EFFECT OF DIETARY ASCORBIC ACID SUPPLEMENTATION LEVEL ON PRODUCTIVITY, CARCASS CHARACTERISTICS AND MORTALITY OF VENDA CHICKENS

BY

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A MINI-DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE, DEPARTMENT OF ANIMAL PRODUCTION,

SCHOOL OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES,

FACULTY OF SCIENCE AND AGRICULTURE,

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JULY 2009

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DECLARATION

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

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

ACKNOWLEDGEMENT

My words of gratitude go to the following: Prof. J.W. Ng'ambi for his superb guidance and patience, Prof. D. Norris for his support and invaluable time, Dr. M. Malatje for his encouragement throughout this study, Dr. K.L.M. Moganedi for her confidence in me, Mr. C.A. Mbajiorgu for his assistance and ingenious input, the National Research Foundation for financial assistance, and to the Almighty God for giving me strength and keeping me safe and healthy throughout my study period.

DEDICATION

This work is dedicated to my late beloved father, Moetji who taught me the greatest things in life.

ABSTRACT

Two experiments were conducted to determine the effect of dietary ascorbic acid supplementation levels on productivity, carcass characteristics and mortality of Venda chickens. The first experiment determined the effect of dietary ascorbic acid supplementation levels on productivity and mortality rate of 175 unsexed Venda chickens between 1 and 6 weeks old. The second experiment determined the effect of dietary ascorbic acid supplementation levels on productivity, carcass characteristics and mortality rate of 140 female Venda chickens between 8 and 13 weeks old. A Completely Randomized Design was used in both experiments. The treatments ranged from 0 to 2000 mg of ascorbic acid per kg DM feed. A quadratic equation was used to determine levels of ascorbic acid supplementation for optimum feed intake, feed conversion ratio, growth rate, live weight and breast meat yield. Feed conversion ratio, growth rate and live weight were optimized at different levels of 1050, 1301 and 1500 mg of ascorbic acid per kg DM feed, respectively, during the starter phase. Similarly, feed conversion ratio, growth rate, live weight and breast meat yield were optimized at different levels of 1000, 1250, 1482 and 769 mg of ascorbic acid per kg DM feed, respectively, during the grower phase. Dietary feed intake in both phases was not optimized within the range of values of ascorbic acid supplementation used in this experiment. The results indicate that at each growth phase, different levels of ascorbic acid supplementation optimized feed conversion ratio, growth rate and live weight of Venda chickens. However, level of ascorbic acid supplementation for optimum breast meat yield was lower than those for feed conversion ratio, growth rate and live weight. These findings have implications on ration formulation for Venda chickens.

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CHAPTER 1

INTRODUCTION

1.1 Background

Over 90% of all poultry comprise the indigenous chickens and are found in almost all rural households (Kingori *et al.*, 2007). These chickens contribute a lot to the household nutrition and income in rural areas of Limpopo province (Swatson *et al.*, 2001). Thus, they contribute to livehood and food security of rural households.

Productivity of the indigenous chickens is low due to stressful conditions such as harsh environmental, pathological and nutritional imbalances. These generate tension that evokes behavioral and physiological chain reaction leading to generally, impaired poultry performance (Kamel *et al.*, 2003). However, nutrition seems to be the main factor limiting these indigenous chickens to meet their production potential (Kingori *et al.*, 2003). Nutrients are known to influence the response of poultry to production challenges. Nutrients are necessary for the maintenance, growth, production and health of poultry (Butcher and Miles, 2002).

Although chickens possess the innate ability to synthesize ascorbic acid (vitamin C), diet supplementation of ascorbic acid has been found to increase productivity and decrease mortality in broiler chickens (Dorairajan *et al.*, 2004). However, ascorbic acid requirements in indigenous chickens are not available.

