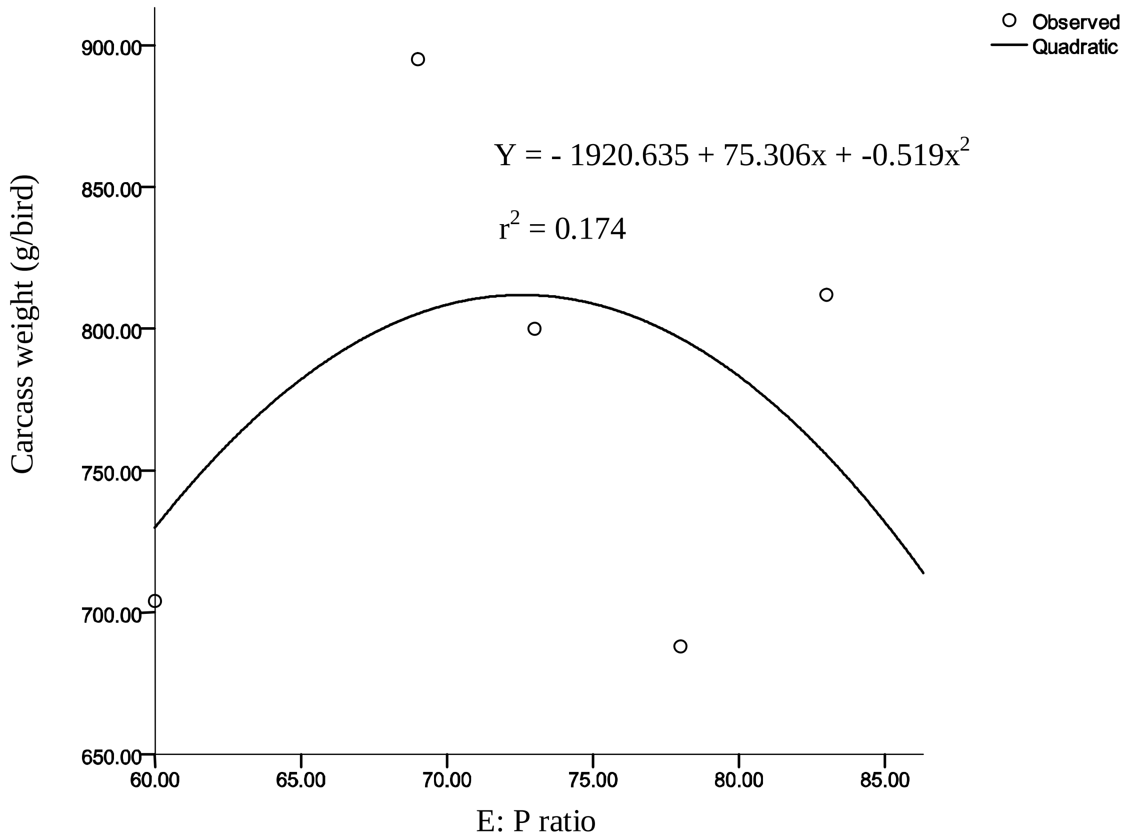

Figure 4.16 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on carcass weight of male Venda chickens between seven and 13 weeks old

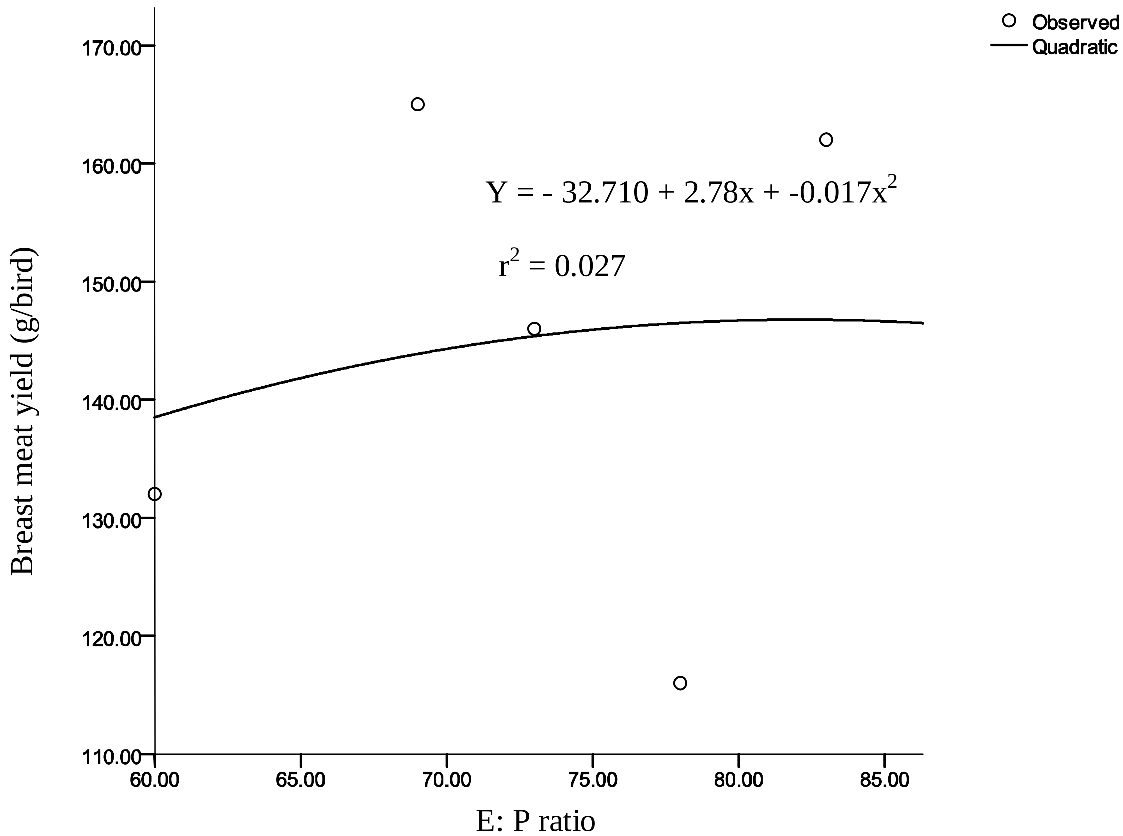

Figure 4.17 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on breast meat yield of male Venda chickens between seven and 13 weeks old

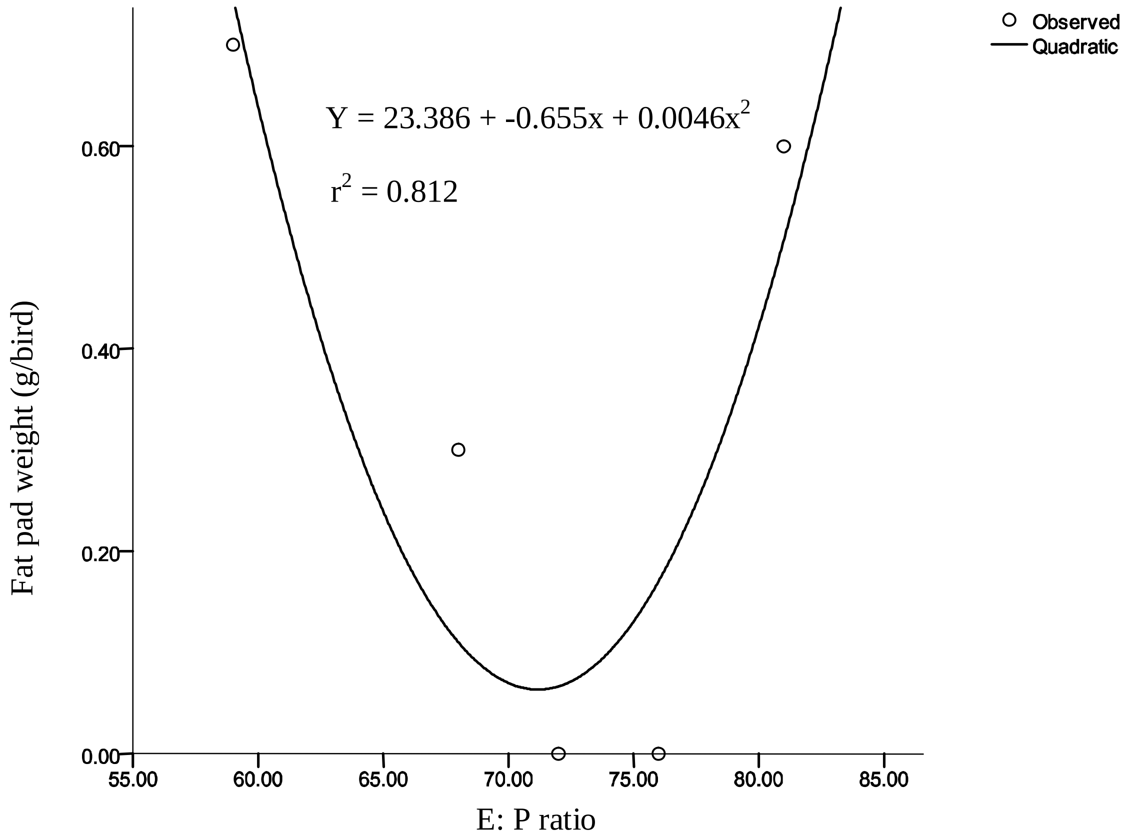

Figure 4.18 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on fat pad weight of male Venda chickens between seven and 13 weeks old

Table 4.11 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day), carcass weight (g/bird), breast meat yield (g/bird) and fat pad weight (g/bird) in male Venda chickens between seven and 13 weeks old

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y = -21.534 + 3.072x + -0.028x^2$	66	81	0.338	0.662
Growth	$Y = -28.128 +1.126x + -0.0078x^2$	71	12	0.103	0.897
FCR	$Y = 22.040 + -0.412x + 0.0027x^2$	75	6.7	0.151	0.849
Lwt	$Y= -1022.130+54.468x + -0.376x^2$	71	950	0.079	0.921
ME	$Y = -0.386 + 0.412x + -0.0029x^2$	70	14.2	0.033	0.967
N-retention	$Y = -8.540 + 0.337x + -0.0026x^2$	64	2.5	0.195	0.805
Carcass wt	$Y = -1920.635+75.306x+ -0.519x^2$	71	811	0.174	0.826
Breast	$Y = - 32.710 + 2.779x + -0.017x^2$	81	146	0.027	0.973
Fat pad	$Y = 23.386 + -0.655x + 0.0046x^2$	71	0.06	0.812	0.188

FCR :Feed conversion ratio
Lwt :Live weight
ME :Apparent metabolisable energy
P :Probability level
E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)
Y-Value :Optimal Y-Value
N-retention :Nitrogen retention
Carcass wt :carcass weight
Breast :Breast meat yield

4.3.3 Experiment 8

Results of the nutrient composition of the diets used in Experiment 8 are presented in Table 4.12. The diets had a similar energy level of 13.2 MJ ME/kg DM but different protein levels, ranging between 160 and 220 g CP/kg DM.

Results of the effect of energy to protein ratio level on feed intake, feed dry matter digestibility, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight of male Venda chickens from seven to 13 weeks of age, based on a dietary energy level of 13.2 MJ ME/kg DM, are presented in Table 4.13. There were no differences (P>0.05) in feed intakes between chickens offered diets having 60, 69, 73, 78 and 83 MJ ME/kg protein ratios. Male Venda chickens offered diets having 60 and 69 MJ ME/kg protein ratios had higher (P<0.05) growth rates than those offered a diet having 83 MJ ME/kg protein ratio. However, male Venda chickens offered diets having 60, 69, 73 and 78 MJ ME/kg protein ratios had similar (P>0.05) growth rates.

Venda chickens offered a diet having 69 MJ ME/kg protein ratio had higher (P<0.05) live weights than those offered a diet having 83 MJ ME/kg protein ratio. However, birds offered diets having 60, 69, 73 and 78 MJ ME/kg protein ratios had similar (P>0.05) live weights. Similarly, male Venda chickens offered diets having 60, 73, 78 and 83 MJ ME/kg protein ratios had similar (P>0.05) live weights. Male Venda chickens offered a diet having 83 MJ ME/kg protein ratio had a poorer (P<0.05) feed conversion ratio than those on diets having 60, 69, 73 and 78 MJ ME/kg protein ratios. Male Venda chickens offered a diet having 60 MJ ME/kg protein ratio had a better (P<0.05) feed conversion ratio than those on diets having 69, 73, 78 and 83 MJ ME/kg protein ratios. However, male Venda chickens offered diets having 73 and 78 MJ ME/kg protein ratios had the same (P>0.05) feed conversion ratios. There were no differences (P>0.05) in apparent metabolisable energy values between chickens offered diets having 60, 69, 73, 78 and 83 MJ ME/kg protein ratios. Male Venda chickens offered diets having 73 and 83 MJ ME/kg protein ratios had higher (P<0.05) nitrogen retentions than those offered diets having 60, 69 and 78 MJ ME/kg protein ratios. However, those offered diets having 73 and 83 MJ ME/kg protein ratios had similar (P>0.05) nitrogen retentions. Male Venda chickens offered diets having 60 and 69 MJ ME/kg protein ratios had higher (P<0.05) carcass weights than those offered a diet having 83 MJ ME/kg protein ratio. However, chickens offered diets having 60, 69, 73 and 78 MJ ME/kg protein ratios had similar (P>0.05) carcass weights. Similarly, birds offered diets having 73, 78 and 83 MJ ME/kg protein ratios had the same (P>0.05) carcass weights.

Male Venda chickens offered a diet having 60 MJ ME/kg protein ratio had higher (P<0.05) breast meat yields than those offered diets having 78 and 83 MJ ME/kg protein ratios. However, male Venda chickens offered diets having 60, 69 and 73 MJ ME/kg protein ratios had similar (P>0.05) breast meat yields. Similarly, male Venda chickens offered diets having 69, 73 and 78 MJ ME/kg protein ratios had the same (P>0.05) breast meat yields. There were no differences (P>0.05) in fat pad weights and digestibility values between male Venda chickens offered diets having 60, 69, 73, 78 and 83 MJ ME/kg protein ratios.

Results of the effect of dietary energy to protein ratio level based on a dietary energy level of 13.2 MJ ME/kg DM on optimal feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight in male Venda chickens between seven and 13 weeks old are presented in Figures 4.19 to 4.27 and Table 4.14. Feed intake was optimized at a dietary energy to protein ratio of 74 MJ ME/kg protein (Figure 4.19). Growth rate, live weight, carcass weight, and fat pad weight were optimized at a single dietary energy to protein ratio of 66 MJ ME/kg protein (Figures 4.20, 4.22, 4.25 and 4.27, respectively and Table 4.14) while FCR, ME, nitrogen retention and breast meat yield were optimized at dietary energy to protein ratios of 65, 73, 71 and 62 MJ ME/kg protein, respectively (Figures 4.21, 4.23, 4.24 and 4.26, respectively and Table 4.14). However, quadratic analysis indicated no optimal digestibility response to dietary energy to protein ratio levels used in this experiment.

Table 4.12 Nutrient composition of diets used in Experiment 8 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed).

	Nutrient					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{13.2}P_{22}$	928.3	13.2	220	10.8	10.7	5.9
$E_{13.2}P_{19}$	927.0	13.2	190	11.0	10.2	5.7
$E_{13.2}P_{18}$	928.1	13.2	185	10.5	10.3	5.2
$E_{13.2}P_{17}$	928.2	13.2	170	11.0	10.0	5.0
$E_{13.2}P_{16}$	928.0	13.2	160	11.3	10.4	5.5

Table 4.13 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day) and feed conversion ratio (FCR) between seven and thirteen weeks of age, live weight at thirteen weeks old (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day) and dry matter digestibility (decimal) between 85 and 91 days of age, and carcass weight (g/bird), breast meat yield (g/bird) and fat pad weight (g/bird) of male Venda chickens based on a dietary energy level of 13.2 MJ ME/kg DM*

Variable	Treatment (E:P ratio)					SE
	60	69	73	78	83	
Intake	74	81	86	79	82	4.55
Growth rate	13[a]	13[a]	12[ab]	11[ab]	8[b]	1.53
FCR	5.7[d]	6.2[c]	7.2[b]	7.2[b]	10.2[a]	1.12
Live weight	938[ab]	970[a]	920[ab]	883[ab]	705[b]	75.06
ME	13.8	14.2	15.1	14.2	14.2	0.35
N-retention	2.5[c]	2.6[bc]	2. 8[a]	2.4[c]	2.8[a]	0.17
Carcass weight	805[a]	824[a]	789[ab]	757[ab]	564[b]	73.57
Breast meat yielc	153[a]	142[ab]	145[ab]	131[b]	112[c]	12.55
Fat pad weight	1.6	1.2	1.7	2.6	2.0	1.56
DM Digestibility	0.9	0.9	0.9	0.9	0.9	0.02

[abcde] Means in the same row not sharing a common superscript are significantly different ($P<0.05$).

ME :Metabolisable energy

N-retention :Nitrogen retention

SE :Standard error

DM Digestibility :Dry matter digestibility

* :Dietary ME determined by NIRA(Valdes and Leeson, 1992)

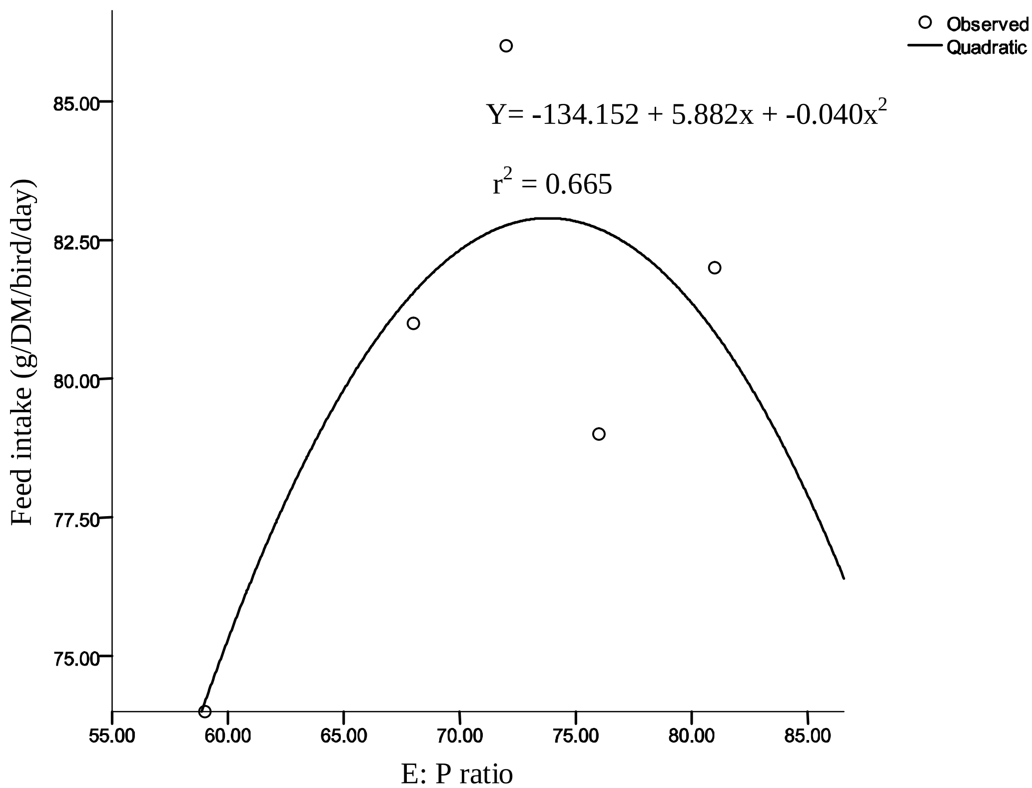

Figure 4.19 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on daily DM feed intake of male Venda chickens between seven and 13 weeks old

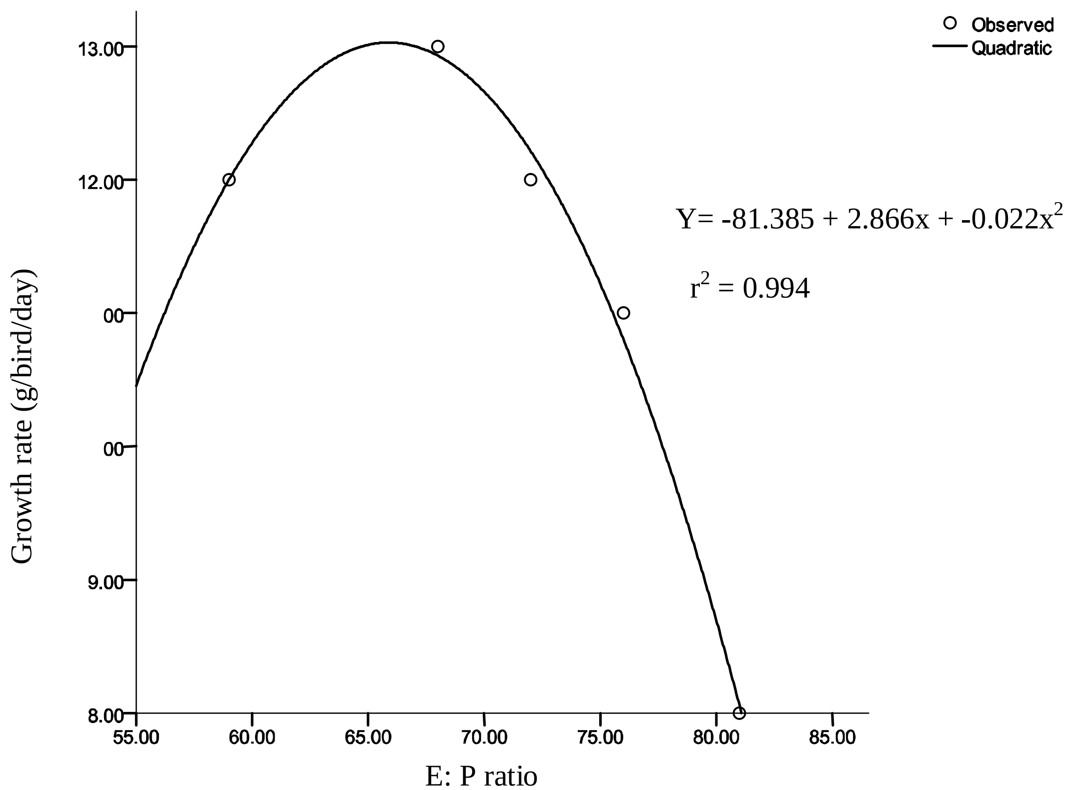

Figure 4.20 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on growth rate of male Venda chickens between seven and 13 weeks old