1.2 Problem

The majority of the population in the rural areas of Limpopo own indigenous chickens. These chickens are kept for nutritional, economic and social status. Despite these important attributes, there is low productivity and high mortality among the indigenous chickens. These factors result in nutritional and economic losses for the rural farmers. However, there is evidence indicating that ascorbic acid supplementation increases productivity, improves carcass characteristics, and reduces mortality rate in broiler chickens (McKee and Harrison, 1995).

1.2 Motivation

Indigenous chickens are kept by rural farmers as a source of income, however productivity is low and mortality is high. This study will determine dietary ascorbic acid supplementation levels for optimum feed intake and digestibility, growth rate, feed conversion ratio, carcass characteristics and mortality in Venda chickens. Such results will be important in terms of improving productivity and reducing mortality in Venda chickens.

1.3 Objective

The objective of this study was to determine levels of dietary ascorbic acid supplementation for optimum feed intake, digestibility, growth rate, feed conversion ratio, carcass characteristics and mortality rate in Venda chickens raised in closed confinement up to 13 weeks of age.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Poultry have the ability to synthesize ascorbic acid in their body (Pardue and Thanxton, 1986; Cheng *et al*., 1990 and Sahin *et al*., 2003a); hence, nutritional requirements have not been published for species that synthesize the vitamin (McDowell, 2000). Ascorbic acid synthesis in poultry is inadequate under stressful conditions such as low or high environmental temperatures, and high productivity levels. Studies have nonetheless demonstrated improved health and performance with dietary ascorbic acid supplementation under various circumstances (McDowell, 2000; Kingori *et al*., 2003). There is evidence that ascorbic acid supplementation has a beneficial effect on productivity, carcass traits and mortality of broiler chickens (Sahin *et al*., 2003b).

However, other studies indicate no beneficial effect of ascorbic acid supplementation on productivity of broiler chickens (Puron *et al*., 1994). Ascorbic acid also improves immunity of chickens, helps in absorption of iron in the gastrointestines and acts as a natural antioxidant to protect the body cells from free radicals that might damage the cells (Ramnath *et al*., 2007). However, extensive research has not been done to determine the effects that ascorbic acid has on productivity, carcass characteristics and mortality of indigenous chickens.

2.2 Biochemical functions of ascorbic acid

Vitamin C occurs in two forms, namely the reduced ascorbic acid and oxidized dehydroascorbic acid. Ascorbic acid is readily oxidized to dehydroascorbic by a number of enzymic or nonenzymatic processes and is then reduced in cells. Absorbed ascorbic acid readily equilibrates with the body pool of the vitamin. Reversible oxidation-reduction of ascorbic acid with dehydroascorbic acid is the most important chemical property of vitamin C and the basis for its known physiological activities and stabilities (McDowell, 1989). Only the L-isomer of ascorbic acid has activity. Although the majority of the vitamin exists as ascorbic acid, both forms are biologically active (McDowell, 1989).

Ascorbic acid is known for its antiscorbutic activity and it is easily synthesized from glucose through the intermediate formations of glucuronic acid and gulonic acid in the kidneys of the chickens (Dorairajan *et al*., 2000). No specific binding proteins for ascorbic acid have been reported and it is suggested that the vitamin is retained by binding to subcellular structures (McDowell, 1989). Ascorbic acid is widely distributed throughout the tissues, both in animals capable of synthesizing it as well as in those dependent on an adequate dietary amount of ascorbic acid (Dorairajan *et al*., 2000).

In experimental animals, highest concentrations of vitamins are found in the pituitary and adrenals, with high levels also found in the liver, spleen, brain, and pancreas (Dorairajan *et al.*, 2000).

The vitamin is a colorless, crystalline, water-soluble compound having acidic and strong reducing properties. It is heat-stable in acid solution but is readily decomposed in the presence of alkali. The destruction of the vitamin is accelerated by exposure to light (Pinnel *et al.*, 1987). Ascorbic acid has the chemical formula $C_6H_8O_6$ and a molecular mass of 176.14 grams per mol. (Figure 2.1). Vitamin C is purely the L-enantiomer of ascorbate; the opposite D-enantiomer has no physiological significance. Both forms are mirror images of the same molecular structure.

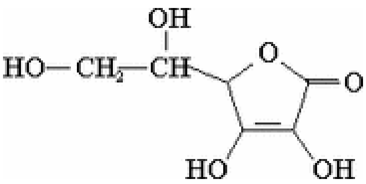

Figure 2.1. Structure of ascorbic acid ($C_6H_8C_6$)

The basic functional property of ascorbic acid is its redox potential (+0.08 mV) whereby the compound can reduce transition metals, thus allowing the vitamin to participate in a number of metabolically important hydroxylation reactions (Pinnel *et al.*, 1987). A major function of ascorbic acid is that it is a co-factor in the biosynthesis of collagen, which is the main structural component of the skin as well as many other chicken body tissues. Ascorbic acid, as a co-factor, prevents oxidation of the iron and, therefore, protects the enzymes against auto-inactivation. In this manner, it promotes the synthesis of a mature and normal collagen pattern through the perfect maintenance of the activity of the lysil and propyl hydroxylase enzymes for collagen synthesis (Khan and Iqbal, 2006).

Ascorbic acid is essential for the synthesis of cartinine (β-hydroxy butyric acid). It acts as a co-factor for hydroxylations involved in cartinine synthesis. Cartinine is required for transport of fatty acids into mitochondria for ATP generation required by birds for their metabolic functions (Naidu, 2003). Further, ascorbic acid acts as a co-factor for the enzyme dopamine-β-hydroxylase, which catalyzes the conversion of neutransmitter dopamine to norepinephrine. Thus, ascorbic acid is essential for synthesis of cathecholamine (Naidu, 2003; Khan and Iqbal, 2006).

Ascorbic acid has been demonstrated to be a natural inhibitor of nitrosamines, which are potent carcinogens. Action of ascorbate in preventing formation of nitrosamine is reported to result from direct reaction with nitrate. Ascorbic acid is found in up to a 10-fold concentration in seminal fluid (as compared to serum levels). Decreasing levels have caused nonspecific sperm agglutination. It has been hypothesized that the vitamin may help to protect sperm from effects of harmful oxidation (McDowell, 1989).

Ascorbic acid, also, enhances the absorption of iron from the gastrointestinal tract via reduction of the ferric form to the more rapidly absorbable ferrous form (Elliot, 2002). It is an essential component of chickens in that it is highly concentrated in leukocytes, which are used rapidly during infection, for example, to prevent oxidative damage. The acid enhances the phagocytic action of leukocytes and the migratory behavior of neutrophils, thus, playing a role in the immune response of broiler chickens (Null, 2001). According to Smith (2007) ascorbic acid enhances lymphocytes proliferative responses to diseases. Supplementation with increased levels of ascorbic acid can help offset some of the challenges, particularly in situations where the bird's immune response has been compromised further by environmental or physiological stress. Over, or prolonged, stimulation should however be avoided as the associated catabolic response can also affect performance of the chickens adversely. Where possible, immune stimulation with increased ascorbic acid usage should only occur at key times in the production cycle (Smith, 2007). Most studies fall into two designs; supplementing marginal or deficient diets with moderate levels (25-100 mg/kg) or supplementing conventional diets with a high level of addition (100-1000 mg/kg). Clear immunomodulatory responses have been seen but most studies fail to determine optimal levels (Smith, 2007).

As a water-soluble antioxidant, ascorbic acid plays a major role in protecting cells from the actions of reactive oxygen by reducing chemical radicals and preventing the process of lipid peroxidation in chickens (Chew, 1996). Environmental stress diminishes *in vivo* antioxidant status. Lower plasma concentrations of antioxidant vitamins such as vitamin C and E have inversely correlated to increased oxidative damage in stressed poultry (Vathana *et al.*, 2002). It works along with vitamin E, a fat-soluble antioxidant, and the enzyme glutathione peroxidase to stop free radical chain reactions (Null, 2001).