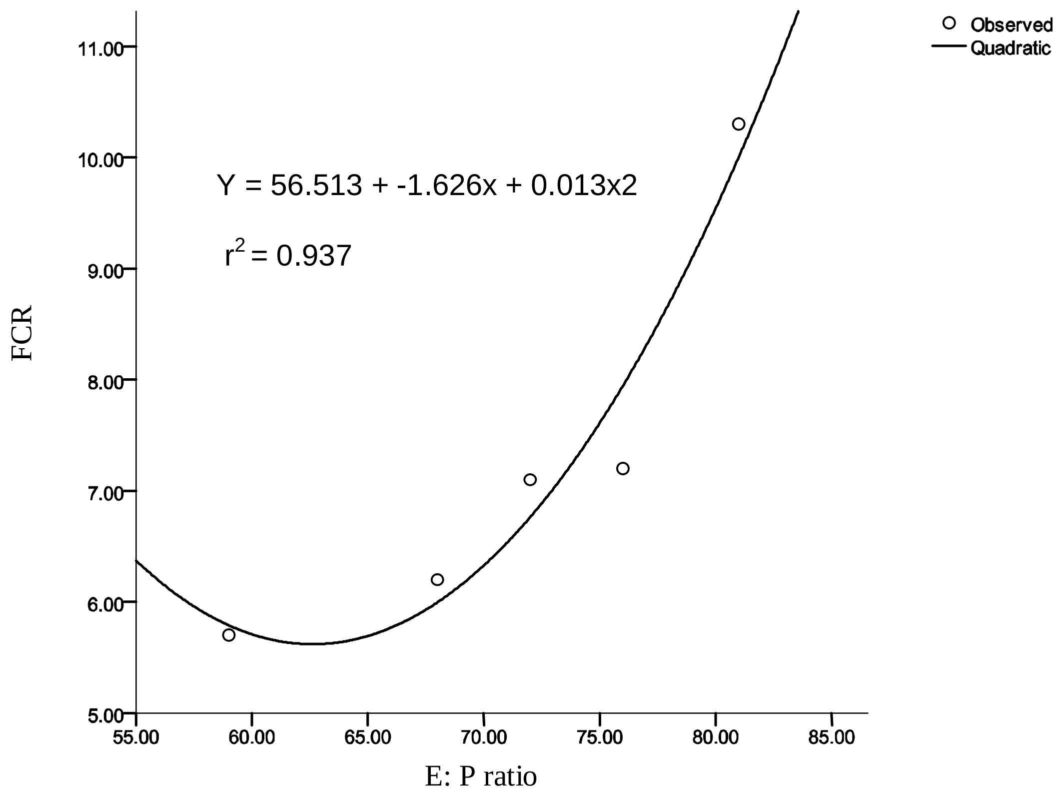

Figure 4.21 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on feed conversion ratio of male Venda chickens between seven and 13 weeks old

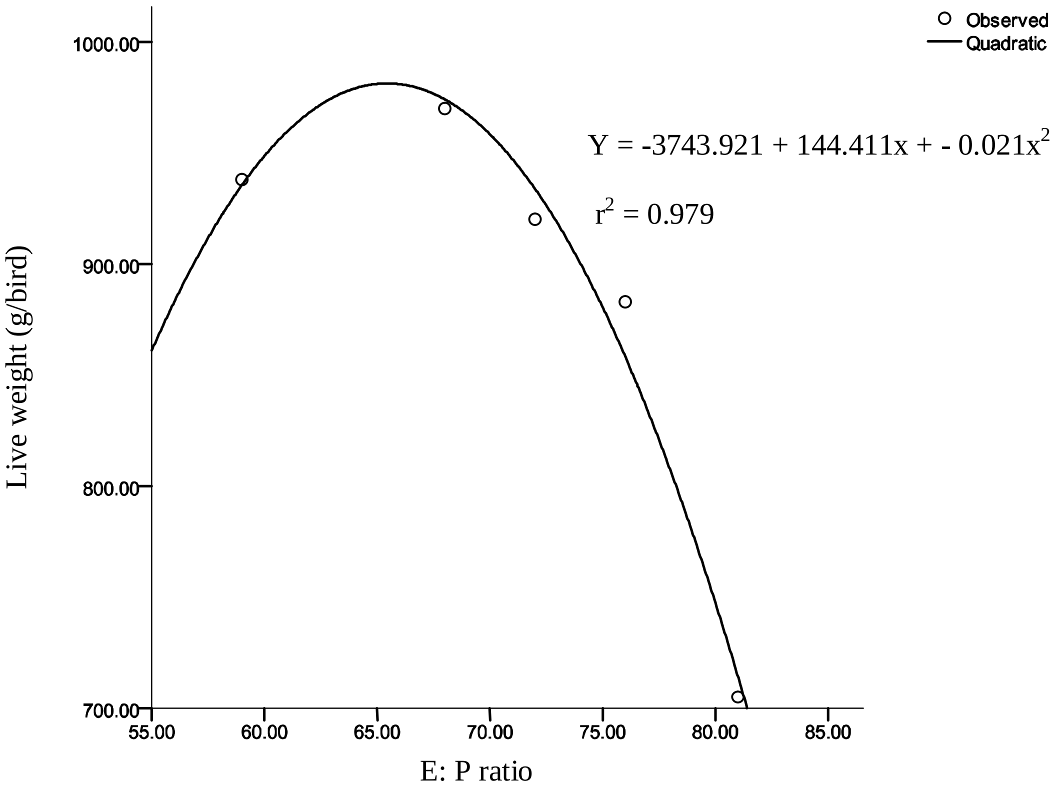

Figure 4.22 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on live weight of male Venda chickens at thirteen weeks old

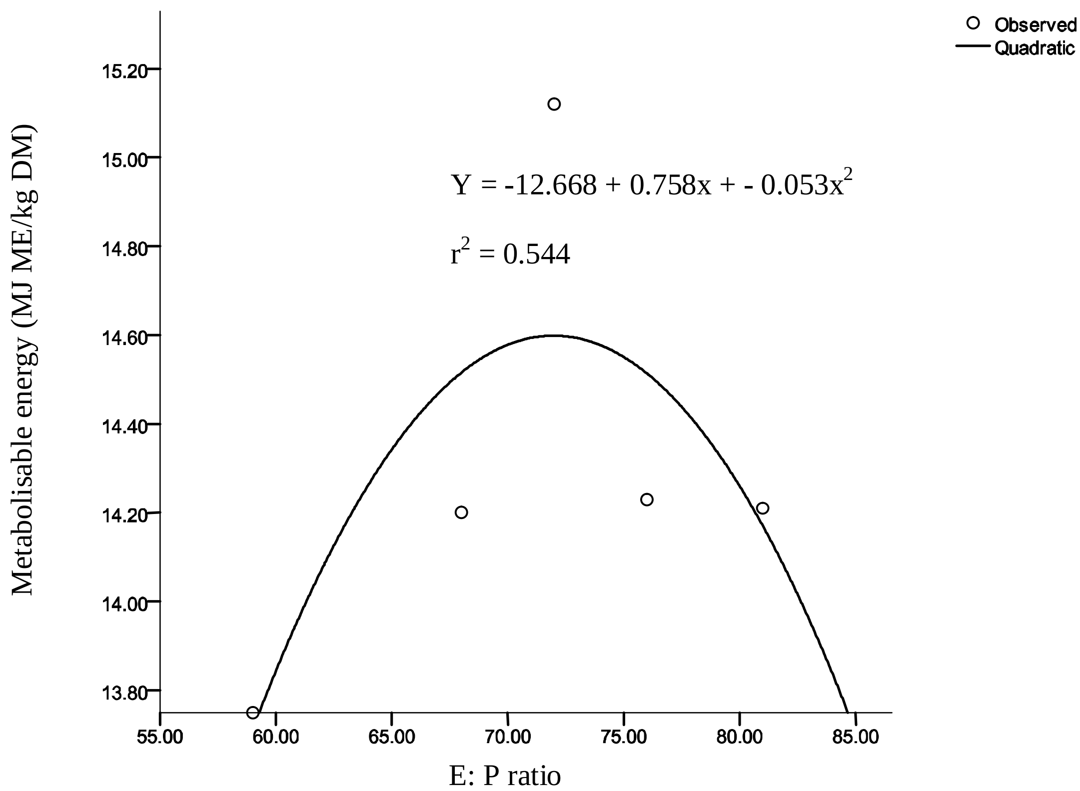

Figure 4.23 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on apparent metabolisable energy level of Venda chickens between seven and 13 weeks old

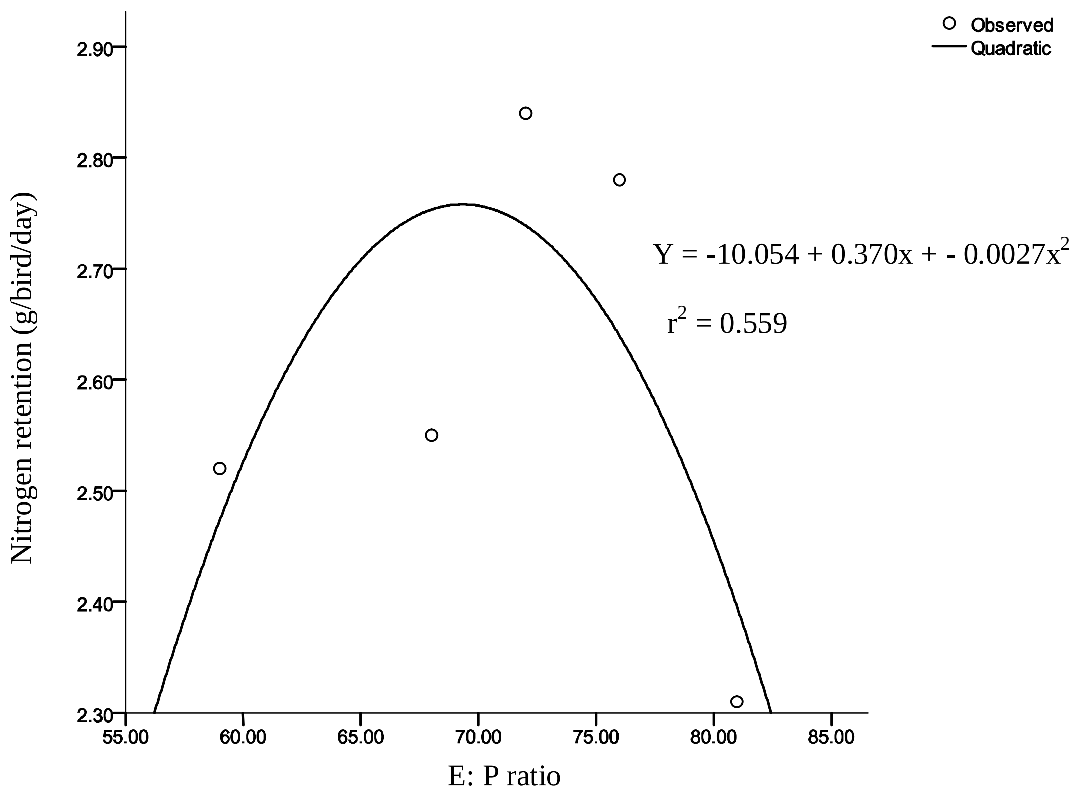

Figure 4.24 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on nitrogen retention of male Venda chickens between seven and 13 weeks old

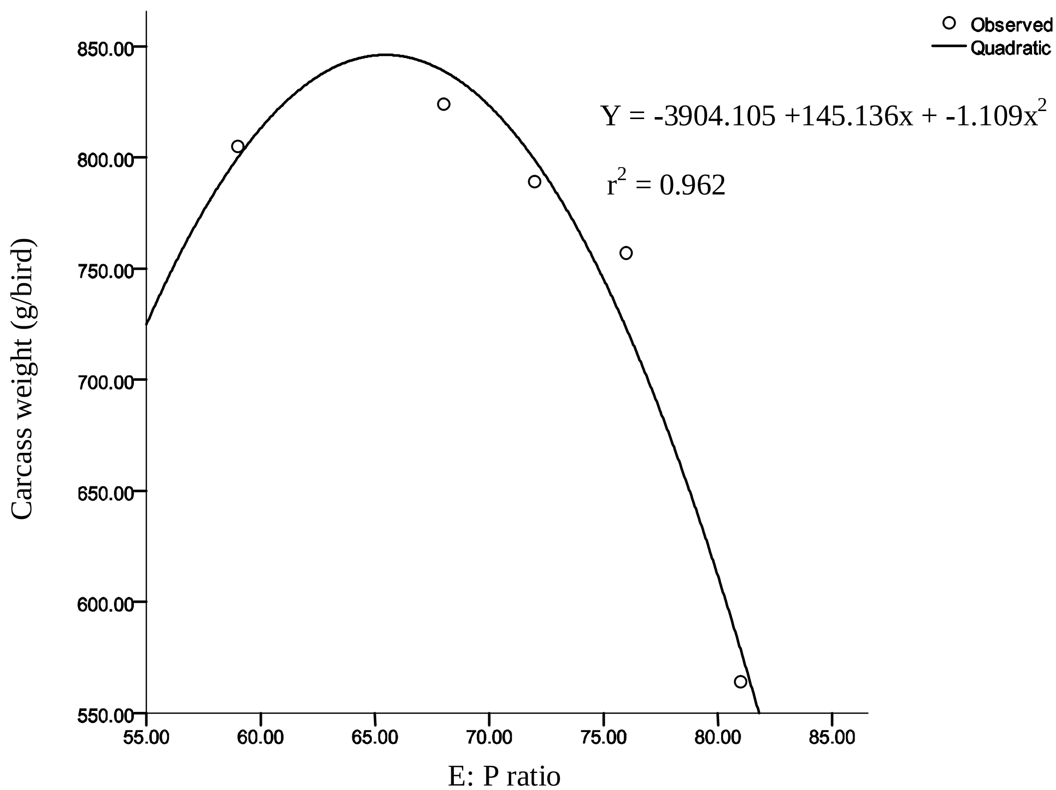

Figure 4.25 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on carcass weight of male Venda chickens between seven and 13 weeks old

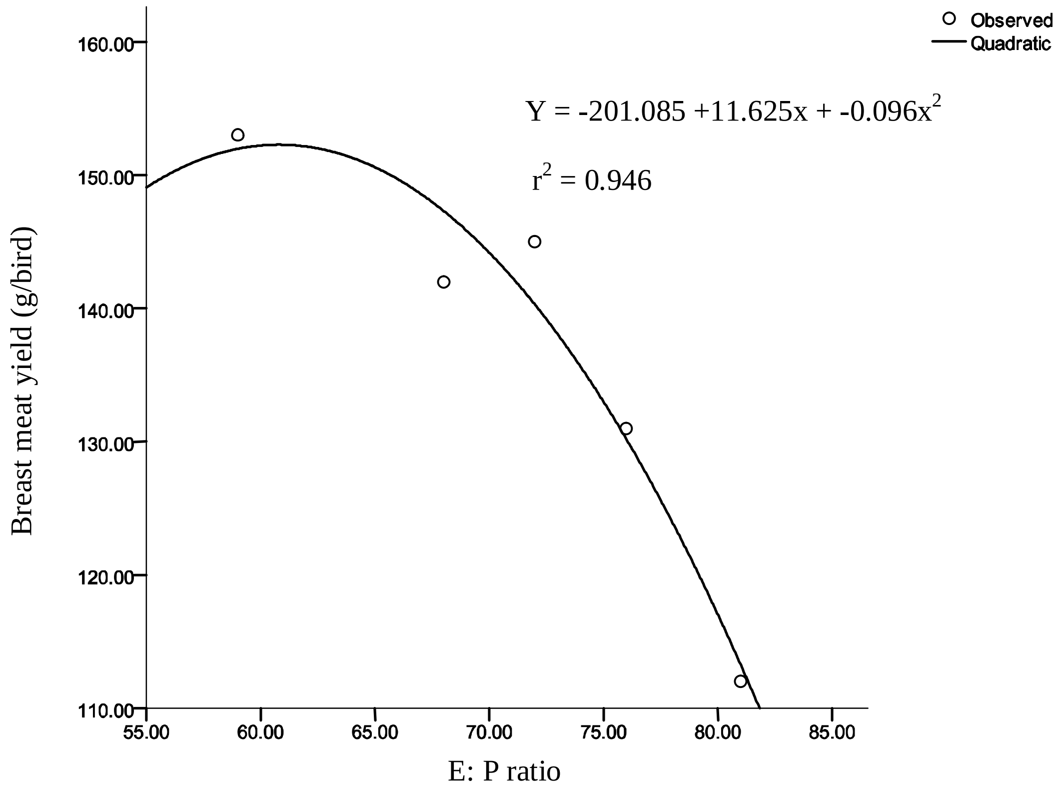

Figure 4.26 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on breast meat yield of Venda chickens between seven and 13 weeks old

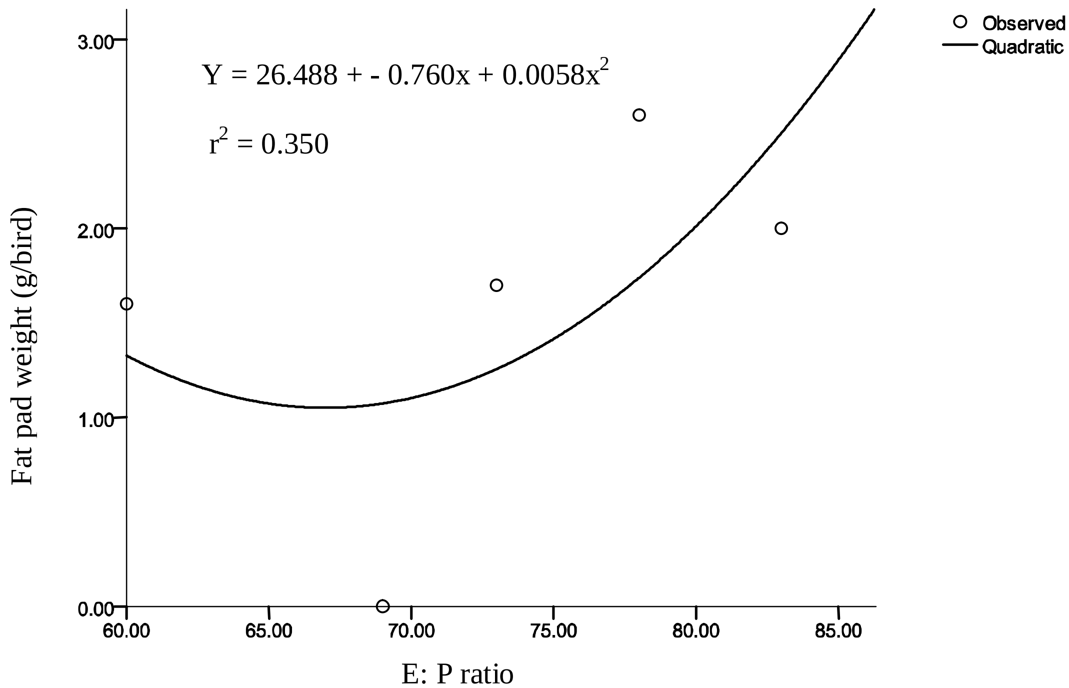

Figure 4.3.27 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.2 MJ ME/kg DM, on fat pad weight of male Venda chickens between seven and 13 weeks old

Table 4.14 Effect of dietary energy to protein ratio level based on a dietary energy level of 13.2 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day), carcass weight (g/bird), breast meat yield (g/bird) and fat pad weight (g/bird) in male Venda chickens between seven and 13 weeks old

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y= -134.152 + 5.882x + -0.040x^2$	74	82	0.665	0.335
Growth	$Y= -81.385 + 2.866x + -0.022x^2$	66	13	0.994	0.006
FCR	$Y = 56.513 + -1.626x + 0.013x^2$	65	5.7	0.937	0.063
Lwt	$Y=-3743.921+144.411x+-.103x^2$	66	983	0.979	0.021
ME	$Y= -12.668 + 0.758x + -0.0053x^2$	73	14.4	0.544	0.456
N-retention	$Y= -10.054 + 0.370x + -0.0027x^2$	71	2.7	0.559	0.441
Carcass wt	$Y=-3904.105 +145.14x+-1.109x^2$	66	844	0.962	0.038
Breast	$Y=-201.085 +11.625x + -0.096x^2$	62	151	0.946	0.973
Fat pad	$Y = 26.488 + - 0.760x + 0.058x^2$	66	1.2	0.350	0.650

FCR :Feed conversion ratio
Lwt :Live weight
ME :Apparent metabolisable energy
P :Probability level
E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)
Y-Value :Optimal Y-Value
N-retention :Nitrogen retention
Carcass wt :carcass weight
Breast :Breast meat yield

4.3.4 Experiment 9

Results of the nutrient composition of the diets used in Experiment 9 are shown in Table 4.15. The diets contained a similar energy value of 13.4 MJ ME/kg DM but with varying crude protein levels, ranging between 160 and 220 g CP/kg DM.

Results of the effect of energy to protein ratio level on feed intake, feed dry matter digestibility, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight of male Venda chickens from seven to 13 weeks of age, based on a dietary energy level of 13.4 MJ ME/kg DM, are presented in Table 4.16. Male Venda chickens offered a diet having 84 MJ ME/kg protein ratio had a lower ($P<0.05$) feed intake than those offered diets having 71 and 79 MJ ME/kg protein ratios. However, male Venda chickens offered diets having 61, 74 and 84 MJ ME/kg protein ratios had similar ($P>0.05$) feed intakes. Similarly, male Venda chickens offered diets having 61, 71, 74 and 79 MJ ME/kg protein ratios had similar ($P>0.05$) feed intakes. There were no differences ($P>0.05$) in growth rates between chickens offered diets having 61, 71, 74, 79 and 84 MJ ME/kg protein ratios. There were no differences ($P>0.05$) in live weights between chickens offered diets having 61, 71, 74, 79 and 84 MJ ME/kg protein ratios.

Male Venda chickens on a diet having 71 MJ ME/kg protein ratio had a better ($P<0.05$) feed conversion ratio than those on a diet having 61 MJ ME/kg protein ratio. However, male Venda chickens offered diets having 71, 74, 79 and 84 MJ ME/kg protein ratios had similar ($P>0.05$) feed conversion ratios. Similarly, male Venda chickens offered diets having 61, 74, 79 and 84 MJ ME/kg protein ratios had similar ($P>0.05$) feed conversion ratios. Male Venda chickens offered a diet having 71 MJ ME/kg protein ratio had a higher ($P<0.05$) apparent ME value than those offered diets having 61, 74, 79 and 84 MJ ME/kg protein ratios. Male Venda chickens offered diets having 61, 79 and 84 MJ ME/kg protein ratios had lower ($P<0.05$) nitrogen retentions than those offered a diet having 74 MJ ME/kg protein ratio. However, those offered diets having 71 and 74 MJ ME/kg protein ratios had similar ($P>0.05$) nitrogen retentions. Similarly, the chickens offered diets having 61 and 79 MJ ME/kg protein ratios had similar (P>0.05) nitrogen retentions. Male Venda chickens offered a diet having 79 MJ ME/kg protein ratio had a lower (P<0.05) carcass weight than those offered a diet having 71 MJ ME/kg protein ratio. However, male Venda chickens offered diets having 61, 71, 74 and 84 MJ ME/kg protein ratios had similar (P>0.05) carcass weights. Similarly, male Venda chickens offered diets having 61, 74, 79 and 84 MJ ME/kg protein ratios had similar (P>0.05) carcass weights. There were no differences (P>0.05) in breast meat yield, fat pad weights and dry matter digestibility values between chickens offered diets having 61, 71, 74, 79 and 84 MJ ME/kg protein ratios.

Results of the effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on optimal feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight of male Venda chickens between seven and 13 weeks old are presented in Figures 4.28 to 4.36 and Table 4.17. Feed intake was optimized at a dietary energy to protein ratio of 71 MJ ME/kg protein (Figure 4.28). Growth rate, feed conversion ratio, live weight and fat pad weight were optimized at a single dietary energy to protein ratio of 72 MJ ME/kg protein (Figures 4.29, 4.30. 4.31 and 4.36, respectively) while ME and nitrogen retention were optimized at a single dietary energy to protein ratio of 70 MJ ME/kg protein (Figures 4.32 and 4.33, respectively). Carcass weight and breast meat yield were optimized at dietary energy to protein ratios of 67 and 70 MJ ME/kg protein, respectively (Figures 4.34 and 4.35, respectively). However, quadratic analysis indicated no optimal digestibility response to dietary energy to protein ratio levels used in this experiment.

Table 4.15 Nutrient composition of diets used in Experiment 9 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed).

	Nutrient					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{13.4}CP_{22}$	923.4	13.4	220	10.9	10.8	5.5
$E_{13.4}CP_{19}$	923.1	13.4	190	11.0	10.2	5.2
$E_{13.4}CP_{18}$	923.2	13.4	185	11.0	10.4	5.4
$E_{13.4}CP_{17}$	9233	13.4	170	11.4	10.0	4.9
$E_{13.4}CP_{16}$	923.0	13.4	160	11.3	10.1	5.6

Table 4.16 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day) and feed conversion ratio (FCR) between seven and thirteen weeks of age, live weight at thirteen weeks old (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day) and dry matter digestibility (decimal) between 85 and 91 days of age and carcass weight (g/bird), breast meat yield (g/bird) and fat pad weight (g/bird) of male Venda chickens based on a dietary energy level of 13.4 MJ ME/kg DM.*

Variable	Treatment (E:P ratic)					SE
	61	71	74	79	84	
Intake	92^{ab}	99^{a}	92^{ab}	98^{a}	86^{b}	2.43
Growth rate	16	21	17	18	15	2.38
FCR	5.8^{a}	4.7^{b}	5.4^{ab}	5.4^{ab}	5.7^{ab}	1.02
Live weight	1083	1325	1153	1202	1070	126.42
ME	13.6^{c}	15.6^{a}	14.3^{b}	13.1^{d}	11.7^{e}	0.14
N-retention	1.9^{bc}	2.2^{ab}	2.3^{a}	1.8^{c}	1.2^{d}	0.09
Carcass weight	909^{ab}	1020^{a}	906^{ab}	800^{b}	887^{ab}	88.65
Breast meat yielc	159	179	163	146	153	18.78
Fat pad weight	4.1	0.9	0.6	2.1	4.9	2.39
DM Digestibility	0.9	0.9	0.9	0.9	0.9	0.02

abcde Means in the same row not sharing a common superscript are significantly different (P<0.05).

ME :Metabolisable energy

N-retention :Nitrogen retention

SE :Standard error

DM Digestibility :Dry matter digestibility

* :Dietary ME determined by NIRA (Valdes and Leeson, 1992)

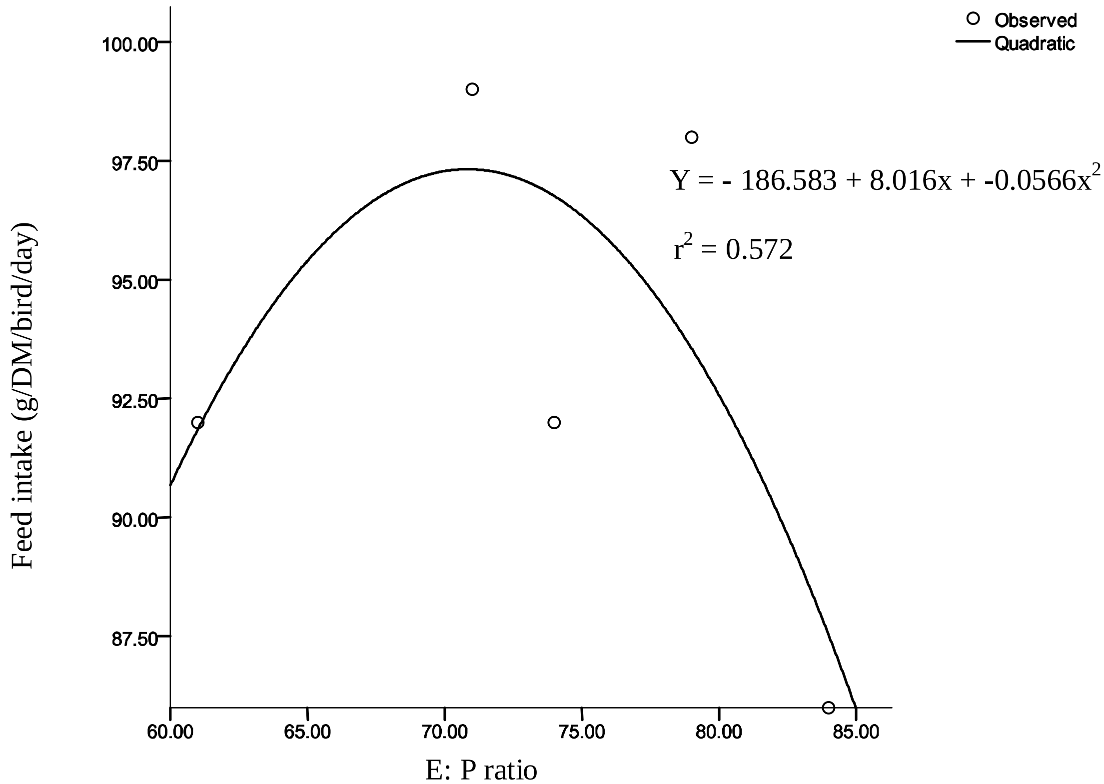

Figure 4.28 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on daily DM feed intake of male Venda chickens between seven and 13 weeks old.

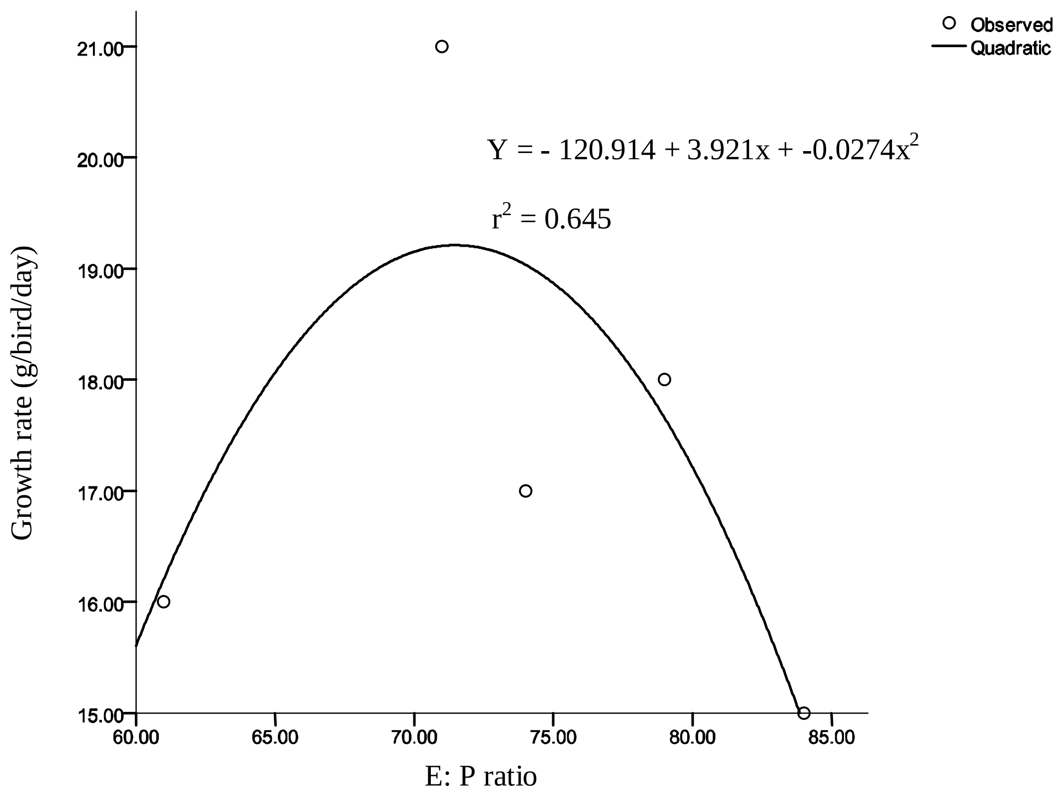

Figure 4.29 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on growth rate of male Venda chickens between seven and 13 weeks old

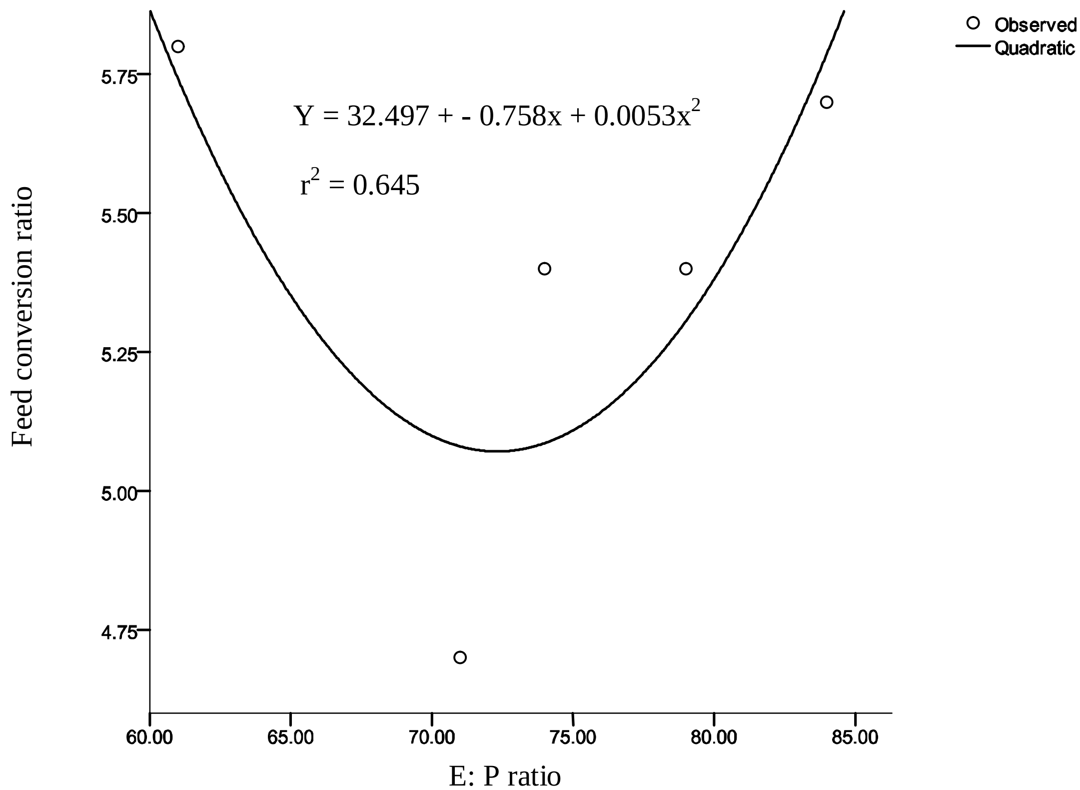

Figure 4.30 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on feed conversion ratio of male Venda chickens between seven and 13 weeks old

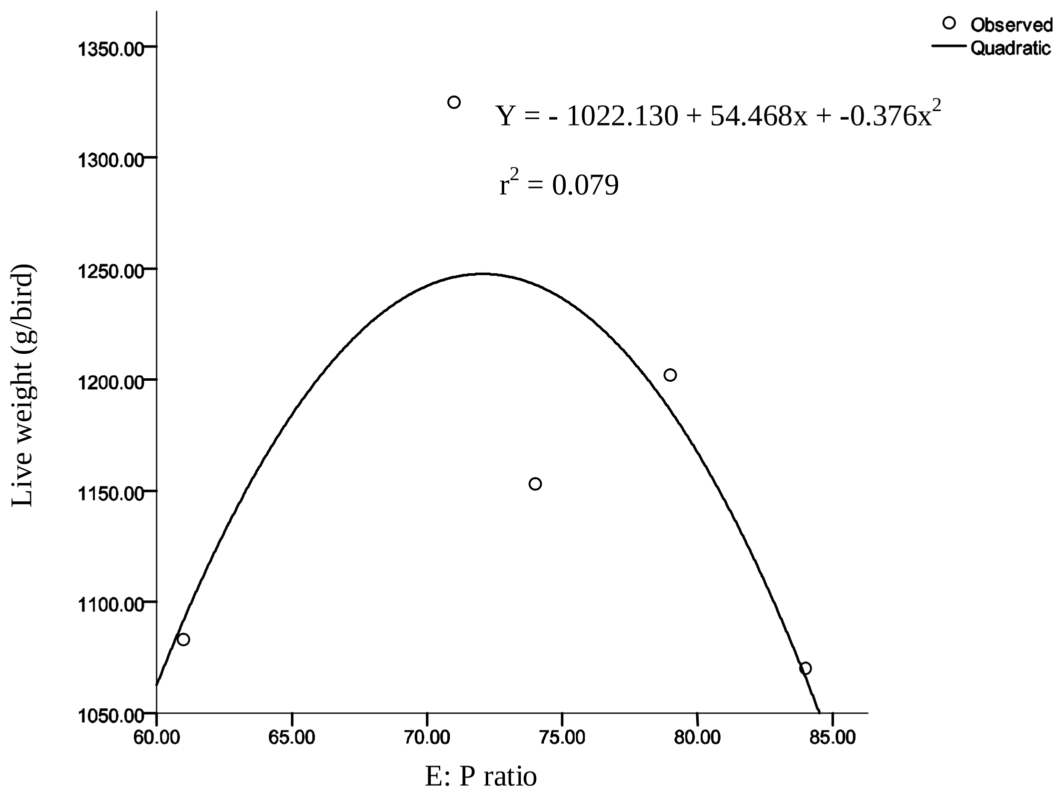

Figure 4.31 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on live weight of male Venda chickens at 13 weeks old

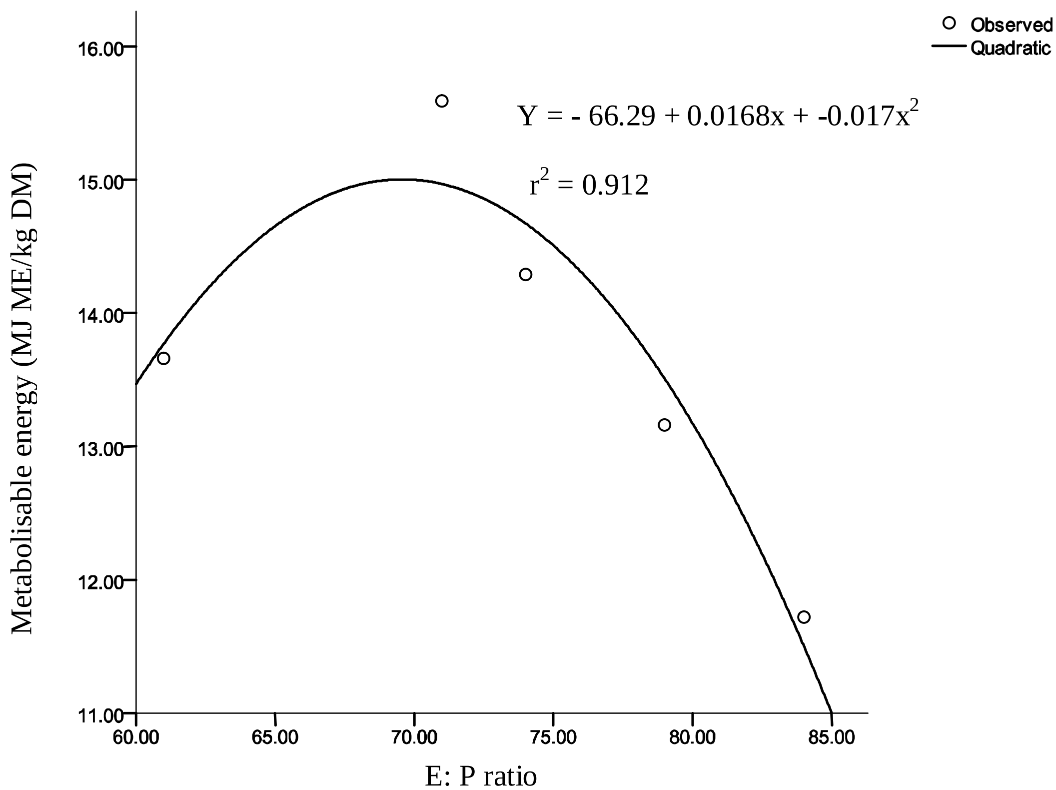

Figure 4.32 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on apparent metabolisable energy level of Venda chickens between seven and 13 weeks old

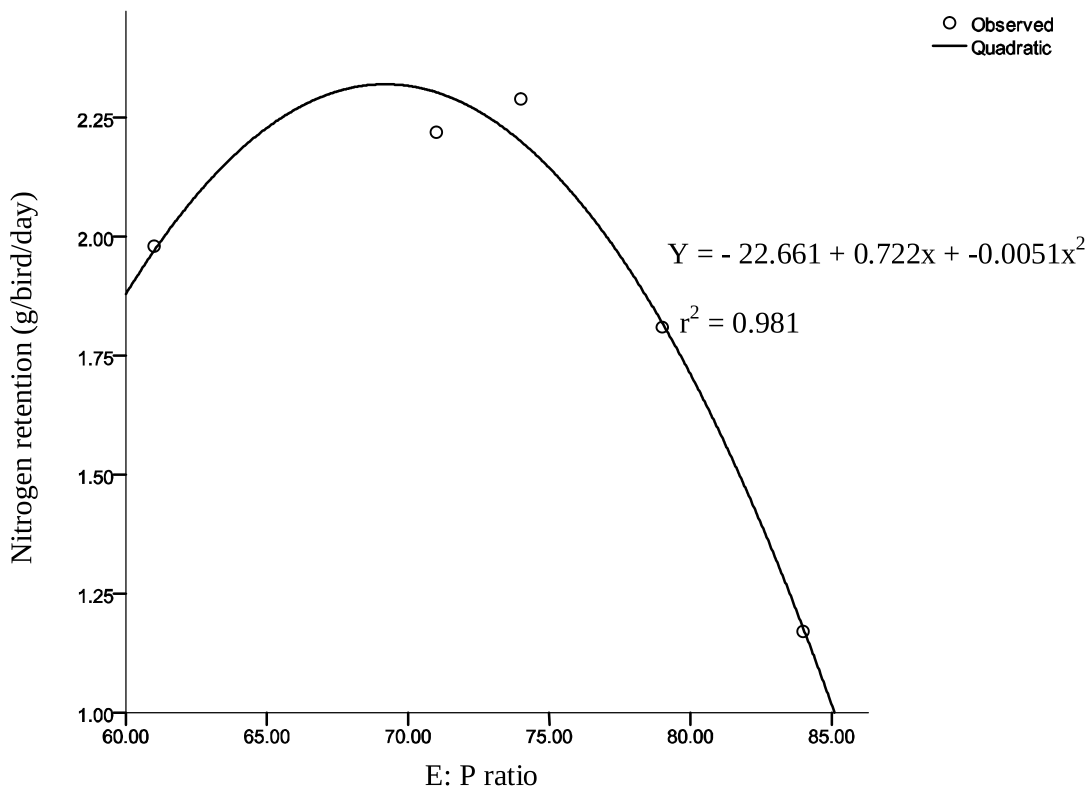

Figure 4.33 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on nitrogen retention of male Venda chickens between seven and 13 weeks old