2.3 Ascorbic acid synthesis in chickens

A wide variety of plant and animal species can synthesize ascorbic acid from carbohydrate precursor including glucose and galactose. The missing step in the path of ascorbic acid biosynthesis in all vitamin C-dependent species has been traced to inability to convert L-gulonolactone to 2-keto-L-gulonate, which is transformed by spontaneous isomerization; these species, therefore, lack the enzyme L-gulonolactone (McDowell, 1989).

Metabolic need for ascorbic acid is a general need among species, but a dietary need is limited to some birds. Even for species that do synthesize ascorbic acid, it has been shown that the synthesizing capacity of liver microsomal preparations varies strongly from animal to animal (McDowell, 1989), suggesting possible dietary need of the vitamin for individuals within a species. In general, domestic animals such as poultry and swine have the ability to synthesize ascorbic acid within their bodies and hence there is no recommended dietary requirement (McDowell, 1989). Like swine, poultry are able to synthesize ascorbic acid and thus it is assumed they do not require dietary source of the vitamin.

However, for newly hatched poultry there is a slow rate of ascorbate synthesis and this combined with encountered stress increases probability of ascorbic acid deficiency (McDowell, 1989). It has long been known that birds resemble rats (Lykkesfeldt *et al.*, 1998) and dogs (Hishiyama *et al.*, 2006) in having little apparent need for ascorbic acid in their diet. Atherton *et al.* (1978) concluded that the growth of the chick in the egg, which is known to be free from ascorbic acid, is one of the best indications that the growing bird does not need ascorbic acid. This statement has been criticized on the ground that the avian embryo may synthesize the vitamin during their development, and indeed Yew (1985) showed that the fertile eggs of chicken contain no detectable ascorbic acid. However, upon incubation, ascorbic acid content in the egg rapidly increases and high concentrations of ascorbic acid are found in various embryonic tissues.

It has been established that in chickens, the location of ascorbic acid synthesis is in the kidneys and not in any other tissues. But in the early stages of embryonic development, the kidneys (mesonephros and metanephros) seemed too small and primitive to be the only tissues capable of supplying the ascorbic acid needed by the rapidly growing embryo (Yew, 1985).

Although there has been speculation that different embryonic tissues might be capable of synthesizing ascorbic acid so far, biosynthesis of ascorbic acid was found in the kidneys of the chick embryo as well as in the yolk sac membrane. The activity of L-gulonolactone oxidase in the yolk sac membrane suggested that it was the major source of ascorbic acid in the chick embryo (Hooper, 2000).

2.4 Effect of ascorbic acid on chicken production

Environmental stress is a general term used to describe the sum of non-specific responses to defense mechanisms of the body when faced with abnormal or extreme environmental conditions. Such stress evokes a combination of behavioral, biochemical and physiological adaptations which generally results in a reduction in the performance of poultry. Supplementation with elevated levels of ascorbic acid during periods of environmental stress can help maintain performance. For broilers reared under stress situations, supplementation with ascorbic acid has been shown to help alleviate some of the associated metabolic problems and allow improved feed intake, weight gain, feed conversion ratio and liveability (Smith, 2007).

Optimum responses appear to occur with a daily intake of around 20 mg per day depending on the degree of stress (Smith, 2007). Ascorbic acid is important in optimum functioning of the immune system through enhancement of neutrophils production and also through protection against free radical damage. Dietary supplementation of ascorbic acid has been shown to provide resistance against infections, minimize loss of productivity and reduction of mortality (Pardue and Thaxton, 1986).