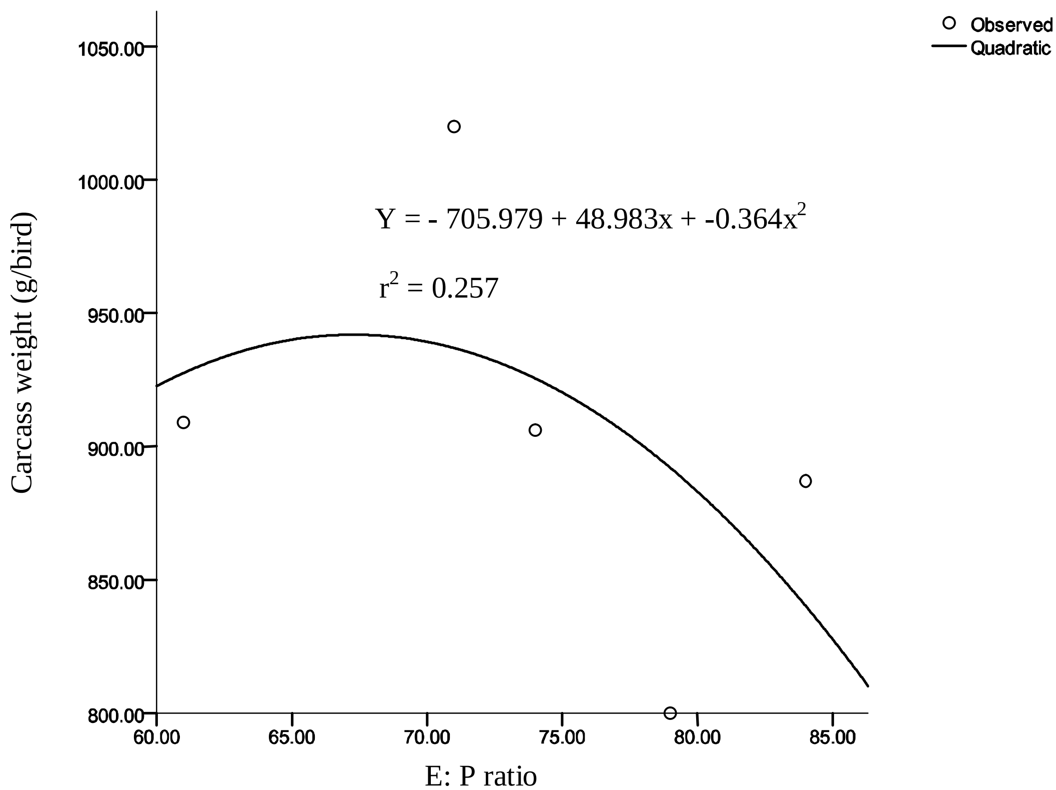

Figure 4.34 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on carcass weight of male Venda chickens between seven and 13 weeks old

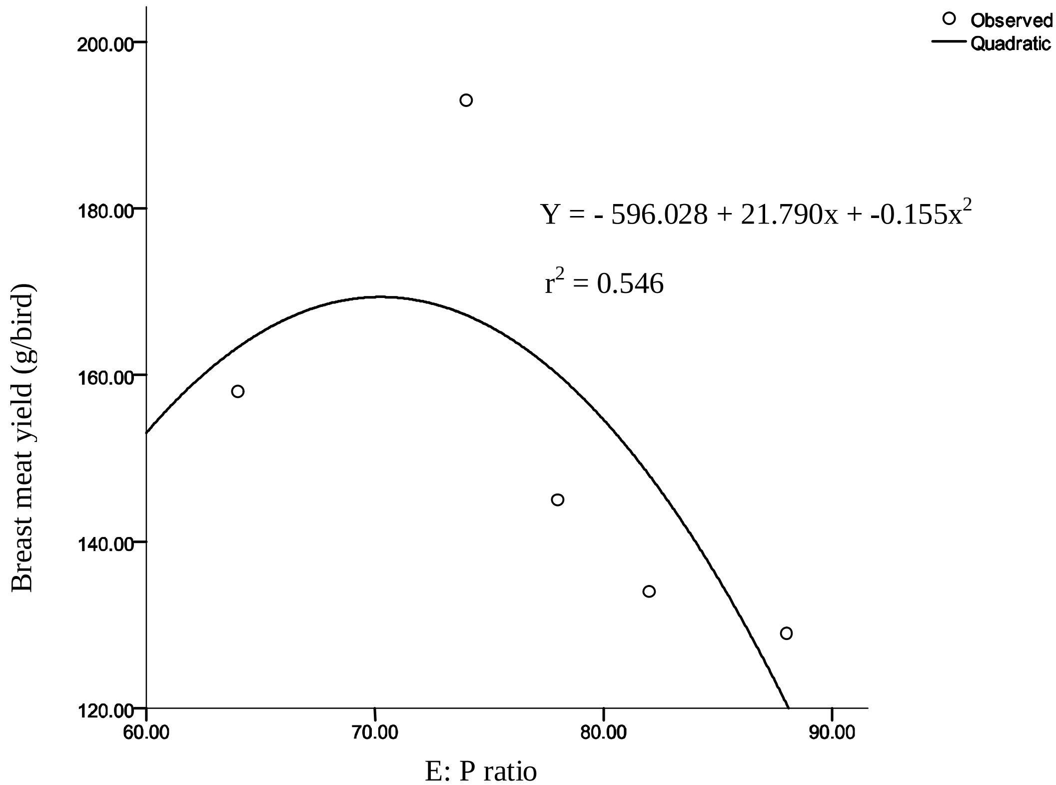

Figure 4.35 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on breast meat yield of male Venda chickens between seven and 13 weeks old

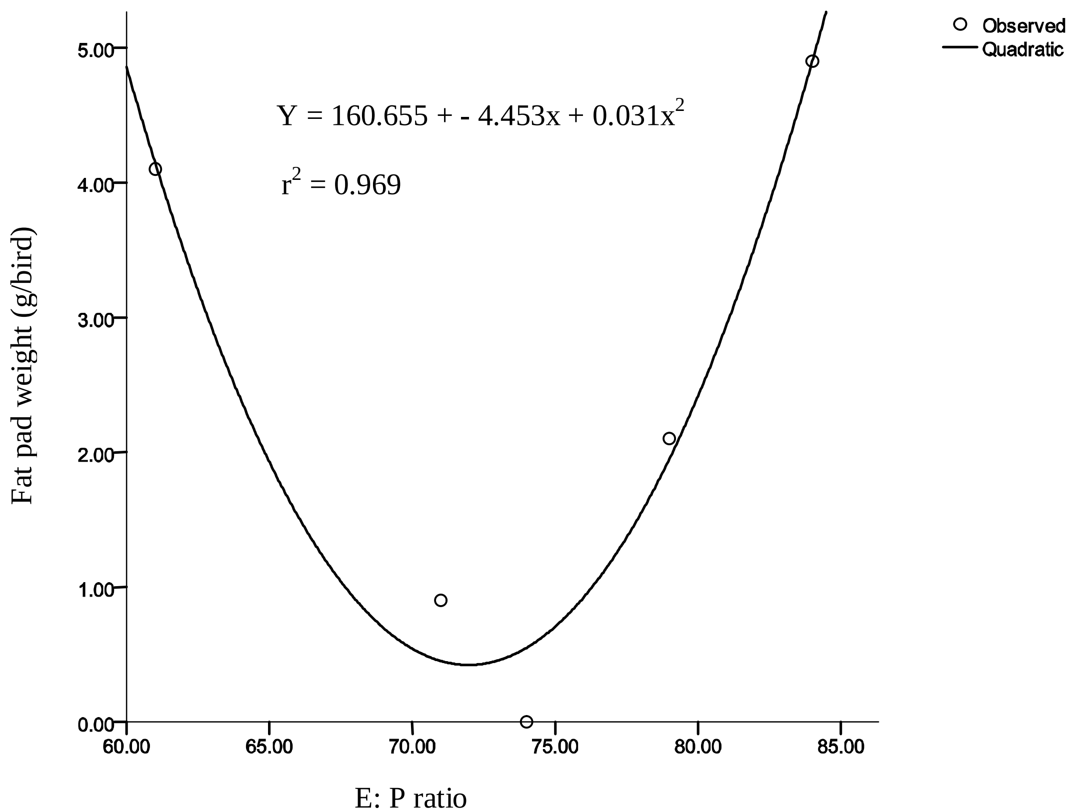

Figure 4.36 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on fat pad weight of male Venda chickens between seven and 13 weeks old

Table 4.17 Effect of dietary energy to protein ratio level, based on a dietary energy level of 13.4 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day), carcass weight (g/bird), breast meat yield (g/bird) and fat pad weight (g/bird) of male Venda chickens between seven and 13 weeks old

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y=-186.583+ 8.016x + -0.0566x^2$	71	97	0.572	0.428
Growth	$Y=-120.914 +3.921x + -0.0274x^2$	72	19	0.645	0.355
FCR	$Y= 32.497 + -0.758x + 0.0053x^2$	72	5.1	0.645	0.355
Lwt	$Y=-5363.88+183.511x+ -1.273x^2$	72	1235	0.659	0.341
ME	$Y= -66.269 + 2.337x + -0.0168x^2$	70	15	0.912	0.088
N-retention	$Y= -22.661 + 0.722x + -0.0051x^2$	70	2.3	0.981	0.019
Carcass wt	$Y=-705.979+ 48.983x + -0.364x^2$	67	942	0.257	0.743
Breast	$Y=-596.028+ 21.790x + -0.155x^2$	70	170	0.546	0.555
Fat pad	$Y= 160.655 + - 4.453x + 0.031x^2$	72	0.7	0.969	0.031

FCR :Feed conversion ratio
Lwt :Live weight
ME :Metabolisable energy
P :Probability level
E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)
Y-Value :Optimal Y-Value
N-retention :Nitrogen retention
Carcass wt :carcass weight
Breast :Breast meat yield

4.3.5 Experiment 10

Results of the nutrient composition of the diets in Experiment 10 are shown in Table 4.18. The diets had a similar energy value of 14 MJ ME/kg DM but with varying crude protein levels, ranging between 160 and 220 g CP/kg DM.

Results of the effect of energy to protein ratio level on feed intake, dry matter digestibility, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight of male Venda chickens from seven to 13 weeks of age, based on a dietary energy level of 14 MJ ME/kg DM, are presented in Table 4.19. There were no differences (P>0.05) in feed intakes between chickens offered diets having 64, 74, 78, 82 and 88 MJ ME/kg protein ratios.

Male Venda chickens offered diets having 82 and 88 MJ ME/kg protein ratios had lower (P<0.05) growth rates than those offered a diet having 74 MJ ME/kg protein ratio. However, male Venda chickens offered diets having 82 and 88 MJ ME/kg protein ratios had similar (P>0.05) growth rates. Similarly, male Venda chickens offered diets having 64, 74 and 78 MJ ME/kg protein ratios had similar (P>0.05) growth rates. Also, chickens offered diets having 64, 78, 82 and 88 MJ ME/kg protein ratios had similar (P>0.05) growth rates. Male Venda chickens offered a diet having 74 MJ ME/kg protein ratios had a higher (P<0.05) live weight than those offered diets having 82 and 88 MJ ME/kg protein ratios. However, those offered diets having 82 and 88 MJ ME/kg protein ratios had similar (P>0.05) live weights. Similarly, male Venda chickens offered diets having 64, 74 and 78 MJ ME/kg protein ratios had the same (P>0.05) live weights.

Male Venda chickens on a diet having 74 MJ ME/kg protein ratio had a better (P<0.05) feed conversion ratio than those on a diet having 88 MJ ME/kg protein ratios. However, male Venda chickens offered diets having 64, 78, 82 and 88 MJ ME/kg protein ratios had similar (P>0.05) feed conversion ratios. Similarly, male Venda chickens offered diets having 64, 74, 78 and 82 MJ ME/kg protein ratios had similar (P>0.05) feed conversion ratios. Male Venda chickens offered a diet having 74 MJ ME/kg protein ratio had a higher

(P<0.05) apparent metabolisable energy than those offered diets having 64 and 78 MJ ME/kg protein ratios. However, those offered diets having 64, 78, 82 and 88 MJ ME/kg protein ratios had similar (P>0.05) apparent ME values. Similarly, male Venda chickens offered diets having 74, 82 and 88 MJ ME/kg protein ratios had the same (P>0.05) apparent ME value. Male Venda chickens offered a diet having 74 MJ ME/kg protein ratio had a higher (P<0.05) nitrogen retention than those offered diets having 64, 78, 82 and 88 MJ ME/kg protein ratios. However, those offered a diet having 64 MJ ME/kg protein ratio had a higher (P<0.05) nitrogen retention value than those offered diets having 78, 82 and 88 MJ ME/kg protein ratios. Similarly, male Venda chickens offered a diet having 78 MJ ME/kg protein ratio had a higher (P<0.05) nitrogen retention value than those offered diets having 82 and 88 MJ ME/kg protein ratios. However, those offered diets having 82 and 88 MJ ME/kg protein ratios had the same (P>0.05) nitrogen retentions.

Male Venda chickens offered a diet having 74 MJ ME/kg protein ratio had a higher (P<0.05) carcass weight than those offered diets having 82 and 88 MJ ME/kg protein ratios. However, those offered diets having 82 and 88 MJ ME/kg protein ratios had similar (P>0.05) carcass weights. Similarly, male Venda chickens offered diets having 64, 74 and 78 MJ ME/kg protein ratios had the same (P>0.05) carcass weights. Venda chickens offered a diet having 74 MJ ME/kg protein ratio had higher (P<0.05) breast meat yield than those offered diets having 64, 78, 82 and 88 MJ ME/kg protein ratios. However, Venda chickens offered diets having 64, 78, 82 and 88 MJ ME/kg protein ratios had similar (P>0.05) breast meat yields. There were no differences (P>0.05) in fat pad weights and dry matter digestibility values between Venda chickens offered diets having 64, 74, 78, 82 and 88 MJ ME/kg protein ratios.

Results of the effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight of male Venda chickens between seven and 13 weeks old are presented in Figures 4.37 to 4.45, respectively and Table 4.20. Feed intake was optimized at a dietary energy to protein ratio of 79 MJ ME/kg protein (Figure 4.37). Growth rate, feed conversion ratio and live weight were optimized at dietary energy to protein ratio of 71 MJ ME/kg protein (Figures 4.38, 4.39 and 4.40, respectively) while apparent ME was optimized at dietary energy to protein ratio of 78 MJ ME/kg protein (Figure 4.41). Nitrogen retention, carcass weight, breast meat yield and fat pad weight were optimized at a dietary energy to protein ratios of 67, 66, 69 and 78 MJ ME/kg protein (Figures 4.42, 4.43, 4.44 and 4.45 respectively). However, quadratic analysis indicated no optimal digestibility response to dietary energy to protein ratio levels used in this experiment.

Table 4.18 Nutrient composition of diets used in Experiment 10 (units are in g/kg DM except energy as MJ ME/kg DM feed and dry matter as g/kg feed).

	Nutrient					
Treatments	Dry matter	Energy	Protein	Lysine	Calcium	Phosphorus
$E_{14}CP_{22}$	926.5	14	220	10.9	10.6	5.6
$E_{14}CP_{19}$	926.4	14	190	11.0	10.3	5.4
$E_{14}CP_{18}$	926.2	14	185	11.0	10.2	5.3
$E_{14}CP_{17}$	926.3	14	170	11.4	10.4	5.4
$E_{14}CP_{16}$	926.2	14	160	11.3	10.5	5.1

Table 4.19 Effect of energy to protein ratio level (MJ ME/kg protein) on feed intake (g/bird/day), growth rate (g/bird/day) and feed conversion ratio (FCR) between seven and thirteen weeks of age, live weight at thirteen weeks old (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day) and dry matter digestibility (decimal) between 85 and 91 days of age, and carcass weight (g/bird), breast meat yield (g/bird) fat pad weight (g/bird) and dry matter digestibility of male Venda chickens based on a dietary energy level of 14 MJ ME/kg DM*

Variable	Treatment (E:P ratio)					SE
	64	74	78	82	88	
Intake	86	101	89	88	95	5.29
Growth rate	15^{ab}	20^{a}	16^{ab}	12^{b}	11^{b}	1.94
FCR	5.7^{ab}	5.0^{b}	5.5^{ab}	7.3^{ab}	8.6^{a}	1.22
Live weight	1048^{ab}	1305^{a}	1085^{ab}	895^{b}	865^{b}	95.13
ME	12.7^{b}	16.1^{a}	13.5^{b}	14.7^{ab}	14.3^{ab}	0.64
N-retention	2.3^{b}	2.6^{a}	1.9^{c}	1.6^{d}	1.6^{d}	0.08
Carcass weight	906^{ab}	993^{a}	835^{ab}	761^{b}	745^{b}	57.99
Breast meat yielc	158^{b}	193^{a}	145^{b}	134^{b}	129^{b}	9.21
Fat pad weight	6.2	0.4	0.2	4.4	2.8	2.28
DM Digestibility	0.9	0.9	0.9	0.9	0.9	0.02

^{abcde} :Means in the same row not sharing a common superscript are significantly different (P<0.05).

ME :Metabolisable energy

N-retention :Nitrogen retention

SE :Standard error

DM Digestibility :Dry matter digestibility

DM***** :Dietary ME determined by NIRA (Valdes and Leeson, 1992)

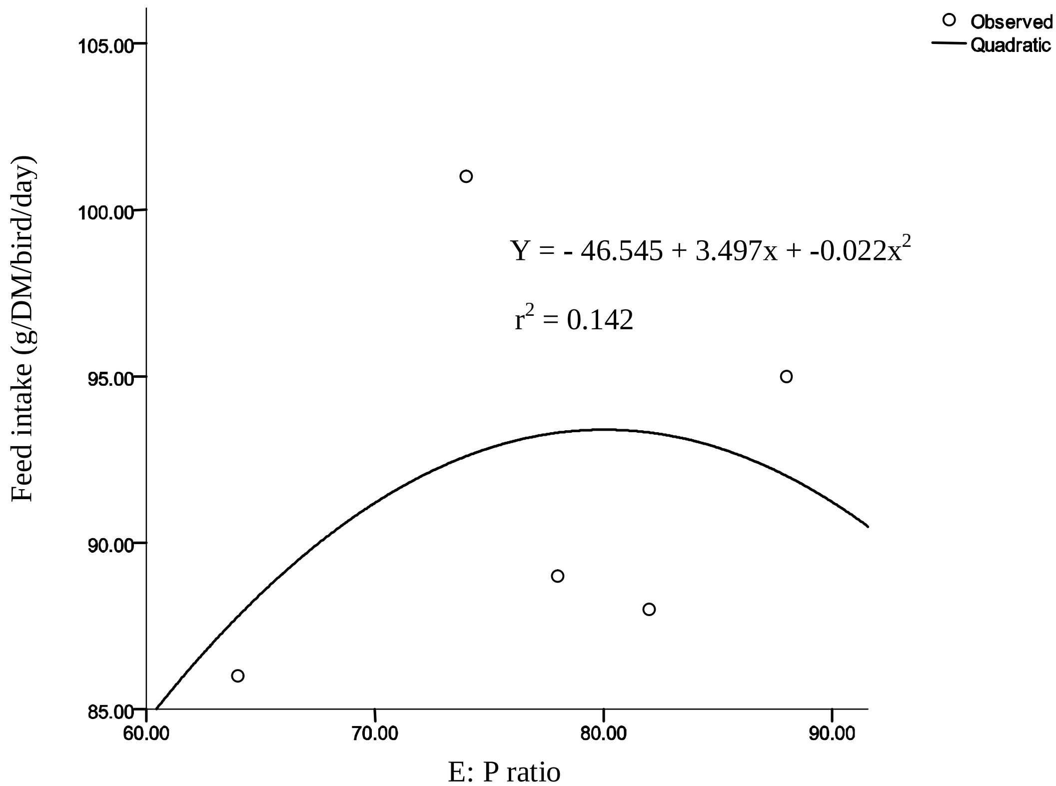

Figure 4.37 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on daily DM feed intake of male Venda chickens between seven and 13 weeks old

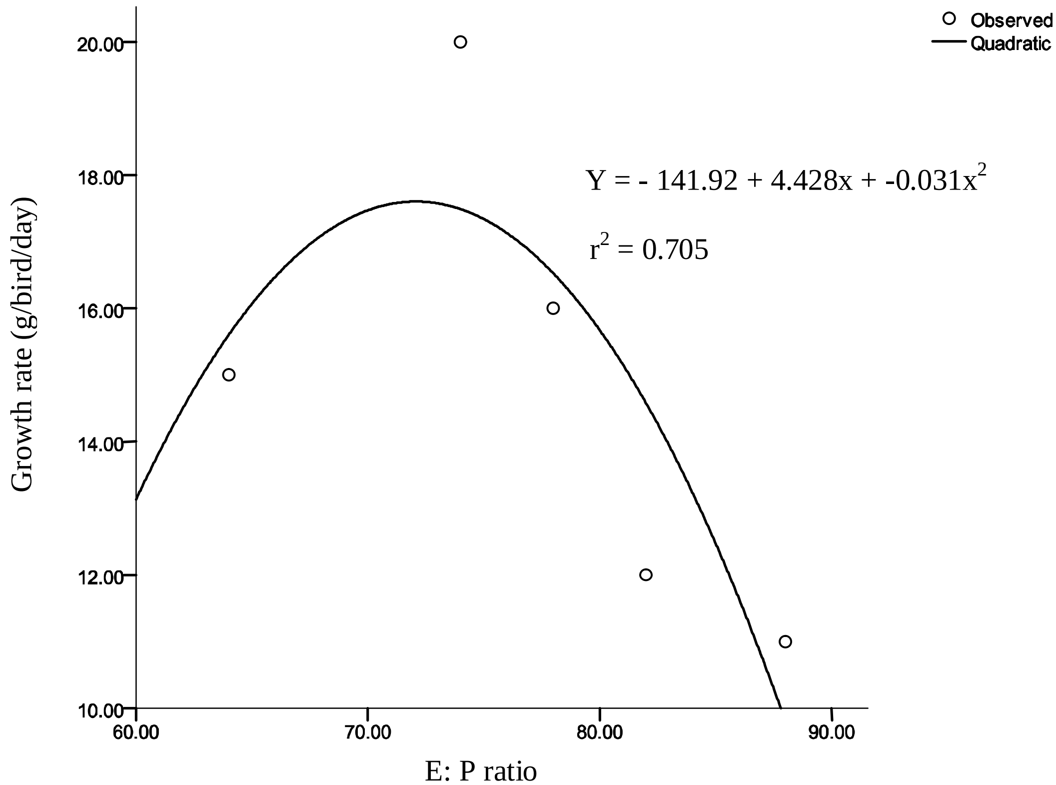

Figure 4.38 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on growth rate of male Venda chickens between seven and 13 weeks old