Poultry may require supplementary dietary vitamins for their productivity and health since common feed ingredients used in poultry production may not contain adequate quantities to meet minimum requirements (Lohakare *et al.*, 2005). It has been postulated that the improved performance of poultry results from a decrease in protein-derived gluconeogenesis (Sahin *et al.*, 2003). Ascorbic acid is associated with the conversion of body proteins and fat into energy for production and survival through increased corticosterone secretion (Bains, 1996). Corticoids depress immune system function, reduce protein concentrations and increase blood glucose concentrations that have damaging effect on poultry performances by decreasing body weight gain (Seyrek *et al.*, 2004).

As corticoids induce gluconeogenesis from non-carbohydrates precursor such as lactate, amino acids and glycerol, decrease of glucocorticoids secretion could limit lipid and protein catabolism (Kucuk *et al.*, 2003).

Kutlu and Forbes (1993) reported that ascorbic acid reduced the synthesis of corticosteroids hormones in birds, which increases when birds are under environmental stresses. Similarly, Sahin *et al*. (2002) reported low concentration of adrenocorticotropic (ACTH) hormone in birds under high temperature fed a diet supplemented with ascorbic acid. By decreasing synthesis and secretion of corticosteroids, ascorbic acid alleviates the negative effect of heat on carcass characteristics (Sahin *et al*., 2003).

Supplementation of ascorbic acid increases feed intake, body weight gain, and improves feed efficiency in broiler chickens reared under high temperatures (Sahin *et al*., 2003). Supplementation of ascorbic acid at 250 mg/kg DM feed increased feed intake (Sahin *et al*., 2002 and Kadim *et al*., 2008). Kassim and Norzihz (1995) also found improved growth rate in the broiler chicks supplemented with ascorbic acid. Jaffar and Blaha (1996) observed a 10.9 % increase in body weight of chickens supplemented with ascorbic acid at 40 mg/bird/day in drinking water during acute heat stress (29 to 43 ºC). Blaha and Kreosna (1997) observed even a higher increase of 18 % among chickens fed a diet supplemented with ascorbic acid. Lohakare *et al*. (2005) observed higher weight gains in the supplemental groups as compared with the control groups, and a positive linear correlation was observed between the supplemental levels and the weight gains.

Ascorbic acid is involved in growth by promoting collagen synthesis, calcium and vitamin D3 metabolism, carnitine synthesis for oxidation of fatty acids, oxidation of amino acids, electron transport in the cells and scavenging of free radicals (Combs, 1992). The results were not in agreement with those of other researchers who observed no improved growth in the supplemental group of birds (Pardue and Thaxton, 1985). Giang and Doan (1998) concluded that supplementation of the chick diet with ascorbic acid at a dose of 150 ppm had no effect on the growth rate, but improved the appearance of the chicks. Puron *et al*. (1994) observed that 220 ppm of dietary ascorbic acid supplementation had no effect on productivity and survivability of chickens when the average environmental temperature was 26 ºC.

Indigenous chickens tend to have high feed conversion ratio as a result of either the poor type of feeds usually available to them or low genetic potential for feed conversion efficiency or both (Roberts 1999 and Tadelle *et al*., 2003). However, high conversion ratios in indigenous chickens have also been reported in cases where they were provided with commercial feed (Kingori *et al*., 2003). Genetic variation has been observed for feed conversion efficiency among strains of indigenous chickens implying that selective breeding can be used to improve feed efficiency (Tadelle *et al*., 2003).

Lohakare (2005) observed poorer feed conversion ratio for birds supplemented with ascorbic acid at 1 to 3 weeks than the control birds, while Cafantaris (1995) observed a better feed conversion ratio with increased ascorbic acid supplementation levels.

Sahin and Kucuk (2001) also observed the same results in broiler chickens. An increased nutrient digestibility in the supplemental groups culminated in increased weight gain; however, there was no explanation regarding an improved nutrient digestibility when ascorbic acid was added in the diet (Sahin and Kucuk 2001). Lohakare *et al*. (2005) also reported greater digestibility of dry matter, organic matter, crude protein and ether extract in chickens when fed a higher dietary ascorbic acid at the level of 200 mg/kg diet. However, scanty reports are available with respect to the effect of ascorbic acid on nutrient digestibility.