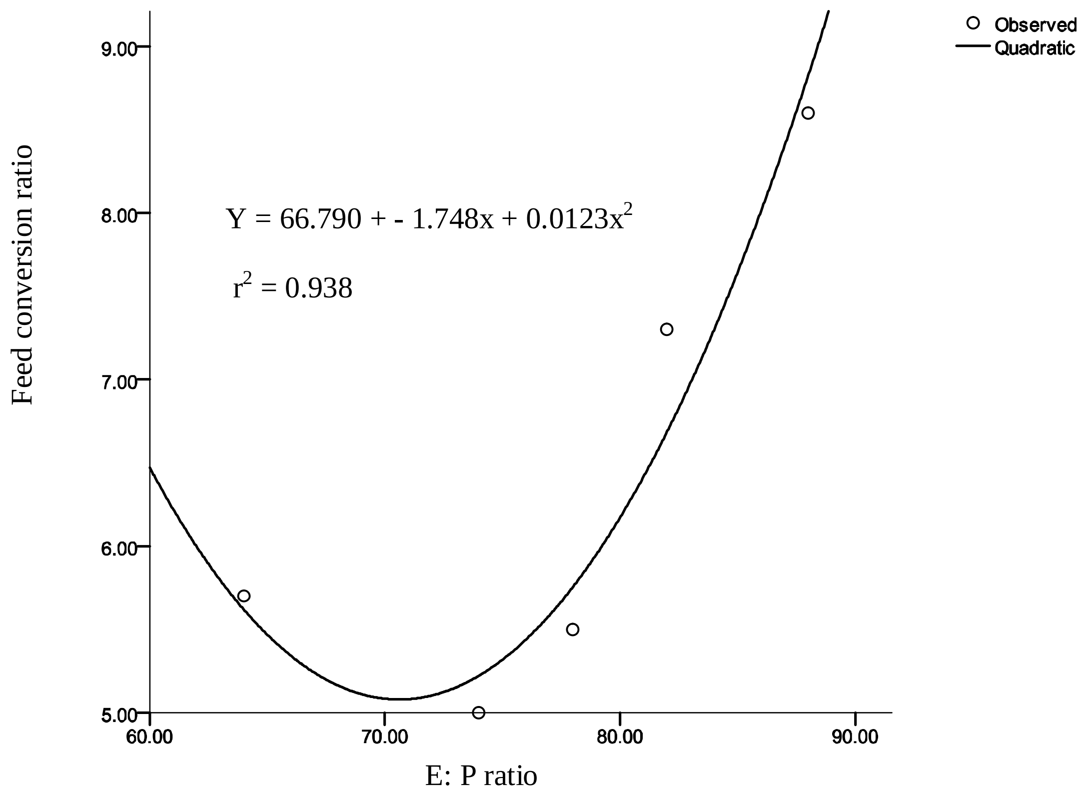

Figure 4.39 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on feed conversion ratio of male Venda chickens

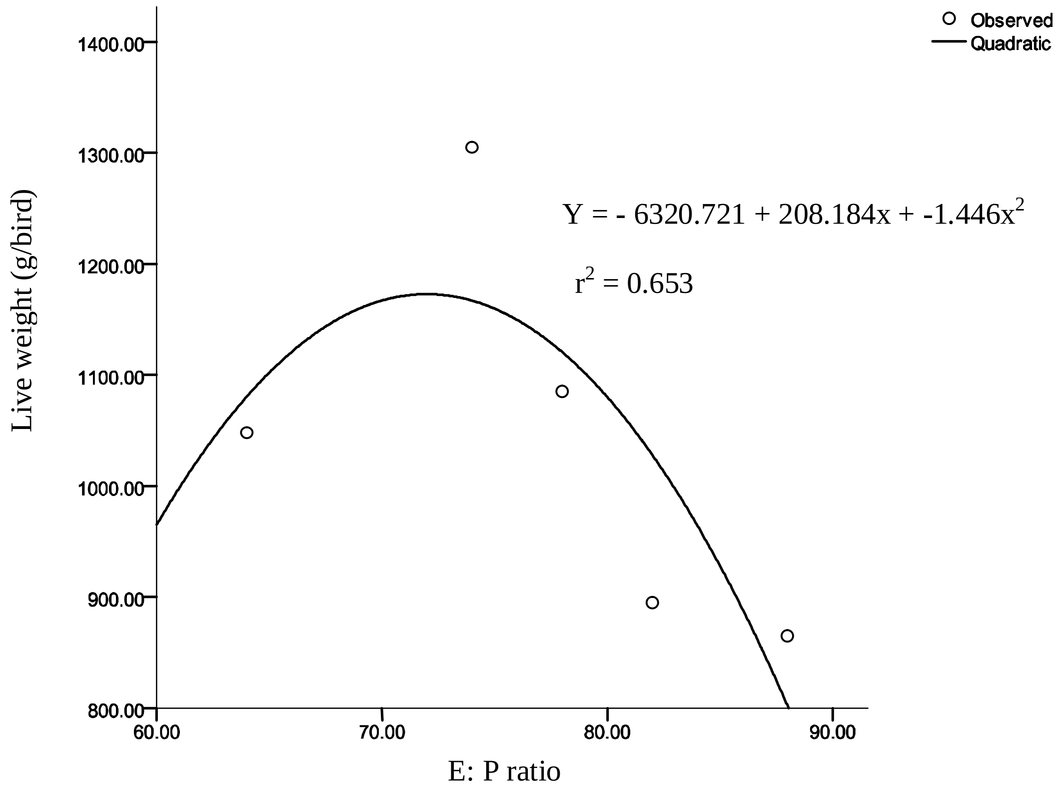

Figure 4.40 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on live weight of Venda chickens at 13 weeks old

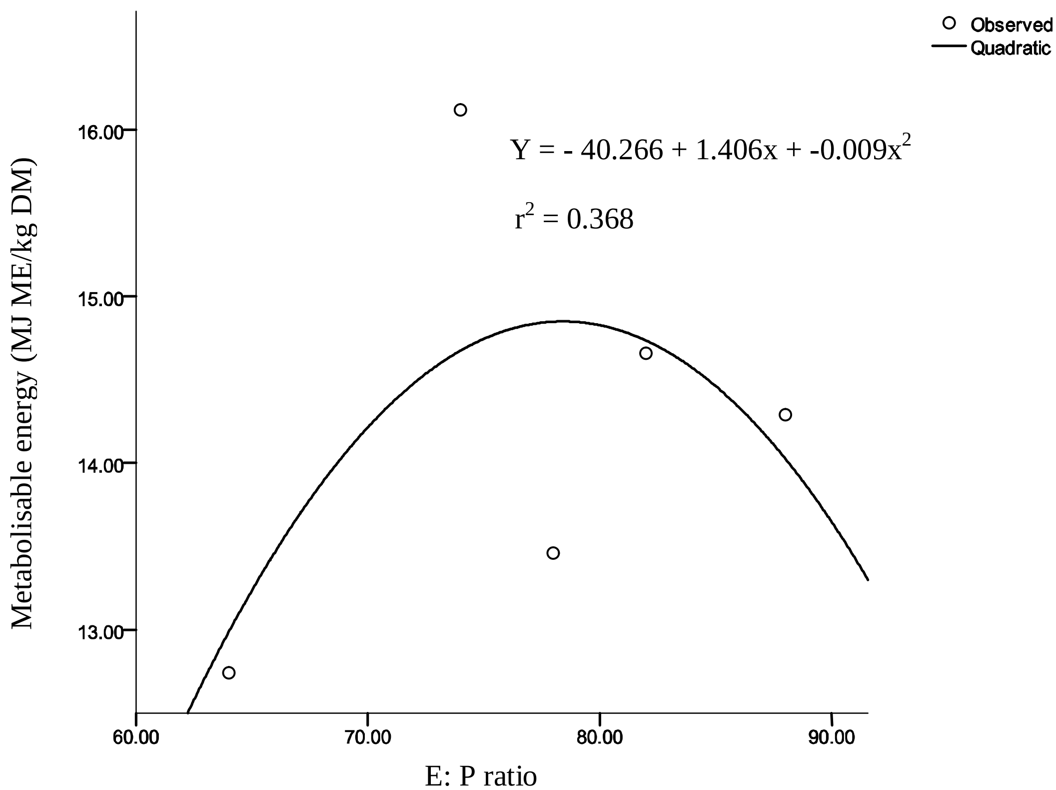

Figure 4.41 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on apparent metabolisable energy level of male Venda chickens between seven and 13 weeks old

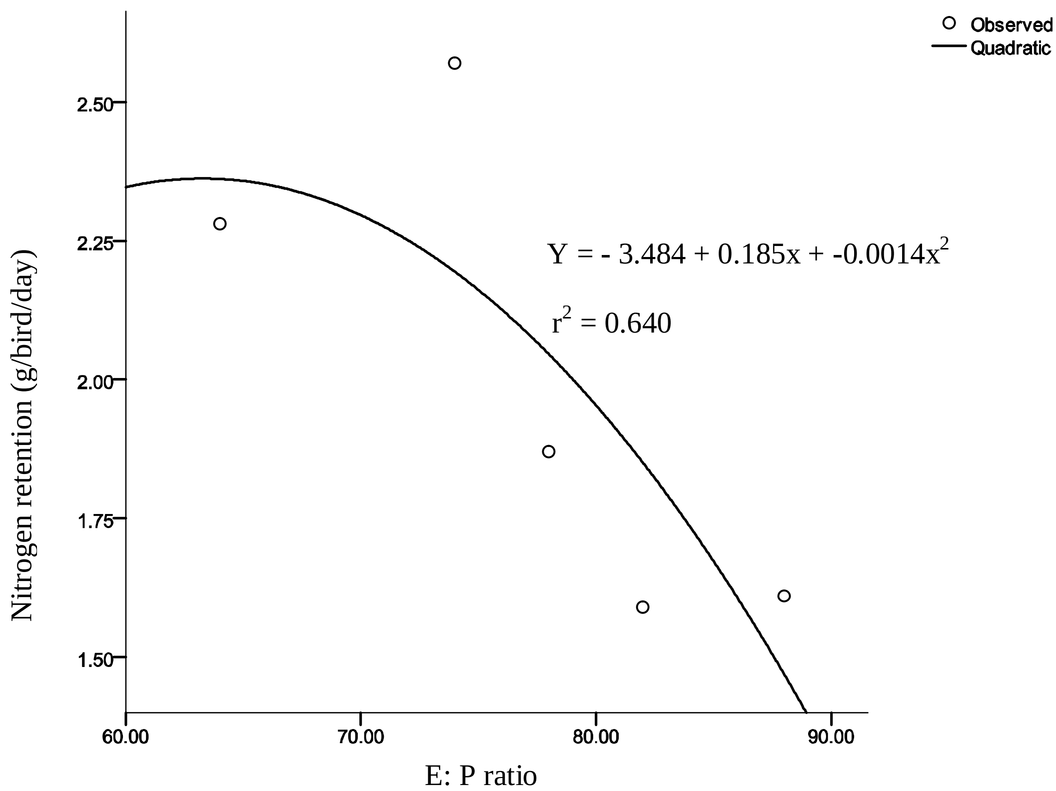

Figure 4.42 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on nitrogen retention of male Venda chickens between seven and 13 weeks old

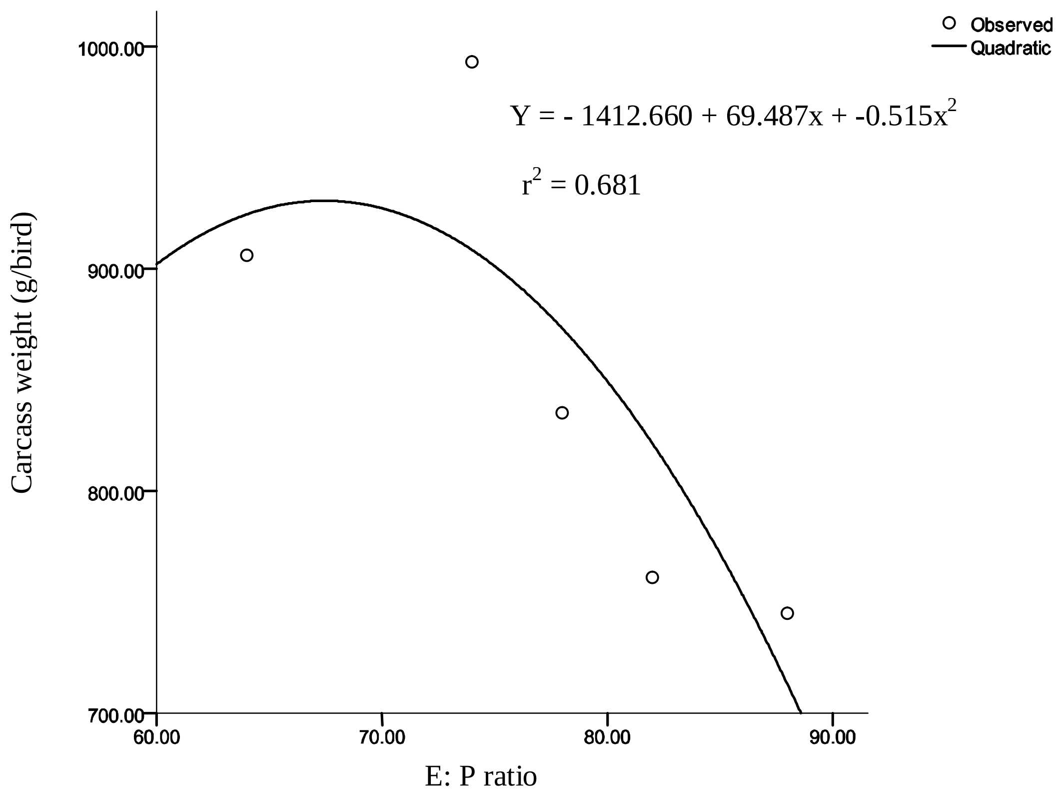

Figure 4.43 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on carcass weight of male Venda chickens between seven and 13 weeks old

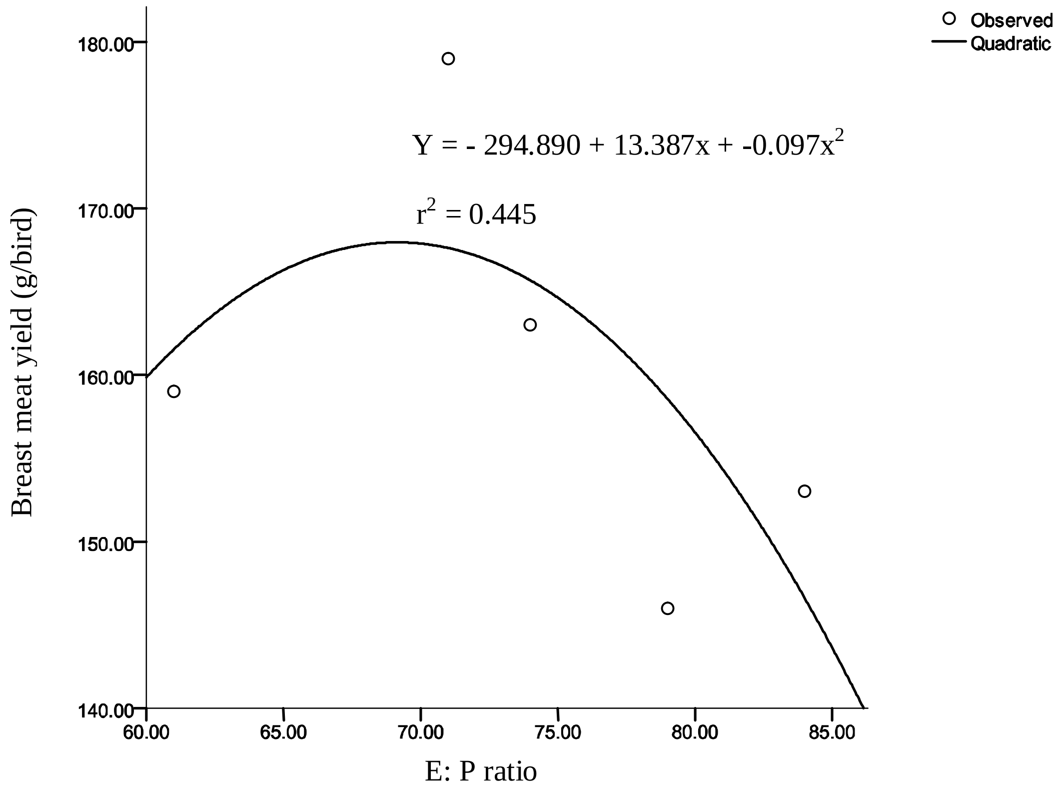

Figure 4.44 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on breast meat yield of male Venda chickens between seven and 13 weeks old

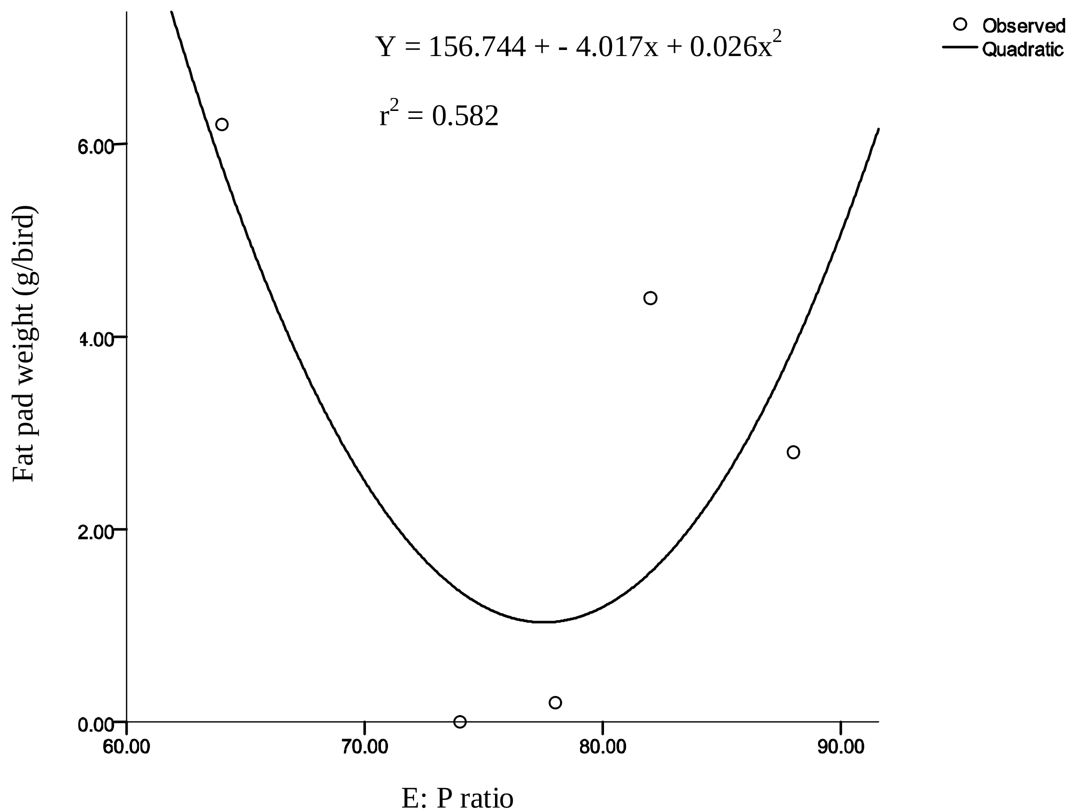

Figure 4.45 Effect of dietary energy to protein ratio level, based on a dietary energy level of 14 MJ ME/kg DM, on fat pad weight of male Venda chickens between seven and 13 weeks old

Table 4.20 Effect of dietary energy to protein ratio level based on a dietary energy level of 14 MJ ME/kg DM, on optimal feed intake (g/bird/day), growth rate (g/bird/day), feed conversion ratio, live weight (g/bird), apparent metabolisable energy (MJ ME/kg DM), nitrogen retention (g/bird/day), carcass weight (g/bird), breast meat yield (g/bird) and fat pad weight (g/bird) in male Venda chickens between seven and 13 weeks old.