According to Cafantaris (1995), dressing percentage of broiler chickens fed diets supplemented with higher ascorbic acid levels was higher as compared to the nonsupplemented ones. The mode of action of ascorbic acid in this regard could be explained via the modulation of the release of corticosteroids hormone involved in gluconeogenesis to enhance energy supply during stress and alleviate the disturbance in the electrolyte balance, thus reducing catabolism of the body reserves and preventing a strong dehydration in the chicken (Cafantaris, 1995). Supplementation of broilers with ascorbic acid at 1000 mg/kg in drinking water prior to collecting for slaughter improved hot and chilled carcass yield (Quarks and Adrian, 1988). However, breast meat was greater in the control group as compared with other supplemental levels. There was no effect observed of ascorbic acid supplemental level on the abdominal fat percentage (Cafantaris, 2005). Sahin and Kucuk (2001) reported that supplemental ascorbic acid yield better carcass traits in broiler chickens. In contrast, Jem *et al*., 2008 indicted no effect of ascorbic acid supplementation level on carcass traits of broiler chickens.

Gross (1988) observed that as the dose of ascorbic acid increased from 0 to 330 mg/kg DM feed, mortality decreased from 40 % to 0 %. However, as the dose of ascorbic acid increased further, there was an increase in mortality. Pretreatment of chicks for 4 weeks with 1000 mg of ascorbic acid per kg of diet reduced mortality from 22 % to 7 %. As the level of supplementation increases, the ascorbic acid content in plasma and liver also increases linearly for defense mechanism in chickens. In the study conducted by Lohakare *et al*., (2005), the lymphocytes subpopulation measured in broiler chickens showed higher CD4 count and T-cell receptor-II cells in the 100 ppm supplemented group as compared with its unsupplemented counterparts. The significant increase of CD4 and TCR-II lymphocytes by addition of ascorbic acid indicates the increase of lymphocytes to exogenous antigen and provokes immune response quickly (Lohakare *et al*., 2005).

Ascorbic acid is present in high concentration in leukocytes and is utilized at a higher rate during infections and phagocytosis (Thomas and Holt, 1978). Viral infections are known to cause reduction in serum ascorbic acid concentration (Beisel, 1982).

Although vaccines are available to prevent outbreak of diseases, additional measures, such as supplementation of ascorbic acid in the diet may prove to be beneficial. Supplementation may improve responses to vaccination in terms of antibody production and specific cell mediated immunity, as well as reduce the effect of vaccination-induced stress in chickens (Amakye-Anim *et al*., 2000). Ascorbic acid functions as a natural antioxidant to remove harmful free radicals produced through normal cellular activity and from environmental stressors, thereby maintaining the structural integrity of immune cells. These free radicals, when allowed to accumulate, are capable of destroying the integrity of cellular membranes, enzymes and nuclear DNA in chickens (Chew, 1996). The vitamin also plays a role in protecting cells from the action of reactive oxygen by reducing chemical radicals and preventing the process of lipid peroxidation in chickens (Ramnath *et al*., 2007).

Therefore, dietary ascorbic acid is important to the health and production capacity of chickens. However, many of the studies that are conducted to examine effects of ascorbic acid supplementation on productivity, carcass characteristics and mortality are largely based on broilers rather than indigenous chickens, such as Venda chickens. In addition, response to dietary ascorbic acid supplementation levels for maximum productivity and minimum mortality in chickens is variable. It is, therefore, important to ascertain the responses to dietary ascorbic acid supplementation in Venda chickens.