Trait	Formula	E:P ratio	Y-Value	r^2	P
Intake	$Y = - 46.545 + 3.497x + -.022x^2$	79	92	0.142	0.858
Growth	$Y = -141.972 +4.428x + -.031x^2$	71	17	0.705	0.295
FCR	$Y=66.790 + -1.748x + .0123x^2$	71	5.4	0.938	0.062
Lwt	$Y=-6320.721+208.184x+-.446x^2$	71	1172	0.653	0.347
ME	$Y = -40.266 + 1.406x + -0.009x^2$	78	14.6	0.368	0.632
N-retention	$Y = -3.484 + 0.185x + -0.0014x^2$	67	2.3	0.640	0.360
Carcass wt	$Y=-1412.660+69.487x+ -0.515x^2$	66	931	0.681	0.319
Breast yld	$Y =-294.890 + 13.387x + -0.097x^2$	69	167	0.445	0.454
Fat pad	$Y = 156.744 + - 4.017x + 0.026x^2$	78	1.5	0.582	0.418

FCR :Feed conversion ratio
Lwt :Live weight
ME :Metabolisable energy
P :Probability level
E: P ratio :E: P ratio for optimal level (MJ ME/kg protein)
Y-Value Optimal :Y-Value
N-retention :Nitrogen retention
Carcass wt :Carcass weight
Breast yld :Breast meat yield

4.3.6 Optimal responses

Optimal responses in feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight were achieved at different energy to protein ratio levels for the different dietary energy levels (Table 4.21). Optimal feed intake (r^2= 0.051), growth rate (r^2= 0.024), feed conversion ratio (r^2= 0.133), apparent metabolisable energy (r^2= 0.023) and nitrogen retention (r^2= 0.156) tended to increase with increase in dietary energy content and energy to protein ratio level (Table 4.21 and Figures 4.46, 4.47, 4.48, 4.50 and 4.51, respectively). Optimal carcass (r^2= 0.299) and breast meat (r^2= 0.085) yields tended to decrease with increase in dietary energy to protein ratio level (Figures 4.52 and 4.53, respectively). However, optimal live weight (r^2= 0.000) and fat pad (r^2= 0.001) deposition did not follow any clear trend with increase in dietary energy to protein ratio level (Figures 4.49 and 4.54, respectively).

Table 4.21 Effect of energy to protein ratio level (MJ ME/kg protein), based on different dietary energy levels on optimal feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy (ME), nitrogen retention, carcass yield, breast meat yield and fat pad weight in male Venda chickens between seven and 13 weeks of age

Variable	Dietary energy level (MJ ME/kg DM)				
	12.2	13	13.2	13.4	14
Optimum intake (g/bird/day)	89	81	82	97	92
E:P ratio level	62	66	74	71	79
Diet CP level (g/kg)	197	197	178	189	177
Optimum growth (g/bird/day)	16	12	13	19	17
E:P ratio level	60	71	66	72	71
Diet CP level (g/kg)	203	183	200	186	195
Optimum FCR	5.5	6.7	5.7	5.1	5.4
E:P ratio level	60	75	65	72	71
Diet CP level (g/kg)	203	174	206	186	197
Optimum Lwt at 13 weeks old (g/bird)	1167	950	983	1235	1172
E:P ratio level	60	71	66	72	71
Diet CP level (g/kg)	203	183	200	186	195
Optimum ME (MJ ME/kg)	14.4	14.2	14.4	15.0	14.6
E:P ratio level	65	70	73	70	78
Diet CP level (g/kg)	187	186	181	191	179
Optimum nitrogen retention	2.3	2.5	2.7	2.3	2.3
E:P ratio level	63	64	71	70	67
Diet CP level (g/kg)	194	203	186	191	209
Optimum carcass yield (g/bird)	916	811	844	942	931
E:P ratio level	60	71	66	67	66
Diet CP level (g/kg)	203	183	200	200	210
Optimum breast meat (g/bird)	160	146	151	170	167
E:P ratio level	60	81	62	70	69
Diet CP level (g/kg)	203	161	213	191	202
Fat pad weight (g/bird)	2.4	0.06	1.2	0.7	1.5
E:P ratio level	70	71	66	72	78
Diet CP level (g/kg)	174	183	200	186	179

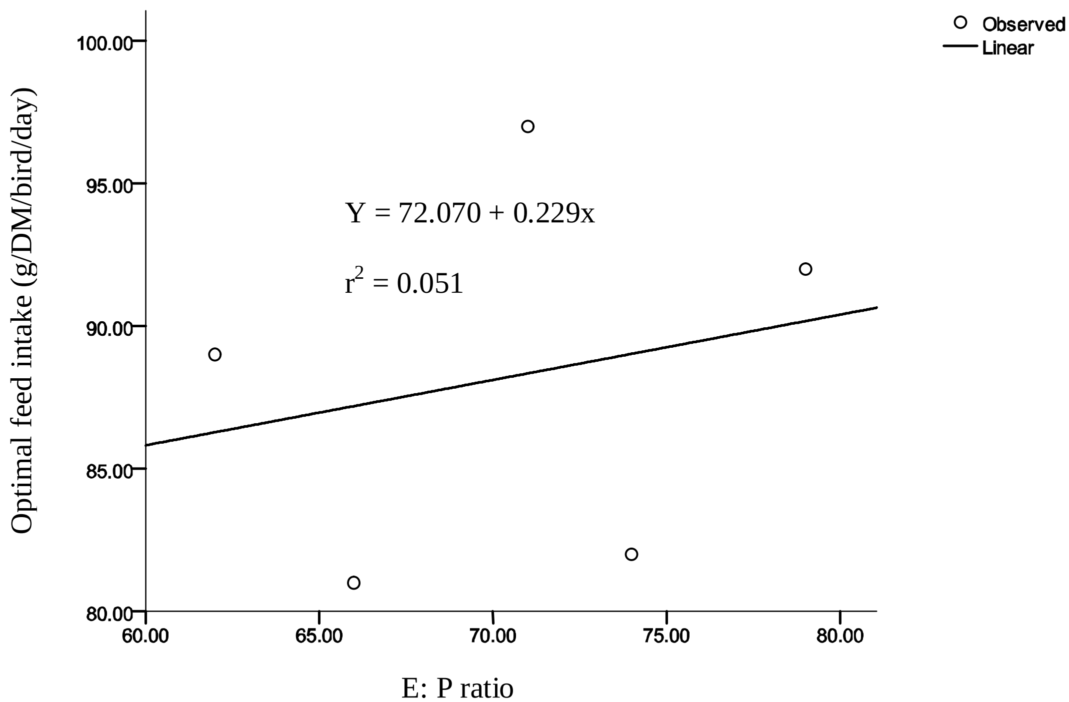

Figure 4.46 Relationship between optimal dietary energy to protein ratio and optimal feed intake of male Venda chickens based on different dietary energy levels between seven and thirteen weeks of age

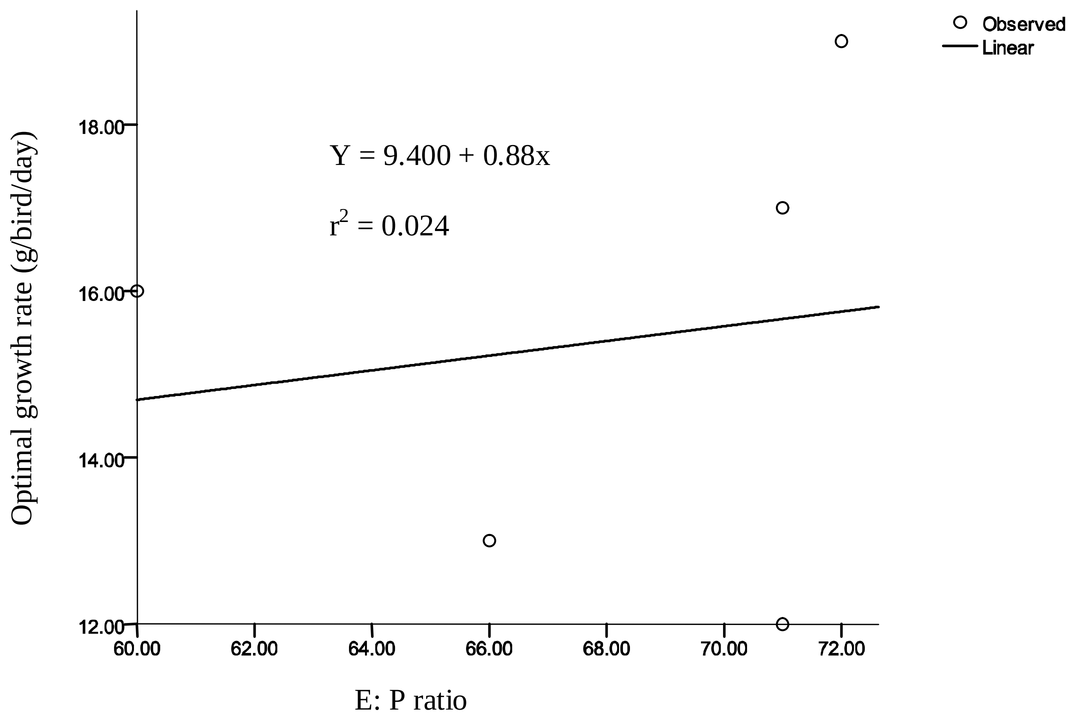

Figure 4.47 Relationship between optimal dietary energy to protein ratio and optimal growth rate of male Venda chickens based on different dietary energy levels between seven and thirteen weeks of age

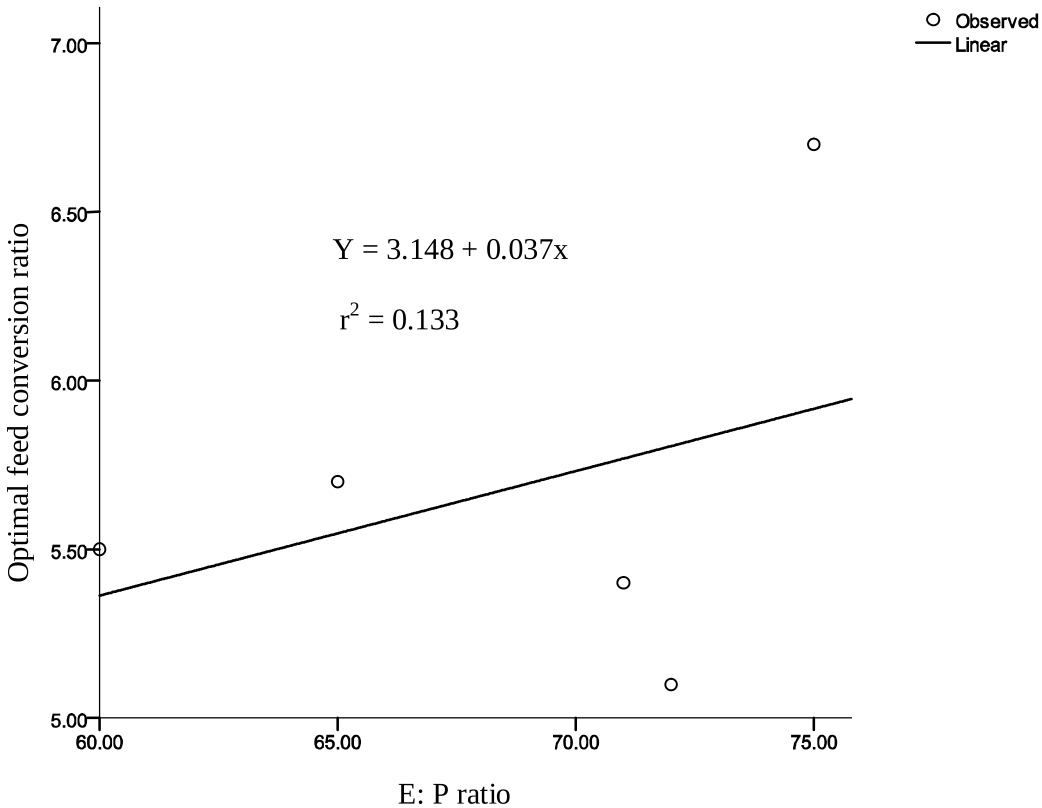

Figure 4.48 Relationship between optimal dietary energy to protein ratio and optimal feed conversion ratio of male Venda chickens based on different dietary energy levels between seven and thirteen weeks of age

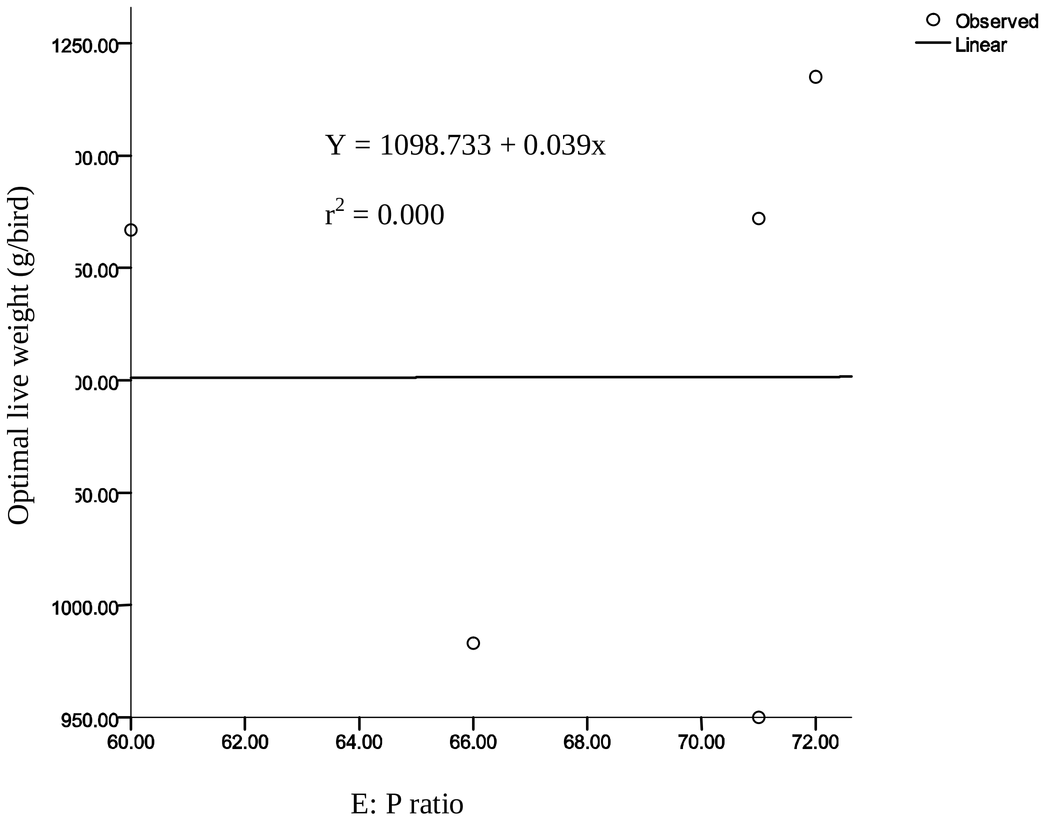

Figure 4.49 Relationship between optimal dietary energy to protein ratio and optimal live weight of male Venda chickens based on different dietary energy levels between seven and thirteen weeks of age

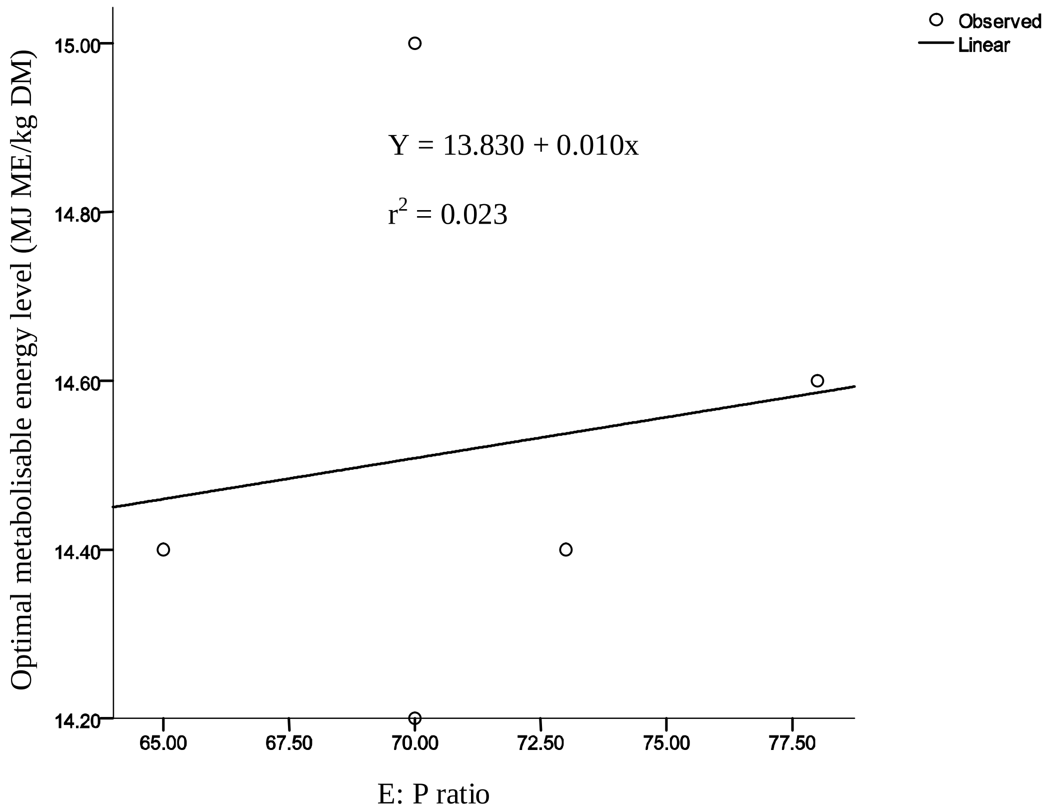

Figure 4.50 Relationship between optimal dietary energy to protein ratio and optimal apparent metabolisable energy level of male Venda chickens based on different dietary energy levels between seven and thirteen weeks of age

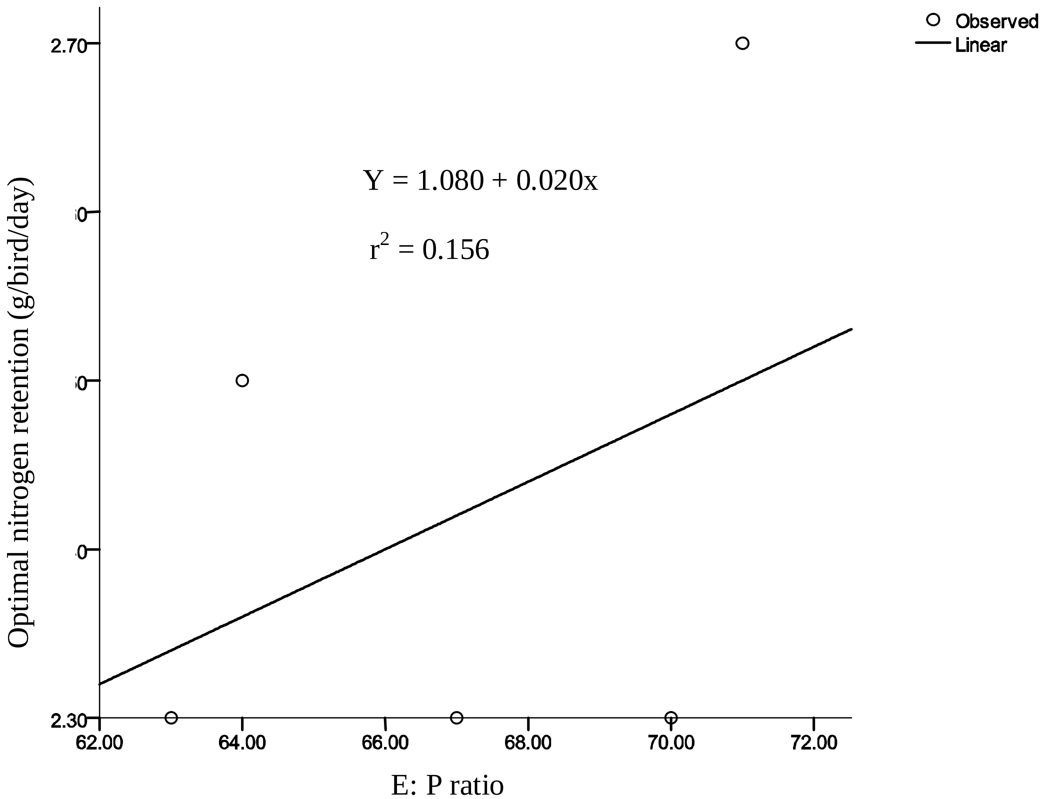

Figure 4.51 Relationship between optimal dietary energy to protein ratio and optimal nitrogen retention of male Venda chickens based on different dietary energy levels between seven and thirteen weeks of age

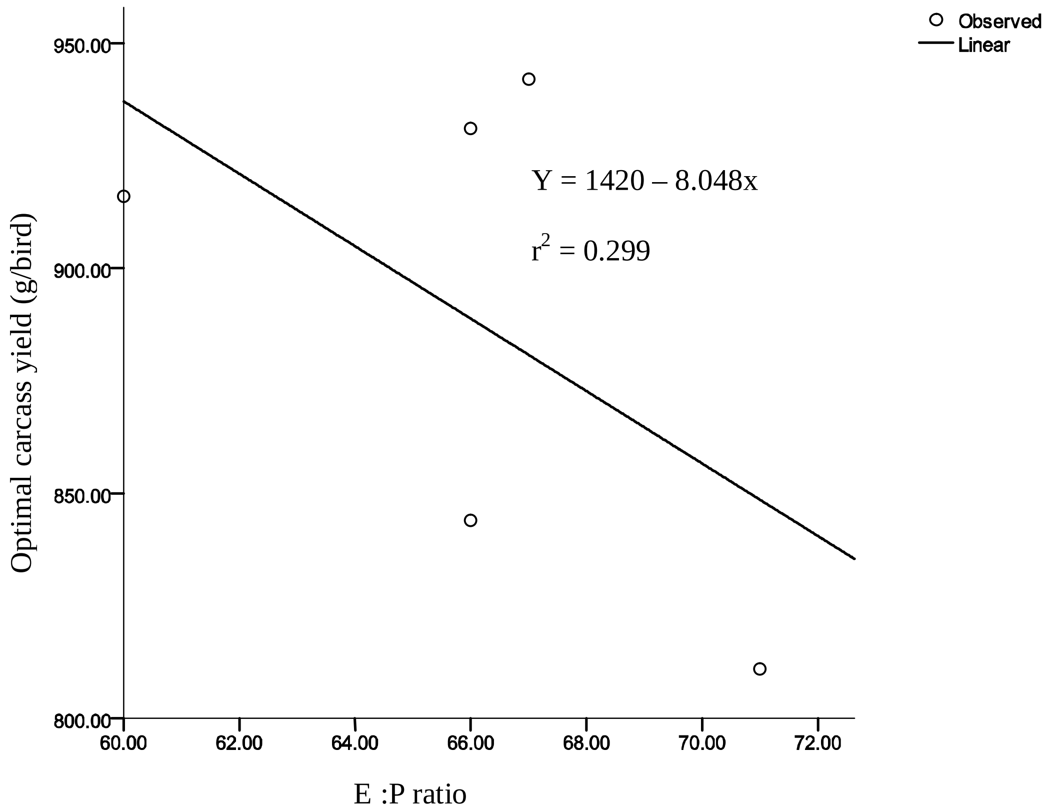

Figure 4.52 Relationship between optimal dietary energy to protein ratio and optimal carcass yield of male Venda chickens based on different dietary energy levels between seven and thirteen weeks of age

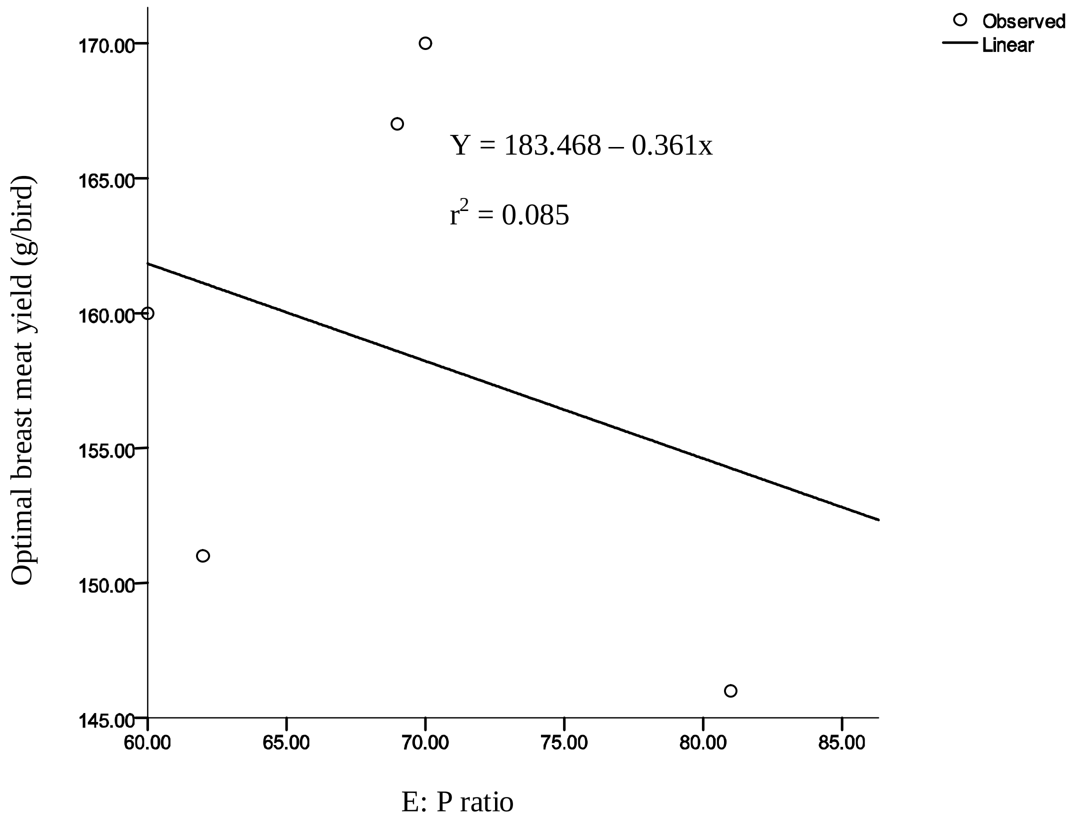

Figure 4.53 Relationship between optimal dietary energy to protein ratio and optimal breast meat yield of male Venda chickens based on different dietary energy levels between seven and thirteen weeks of age

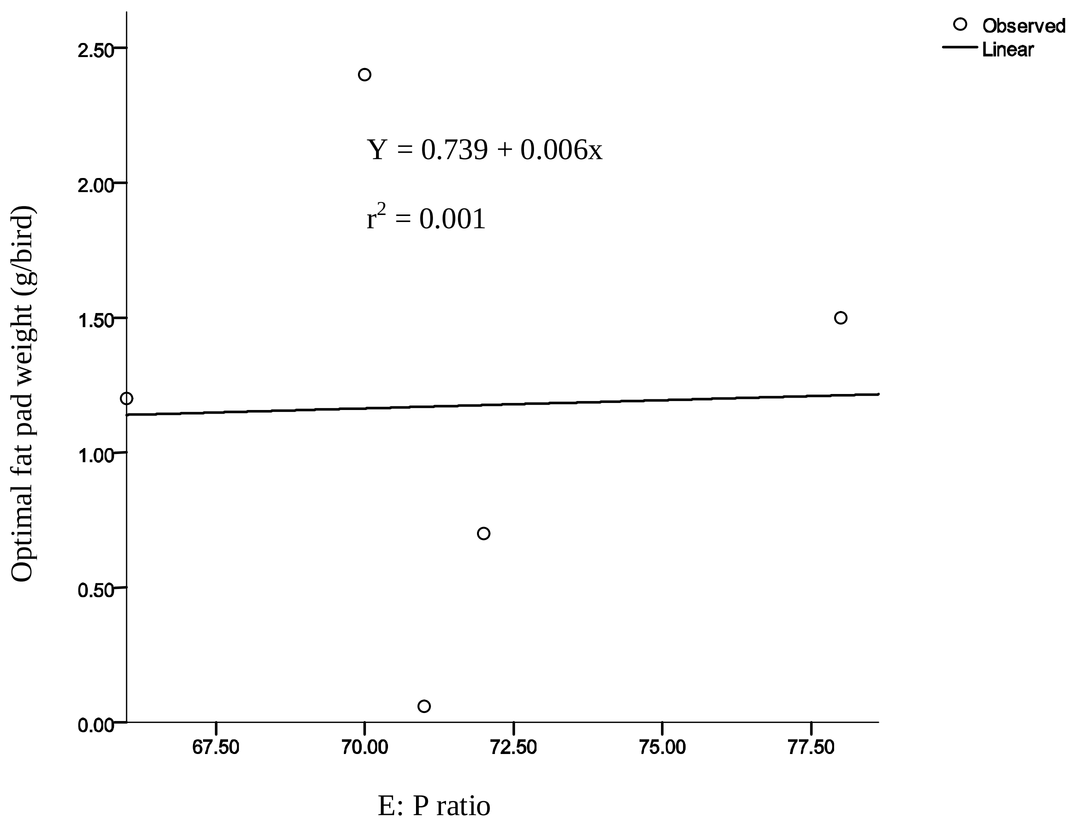

Figure 4.54 Relationship between optimal dietary energy to protein ratio and optimal fat pad weight of male Venda chickens based on different dietary energy levels between seven and thirteen weeks of age

4.3.7 Efficiency of dietary protein and energy utilization

Results of the effect of dietary energy to protein ratio level on efficiency of dietary protein and energy utilization for optimal growth rate in male Venda chickens between seven and thirteen weeks of age, based on all the dietary energy levels, are presented in Table 4.22 and Figures 4.55 to 4.56. Efficiency of crude protein utilization decreased with increasing dietary energy to protein ratio (Figure 4.55). Efficiency of metabolisable energy utilization increased with increasing dietary energy to protein ratio (Figure 4.56).

Table 4.22 Effect of dietary energy to protein ratio levels(MJ ME/kg protein), based on all the dietary energy levels, on efficiency of dietary protein and energy utilization for optimal growth rate (g/bird/day) in male Venda chickens between seven and thirteen weeks

Variable	Dietary energy level (MJ ME/kgDM)				
	12.2	13	13.2	13.4	14
Optimum growth (g/bird/day)	16	12	13	19	17
E:P ratio level	60	71	66	72	71
Diet CP level (g/kg)	203	183	200	186	195
Efficiency of utilization of diet CP	0.20	0.18	0.20	0.18	0.19
Efficiency of utilization of diet energy	12.5	13.3	13.1	13.2	14

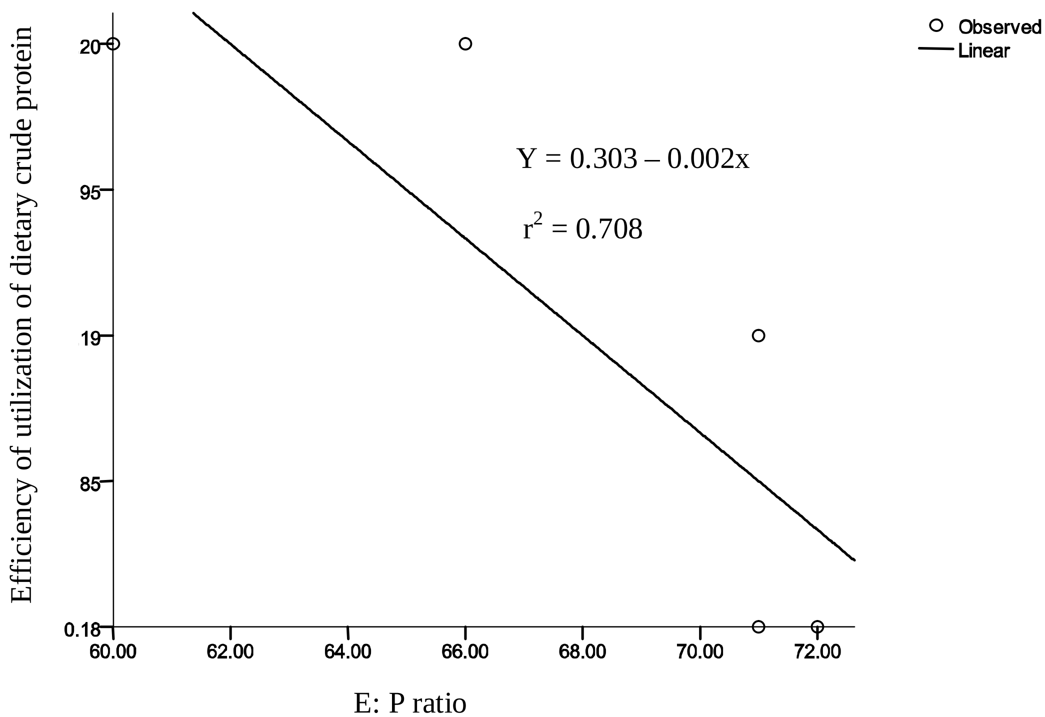

Figure 4.55 Relationship between optimal dietary energy to protein ratio and efficiency of utilization of dietary protein, based on different dietary energy levels, in male Venda chickens between seven and thirteen weeks of age.

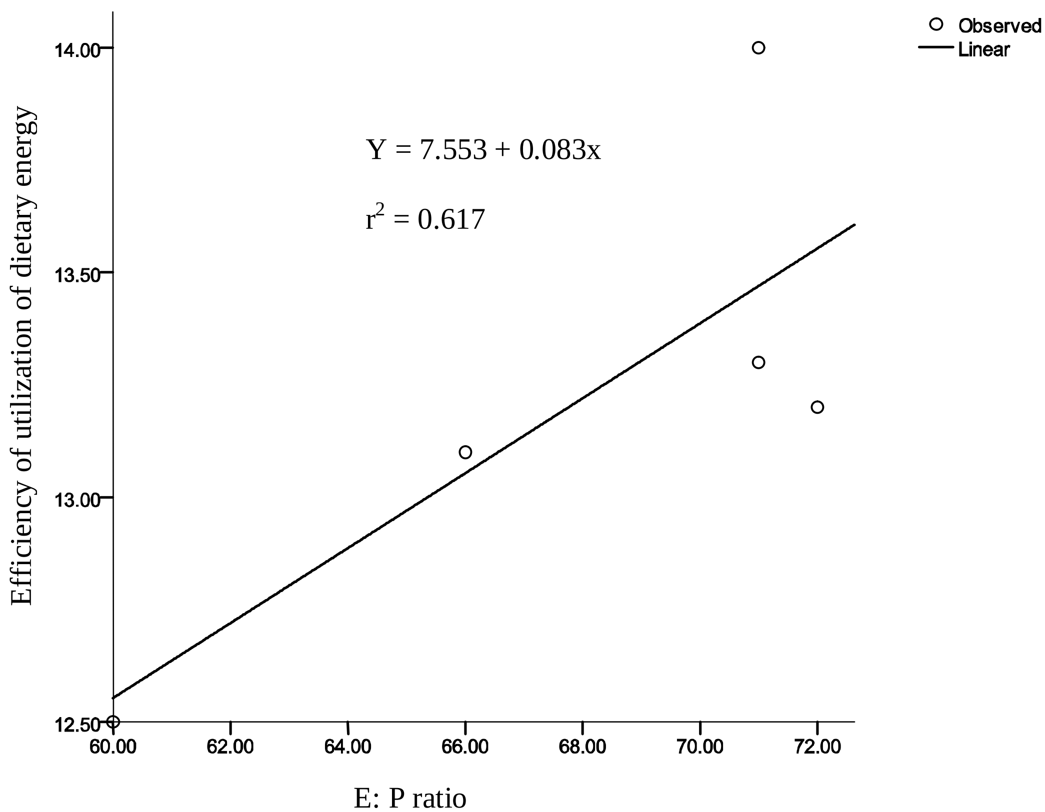

Figure 4.56 Relationship between optimal dietary energy to protein ratio and efficiency of utilization of dietary energy, based on different dietary energy levels, in male Venda chickens between seven and thirteen weeks of age.

4.3.8 Optimal dietary crude protein level and energy utilization

Results of the relationship between optimal dietary crude protein level and optimal dietary energy utilization for feed intake and growth rate of male Venda chickens between seven and 13 weeks of age, based on all the dietary energy levels, are presented in Table 4.23 and Figures 4.57 and 4.58, respectively. Quadratic calculations indicate that protein requirements for optimal energy utilization to maximize feed intake is generally lower than that for maximizing growth rate.

Table 4.23 Relationship between optimal dietary crude protein level (g/kg DM) and optimal dietary energy utilization for feed intake (g/bird/day) and growth rate (g/bird/day) in male Venda chickens between seven and thirteen weeks of age, based on all the dietary energy levels

Trait	Formula	Optimal protein	Y-Value	r^2	P
Intake	$Y= -84.984 +1.103x + -0.0031x^2$	178	13.13	0.617	0.383
Growth	$Y= -537.415 + 5.746x + -0.0149x^2$	193	14	0.971	0.029

P :Probability level

Optimal protein :Optimal protein level (g/kg DM)

Y-Value : Energy value for optimal protein level (MJ ME/kg DM)

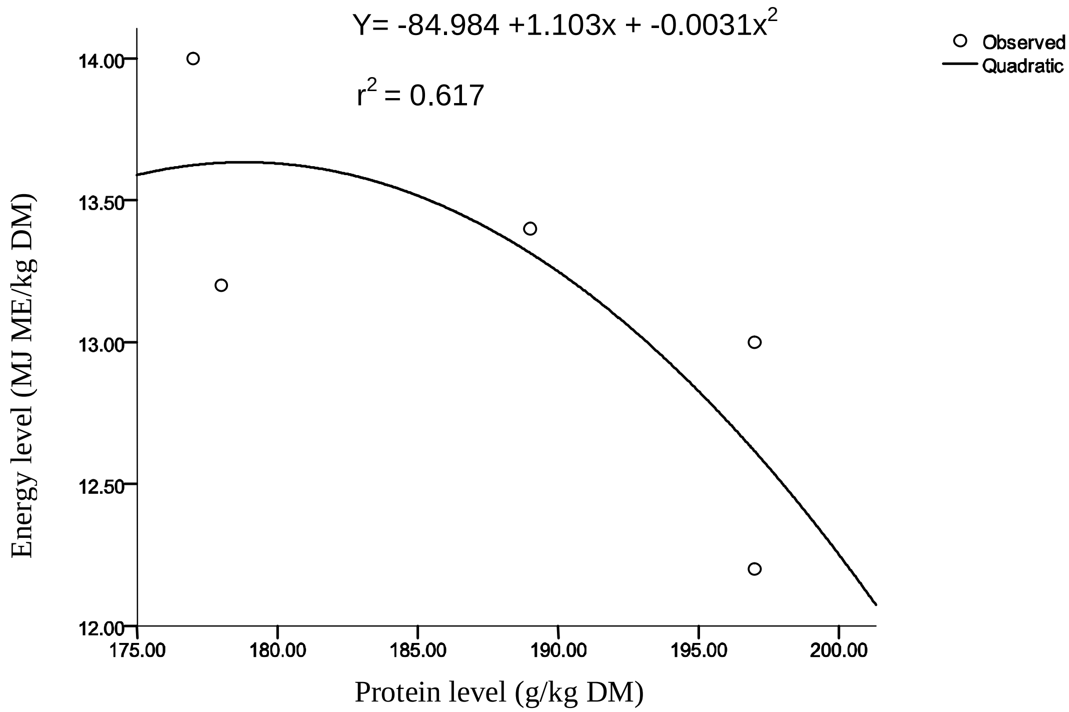

Figure 4.57 Relationship between optimal dietary crude protein level and optimal dietary energy utilization for feed intake in male Venda chickens between seven and thirteen weeks of age

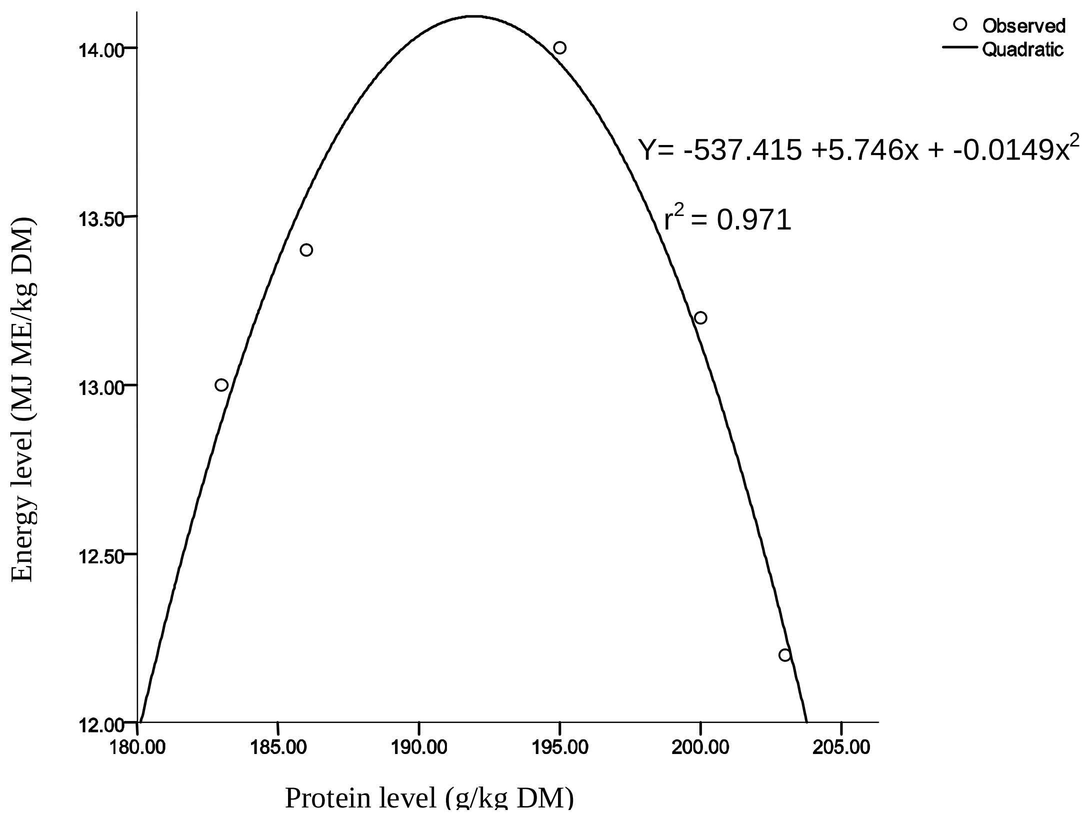

Figure 4.58 Relationship between optimal dietary crude protein level and optimal dietary energy utilization for growth in male Venda chickens between seven and thirteen weeks of age

4.4 DISCUSSION

4.4.1 Experiment 6

The dietary treatments for Experiment 6 were similar to those used in Experiment 1. Dietary energy to crude protein ratios varied across all the diets ranging from 55 to 76 MJ ME/kg protein. These cover both low and high ratios. The diets contained levels of other nutrients, which met the chicken's requirements as recommended by the NRC (1994).

Results from the present study showed that dietary energy to protein ratio level had a significant effect on feed intake, growth rate, feed conversion ratio, live weight, metabolisable energy, nitrogen retention, carcass weight and breast meat yield of male Venda chickens during the grower phase. Buyse *et al*. (1992) Jones and Smith (1986) and Lin *et al*. (1980) found similar results. in broiler chickens. These authors observed that feeds of different dietary energy to protein ratio levels will give different performance responses. Contrary to the present findings, Han et al. (1992) found no differences in performance variables of broiler chickens when dietary energy to protein ratio of the feed was changed by decreasing the diet crude protein content from 23 to 20 %.

In the present study, dietary energy to protein ratio level had no effect on fat pad weight and dry matter digestibility values of male Venda chickens. Similarly, Nawaz *et al.* (2006) reported no effect of dietary crude protein and/or metabolisable energy on abdominal fat weight in broiler chickens. Similar results were also reported by Jackson et al. (1982) who showed that the effect of dietary energy to protein ratio levels on fat deposition was similar in broiler chickens at any given dietary energy to protein ratio value. Contrary to the present findings, Bartov and Plavnik (1998) found that the relative abdominal fat pad weight increased significantly in chickens by increasing energy to protein ratio of the diet. Similarly, Cheng *et al.* (1997) reported a significant decrease in abdominal fat in broiler chickens when dietary energy to protein ratio level of the feed was changed by increasing the diet crude protein content. On the other hand, Si *et al.* (2004) reported significant increase in abdominal fat pad in broiler chickens with decrease in the dietary crude protein level. Thus, it seems that, as suggested by Leenstra (1984), the effect of diet on fat deposition vary with chicken strains. In addition, Marks (1990) showed that there is a significant genotype x diet interactions for percent abdominal fat deposition in chickens. Thus, one possible consequence of the intrinsic genetic limitations of indigenous chickens might be the inability to change their body fat composition according to alteration in dietary energy to protein ratio level. This might reflect the differences between indigenous and broiler chickens in terms of their genetic and physiological abilities to change their body fat composition according to changes in dietary energy to protein ratio value of the diet.

The results of the present study indicate that during the grower phase, based on a feed energy level of 12.2 MJ ME/kg DM, dietary energy to protein ratio of 62 MJ ME/kg protein optimized feed intake in male Venda chickens. This value is lower than the ratio of 69.77 MJ ME/kg protein calculated from the data of Nawaz et al. (2006) for optimum feed intake in broiler chickens during the grower phase. This may indicate higher energy requirement for broiler chickens than Venda chickens during the growing phase since broiler chickens have a bigger body to maintain. Such discrepant variation in requirements may be due to genetic differences. However, a single dietary energy to protein ratio of 60 MJ ME/kg protein optimized growth rate, feed conversion ratio, live weight, carcass weight and breast meat yield. This is lower than the result of Brown and McCartney (1982) who estimated the ratio of 61.73 MJ ME/kg protein for live weight in broiler chickens during the grower phase.

The ratio of 60 MJ ME/kg protein is lower than the ratios of 63, 65 and 70 MJ ME/kg protein for optimum nitrogen retention, metabolisable energy and fat pad weight respectively, under this dietary energy level. This may imply that an alteration of tissues takes place, particularly muscle and fat deposits, which may differ in nutrient contents (Moran and Bilgili, 1990) and hence, suggest that the dietary energy to protein ratio level for optimal responses in Venda chickens offered isocaloric diet with varying protein levels may depend on the production variable in question. Contrary to the present findings, NRC

(1994) and Kamran et al. (2008) estimated single ratios of 66.9 and 59.83 MJ ME/kg protein for all production variables in broiler chickens during the entire grower phase.

4.4.2 Experiment 7

Experiment 7 was designed to have high and low dietary energy to protein ratio levels ranging from 59 to 81 MJ ME/kg protein but with a similar energy value of 13 MJ ME/kg DM. The diets contained similar levels of other nutrients, which met the chicken's requirements as recommended by the NRC (1994).

This study showed that dietary energy to protein ratio levels had no significant effect on growth rate, live weight, carcass weight, breast meat yield and fat pad weight in male Venda chickens. These results could be explained in terms of similarities in digestibility values, irrespective of the treatment. Contrary to the present findings, Buyse *et al*. (1992), Collin *et al*. (2003) and Jones and Smith (1986) found that feeds of different dietary compositions had major effects on performance and body composition of broiler chickens. Dietary energy to protein ratio level had a significant effect on feed intake, feed conversion ratio, apparent metabolisable energy level and nitrogen retention values. Thus, differences in feed intake and feed conversion ratio may have been expected since feeds of different dietary compositions would give different performance responses (Lin et al., 1980; Collin et al., 2003).

Results of the present study indicate that a single dietary energy to protein ratio of 71 MJ ME/kg protein optimized growth rate, live weight, carcass weight and fat pad weight in male Venda chickens under this feed energy level. The ratio of 71 MJ ME/kg protein is slightly higher than the ratios of 66, 64 and 70 MJ ME/kg protein for optimum feed intake, nitrogen retention and apparent metabolisable energy, respectively but lower than the ratios of 75 and 81 MJ ME/kg for optimum feed conversion ratio and breast meat yield, respectively. Contrary to the present findings, NRC (1994) and Kamran et al. (2008) estimated single ratios of 66.9 and 59.83 MJ ME/kg protein, respectively for all production variables in broiler chickens during the entire grower phase.

4.4.3 Experiment 8

This experiment was designed to have high and low dietary energy to protein ratio levels. The experimental diets were isocaloric but with different levels of protein, thus ending up with different dietary energy to protein ratio levels ranging from 60 to 83 MJ ME/kg protein. The diets contained similar levels of other nutrients, which met the chicken's requirements as recommended by the NRC (1994).

Results of the present study indicate that dietary energy to protein ratio level had a significant effect on growth rate, feed conversion ratio, live weight, nitrogen retention, carcass weight and breast meat yield of Venda chickens. These results could not be explained in terms of similar feed intakes and digestibility values, irrespective of the treatment. Contrary to the present findings, Ferguson *et al*. (1998) observed that changing the dietary energy to protein ratio of the diet by reducing the feed crude protein content had no effect on live weight gain of broiler chickens. In the present study, dietary energy to protein ratio level had no effect on fat pad weight and apparent metabolisable energy values in male Venda chickens. It is possible that the dietary energy to protein ratio level required for fat pad deposition and metabolisable energy intake were lower than or equal to ratios used in the present study. Thus, increasing the ratio level could not have any effect on fat pad deposition and metabolisable energy value. Contrary to the present findings, Leeson *et al*. (1996) showed that altering the dietary energy to protein ratio value increased fat deposition in broiler chickens. No similar studies in indigenous male Venda chickens were found.

Results of the present study indicate that a single dietary energy to protein ratio of 66 MJ ME/kg protein optimized growth rate, live weight, carcass weight and fat pad weight in male Venda chickens under this feed energy level. This is different from the result of Brown and McCartney (1982) who estimated the ratio of 61.73 MJ ME/kg protein for live weight in broiler chickens during the grower phase. The ratio of 66 MJ ME/kg protein is higher than the ratios of 65 and 62 MJ ME/kg protein for optimum feed conversion ratio and breast meat yield but lower than the ratios of 74, 73 and 71 MJ ME/kg for optimum feed intake, metabolisable energy and nitrogen retention, respectively. This may suggest that the dietary energy to protein ratio level for optimal responses in male Venda chickens offered isocaloric diet with varying protein levels may depend on the production variable in question. This may be because an alteration of tissues takes place, particularly muscle and fat deposits, which may differ in nutrient contents (Moran and Bilgili, 1990).

4.4.4 Experiment 9

The diets used in this experiment had a similar energy value of 13.4 MJ ME/kg DM but varying crude protein concentrations, thus ending up with different dietary energy to protein ratio levels. Dietary energy to protein ratio levels ranged between 61 and 84 MJ ME/kg protein. These cover both low and high ratios. The diets contained similar levels of other nutrients, which met the chicken's requirements as recommended by the NRC (1994).

Results of the present study indicate that dietary energy to protein ratio level had a significant effect on feed intake, feed conversion ratio, metabolisable energy level, nitrogen retention and carcass weight of male Venda chickens. These results are different from the findings of Kamran *et al.* (2004) who found non-significant effect of altering the dietary energy to protein level on feed intake of broiler chickens. Similarly, Han *et al.* (1992) observed no differences in feed intake of broiler chickens when crude protein contents of the diet were decreased from 230 to 210 g/kg. The present study showed that there were no differences in growth rate, live weight, breast meat yield and fat pad weight of the chickens, irrespective of the treatment. These results could be partly explained in terms of similarity in digestibility values among the treatments. Contrary to the present findings, Buyse et al. (1992) showed that dietary energy and protein compositions affected growth rate and fat pad deposition in broiler chickens

Results of the present study indicate that a single dietary energy to protein ratio of 72 MJ ME/kg protein optimized growth rate, feed conversion ratio, live weight and fat pad weight. Similarly, a single dietary energy to protein ratio of 70 MJ ME/kg protein optimized metabolisable energy, nitrogen retention and breast meat yield in male Venda chickens under this feed energy level. However, the ratio of 72 MJ ME/kg protein is slightly higher than the single ratio of 70 MJ ME/kg protein for optimum metabolisable energy, nitrogen retention and breast meat yield and the ratios of 71and 67 MJ ME/kg protein for optimum feed intake and carcass weight, respectively. This is different from the findings of NRC (1994) and Kamran et al. (2008) who estimated single ratios of 66.9 and 59.83 MJ ME/kg protein for all production variables in broiler chickens during the entire grower phase.

4.4.5 Experiment 10

Experiment 10 was designed to have an isocaloric energy value of 14 MJ ME/kg DM but with different levels of protein, ranging between 160 and 220 g CP/kg DM. Thus, ending up with varying dietary energy to protein ratio levels, ranging between 64 and 88 MJ ME/kg protein. The diets contained similar levels of other nutrients, which met the chicken's requirements as recommended by the NRC (1994).

Dietary energy to protein ratio levels had a significant effect on growth rate, feed conversion ratio, live weight, apparent metabolisable energy level, nitrogen retention, carcass weight and breast meat yield in male Venda chickens. These results could not be explained in terms of similar feed intakes and digestibility in the chickens, irrespective of treatment. Similar results were obtained by Buyse *et al.* (1992) and Collin *et al*. (2003) who showed that feeds of different dietary energy to protein ratio levels will give different performance responses in broiler chickens. Dietary energy to protein ratio level had no significant effect on fat pad weight in male Venda chickens. It is possible that the dietary energy to protein ratio levels required for fat pad deposition were lower or equal to the ratios used in the present study. However, contrary to the present findings, Leeson *et a*l. (1996) showed that altering the dietary energy to protein ratio value increased fat deposition in broiler chickens. No similar studies in indigenous male Venda chickens were found.

Results of the present study indicate that a single dietary energy to protein ratio of 71 MJ ME/kg protein optimized growth rate, feed conversion ratio and live weight, respectively, in male Venda chickens. This is different from the findings of Brown and McCartney (1982) who estimated a ratio of 62 MJ ME/kg protein for optimum live weight in broiler chickens. On the other hand, dietary energy to protein ratio of 67 MJ ME/kg protein optimized nitrogen retention n the present study while carcass weight was optimized at dietary energy to protein ratio of 66 MJ ME/kg protein. These values are lower than the ratio of 71MJ ME/kg protein for optimum growth rate, feed conversion ratio and live weight. Similarly, the ratios of 67 and 66 MJ ME/kg protein are lower than the ratios of 69, 78 and 79 for optimum breast meat yield, apparent metaboilsable energy level, fat pad weight and feed intake, respectively. This may imply that an alteration of tissues takes place, particularly muscle and fat deposits, which may differ in nutrient contents (Moran and Bilgili, 1990) and hence, suggest that the dietary energy to protein ratio levels for optimal responses in Venda chickens offered an isocaloric diet with varying crude protein levels is relative and may depend on the feed energy and protein values and the variable in question.

4.4.6 Optimal responses

This study showed that optimal responses in feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy, nitrogen retention, carcass weight, breast meat yield and fat pad weight were achieved at different dietary energy to protein ratio levels for the different dietary energy levels. Thus, there seems to be no single dietary energy to protein ratio level for all the production variables across the different dietary energy levels. Similar results were reported by Gonzalez-a and Pesti (1993) who evaluated the concept of an optimum dietary metabolisable energy to crude protein ratio in broiler chickens. Their data revealed that while there was no single optimum dietary metabolisable energy to crude protein ratio, optimal responses in production variables could best be predicted as quadratic functions of both metabolisable energy and crude protein levels. This implied that both nutrients affect productivity and as such, dietary energy to protein ratio levels varied at different feed energy levels to meet the nutrient requirements of the chickens. Thus, energy and protein requirements of the chicken may influence the dietary energy to protein level for optimum production of a particular variable.

Optimal responses in feed intake, metabolisable energy, growth rate, feed conversion ratio and nitrogen retention tended to increase with increase in dietary energy to protein ratio level. This means that feed intake, metabolisable energy, growth rate, feed conversion ratio and nitrogen retention increased with an increase in feed energy level and with decrease in feed protein content. Thus, the increase in feed intake to increasing feed energy density level in the present study and the associated increase in the dietary metabolisable energy intake of the chickens may imply that regulation of feed intake in male Venda chickens aged seven to 13 weeks old was not influenced by feed energy value. The present results support the revised thinking of the NRC (1994) that some chicken strains do not adjust their feed intake to changes in the dietary metabolisable energy density and, as a result, may be prone to over-consuming metabolisable energy in an attempt to obtain sufficiency of the limiting nutrient when offered diets high in energy. This may be the scenario when male Venda chickens received feeds marginally deficient in protein since increasing the dietary energy to protein ratio value decreases feed protein content. Apparently, the increase in feed intake to increasing dietary energy to protein ratio level observed in the present study may indicate an attempt by the chickens to obtain more of the low protein diets to satisfy their protein requirements for growth. However, this increase in feed intake with low protein diets was achieved with increasing growth rate in the chickens offered these diets. This may indicate that the increasing feed intake allowed for maximum utilization of dietary protein for growth rather than for energy. Importantly, the increased feed intake seemed to have enhanced energy supply with increasing feed energy content thereby, sparing protein for the bird’s growth. Thus, it is possible that this was the most likely cause for the increasing growth rate observed with the low protein and high energy feeds. This was evident in the significant increase in nitrogen retention to increasing dietary energy to protein ratio level. Similar protein-sparing effects have been reported in fishes for hybrid striped bass (Gaylord and Gatlin, 2000) and Atlantic salmon (Hemre and Sandnes, 1999). In addition to the above observations, Zaman *et al.* (2008) found that low protein and high energy diets improved body weight gain in broiler chickens. Similarly, Kamran *et al.* (2004) reported improvement in body weight gain of broiler chickens when crude protein content of the diet was reduced from 230 to 210 g/kg. However, the results of the present study are contrary to the findings of Han *et al.* (1992) who observed no differences in body weight gain or growth rate of broiler chickens fed differing protein diets. Thus, the present results have shown that increase in feed intake to increasing dietary energy to protein ratio level allowed for maximum utilization of absorbed dietary protein for growth. This was evident in the significant increase in nitrogen retention and the associated increase in growth rate observed with increasing dietary energy to protein ratio level.

Optimal feed conversion ratio tended to increase with increasing dietary energy to protein ratio level. This means that optimal feed conversion ratio deteriorated with increasing feed energy level and decreasing feed protein content. These results could not be explained in terms of improved growth rate and nitrogen retention values obtained with increasing dietary energy to protein ratio level. However, the present results support the results of Jackson *et al.* (1982) who found that feed conversion ratio increased with increasing feed energy level in broiler chickens. Similar results were also reported by Ferguson *et al.* (1998) who observed increased feed conversion ratio with decreasing protein content. Si *et al.* (2004) also reported a significant negative effect of dietary crude protein content on feed conversion ratio. However, the results of the present study are contrary to the findings of Leeson *et al.* (1996) who reported improved feed conversion ratio with increasing feed energy level and increasing protein content.

Optimal carcass and breast meat yields tended to decrease with increasing dietary energy to protein ratio level. This was expected since feed conversion ratio deteriorated with increasing feed energy level and decreasing feed protein content. The results of the present study are in accordance with the findings of Moran *et al.* (1992) and Leeson *et al*. (1996). These authors observed that alterations in feed energy and protein content affected carcass and breast yields in broiler chickens. Similarly, Zarate *et al.* (2003) reported that reducing crude protein content reduced breast meat yield significantly in broiler chickens. Contrary to the present findings, Kamran *et al.* (2004) reported an increase in carcass yield in low crude protein diets due to reduced heat increment associated with the metabolism of excessive protein, which led to reduced heat stress, and, therefore, improved feed utilization.

Optimal live weight and fat pad deposition did not follow any clear trend with increase in dietary energy to protein ratio level. Thus, the absence of significant changes in these traits may indicate that the effect of diet was essentially the same and suggest that fat pad deposition in male indigenous Venda chickens is independent of dietary energy to protein ratio value of the diet. Contrary to the present findings, Bartov and Plavnik (1998) found that relative abdominal fat pad weight increased significantly in broiler chickens by increasing energy to protein ratio of the diet. However, Leestra (1984) suggested that the effect of diet on fat deposition vary with chicken strains. In addition, Marks (1990) showed that there is a significant genotype x diet interactions for percent abdominal fat deposition in chickens. Thus, one possible consequence of the intrinsic genetic limitations of indigenous chickens might be the inability to change their body fat composition according to alteration in dietary energy to protein ratio level. This might reflect the differences between indigenous and broiler chickens in terms of their genetic and physiological abilities to change their body fat composition according to changes in dietary energy to protein ratio value of the diet.

Regression analyses indicate that optimal feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy level, nitrogen retention and fat pad weight were poorly but positively predicted by dietary energy to protein ratio levels. However, negative and poor correlation coefficients were observed between optimal carcass weight and breast meat yield and dietary energy to protein ratio levels. The poor but positive correlation between feed intake, growth rate, feed conversion ratio, live weight, apparent metabolisable energy level and fat pad deposition and dietary energy to protein ratio level indicated that dietary energy to protein ratio level provided no reliable indication of these variables in male indigenous Venda chickens. Contrary to the present findings, Bartov and Plavnik (1998) found that relative abdominal fat pad weight increased significantly with dietary energy to protein ratio level in broiler chickens. On other hand, the poor but negative correlation values obtained between carcass weight and breast meat yield and dietary energy to protein ratio level were expected and support the earlier observation that increasing dietary energy to protein ratio level decreases protein concentration, thereby limiting protein utilization for tissue synthesis. This is similar to the findings of Holsheimer and Ruesink (1998) who found that protein limitations in the diets of broiler chickens affect performance and carcass quality.

Efficiency of utilization of dietary protein appears to be improved with increasing dietary energy to protein ratio level. As energy was not limiting, an efficient conversion of the consumed protein to growth was expected. Similar results have been reported elsewhere (Ward *et al*., 2003). However, as suggested by Hewitt (1992), at low protein content, improved protein efficiency may be the product of reduced protein catabolism rather than increased tissue synthesis alone. Thus, applying this thesis to the present results may explain the improved protein efficiency with decreasing feed protein content. On the other hand, the converse applies to efficiency of utilization of apparent metabolisable energy. Apparent metabolisable energy utilization deteriorated with increasing dietary energy to protein ratio levels. This was expected since increasing dietary energy to protein ratio level promotes excessive energy intake as similarly observed by the NRC (1994).

Results of the present study indicate that protein requirements for optimal energy utilization to maximize feed intake is generally lower than that for growth rate. This may imply that an alteration of tissues takes place, particularly muscle and fat deposits, which may differ in nutrient contents

(Moran and Bilgili, 1990). The present study has shown that a diet containing a crude protein level of 193 g/kg DM and an energy level of 14 MJ ME/kg DM allowed for optimal utilization of absorbed protein and energy for growth in male indigenous Venda chickens aged between seven and thirteen weeks old. NRC (1994) recommended a diet containing 200 g/kg DM crude protein and a 13.38 MJ ME/kg DM for broiler chickens during the grower period of growth. No similar studies in indigenous chickens on this subject were found.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Optimal response trends for different production variables in one to six weeks old Venda chickens were influenced by the dietary limiting nutrient, in this case the diet crude protein content. However, dietary energy to protein level for optimal response depended on the variable in question. Thus, optimal feed intake increased with increasing dietary energy to protein ratio. Similarly, optimal metabolisable energy level increased with increasing dietary energy to protein ratio without any increase in live weight. On the other hand, increasing dietary energy to protein ratio levels resulted in poor feed conversion ratio and decreased growth rates, thus, negatively affecting live weight at six weeks of age. However, efficiency of protein utilization improved with increasing dietary energy to protein ratio. Thus, the present study indicated that a diet containing a crude protein content level of 178 g/kg DM and an energy level of 14 MJ ME/kg DM allowed for optimal utilization of absorbed protein and energy for growth in unsexed indigenous Venda chickens aged between one and six weeks.

Optimal response trends in feed intake, growth rate, feed conversion ratio, nitrogen retention, and metabolisable energy intake in male Venda chickens aged between seven and 13 weeks old tended to increase with an increase in dietary energy to protein ratio level. In contrast, optimal carcass and breast meat yields tended to decrease with increasing dietary energy to protein ratio level.

However, optimal live weight and fat pad deposition remained unchanged regardless of increase in dietary energy to protein ratio value. Increasing dietary energy to protein ratio level improved efficiency of protein utilization with deteriorating metabolisable energy utilization. However, with such diets, protein became limiting and birds increased their feed intake attempting, thereby, to obtain more of the limiting protein regardless of the energy value of the diet. Thus, the present study indicated that a diet containing a crude protein content level of 193 g/kg DM and an energy level of 14 MJ ME/kg DM allowed for optimal utilization of absorbed protein and energy for growth in male indigenous Venda chickens aged between seven and thirteen weeks.

It has also been observed that growing Venda chickens increased their feed intake with an increase in dietary energy to protein ratio. This is contrary to what has been observed in broiler chickens. Broiler chickens decrease their intake with an increase in dietary energy value. This might reflect the differences between indigenous and broiler chickens in terms of their genetic and physiological abilities to regulate their feed intakes according to dietary energy levels.

5.2 Recommendations

Dietary energy to protein ratio level for optimal response in indigenous Venda chickens was relative and depended on the energy and protein values of the diet. This may imply that the nutrient requirements of indigenous Venda chickens are dynamic and dependent on which production variable is taken into consideration when formulating the rations. Thus, the feeding program for optimal production in indigenous Venda chickens must take into consideration the primary variable in question. However, with such variable dietary energy to protein ratio values, feed intake plays a key role and hence the amount of nutrients consumed by the chicken in response to any dietary energy to protein ratio level has a pronounced effect on productivity. Thus, it is suggested that indigenous Venda chicken feed should contain 178 g CP/kg DM and an energy level of 14 MJ ME/kg DM for the unsexed chickens aged between one and six weeks old while that of male Venda chickens aged between seven and thirteen weeks should contain 193 g CP/kg DM and an energy level of 14 MJ ME/kg DM to ensure optimal utilization of absorbed nutrients for growth.

More research is suggested to fully understand the effects of dietary energy to protein ratio level on productivity and carcass characteristics of indigenous Venda chickens raised in closed confinement from day-old up to thirteen weeks of age. For example, the effect of dietary energy to protein ratio level on meat composition and sensory attributes.

CHAPTER 6

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