2.7 Summary

There is evidence that increased level of dietary ascorbic acid supplementation increases productivity, decreases mortality and improves carcass characteristics of broiler chickens. However, there is no published data that shows that studies have been conducted on Venda chickens to determine their response to ascorbic acid supplementation. With such improvements observed in broiler chickens in terms of responses to ascorbic acid supplementation, it is, therefore, necessary to determine the dietary ascorbic acid supplementation levels for optimum productivity, reduced mortality and improved carcass characteristics of Venda chickens.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study site

This study was conducted at the University of Limpopo Experimental farm. The farm is situated 10 km Northwest of the University. The mean ambient temperatures at the farm are around 25 °C and 35 °C during winter and summer seasons, respectively. The annual rainfall ranges between 446.8 and 450 mm.

3.2 Preparation of the house

The experimental house was cleaned properly with water and a disinfectant (Jeyes fluid, NTK Polokwane). The house was then left empty for two weeks after cleaning to break the life cycle of any disease causing organisms. The house was divided into 35 floor pens of equal size (1.5 m^2). Fresh saw dust was spread on the floor to a depth of 7 cm. All equipment that were used in the experiment were cleaned thoroughly and disinfected. The footbath was also cleaned and fresh Jeyes fluid was added.

3.3 Acquisition of materials

All the materials were purchased from NTK Company in Polokwane, prior to the commencement of the experiment. Chicks used in all experiments were obtained from the University of Limpopo Hatchery. Ascorbic acid used for supplementation in chicken feed was purchased from NTK Company in Polokwane.

3.4 Experimental design, treatments and procedure

Before commencing the experiments, permission from Animal Ethics Committee of the Senate was obtained. Two experiments for this study were conducted between May and September, 2008. The first experiment determined dietary ascorbic acid supplementation levels for optimum feed intake and digestibility, growth rate, feed conversion and mortality rate in unsexed Venda chickens between 1and 6 weeks of age. The experiment commenced with day-old Venda chickens with an average weight of 27.4 ± 2 g, and was carried out for a period of 6 weeks. The chicks were assigned to 7 treatments, in a Completely Randomized Design. Each treatment group consisted of 5 replicates with 5 chickens per replicate. The chickens were fed a starter diet consisting of 16 % CP and 11.0 MJ ME/kg DM. Feeds were supplemented with different levels of dietary ascorbic acid throughout the experimental period. The treatments were as follows:

V_{0}: Unsexed chickens fed a grower diet without vitamin C supplementation

V_{100}: Unsexed chickens fed a grower diet supplemented with 100 mg vitamin C per kg DM feed

V_{400}: Unsexed chickens fed a grower diet supplemented with 400 mg vitamin C per kg DM feed

V_{800}: Unsexed chickens fed a grower diet supplemented with 800 mg vitamin C per kg DM feed

V_{1000}: Unsexed chickens fed a grower diet supplemented with 1000 mg vitamin C per kg DM feed

V_{1200}: Unsexed chickens fed a grower diet supplemented with 1200 mg vitamin C per kg DM feed

V_{2000}: Unsexed chickens fed a grower diet supplemented with 2000 mg vitamin C per kg DM feed

The second experiment determined dietary ascorbic acid supplementation levels for optimum feed intake, digestibility, growth rate, fed conversion ratio, carcass characteristics and mortality rate in female Venda chickens between 8 and 13 weeks of age. A total of 140 female chickens were used for this experiment. The average weight of the birds was 336 ± 2 g. The chickens were assigned to 7 treatments in a Completely Randomized Design. Each treatment group consisted of 5 replicates with 4 chickens per replicate. The chickens were fed a grower diet consisting of 16 % CP and 11.0 MJ ME/kg DM. The treatments were as follows:

V_{0}: Female chickens fed a grower diet without vitamin C supplementation

V_{100}: Female chickens fed a grower diet supplemented with 100 mg vitamin C per kg DM feed

V_{400}: Female chickens fed a grower diet supplemented with 400 mg vitamin C per kg DM feed

V_{800}: Female chickens fed a grower diet supplemented with 800 mg vitamin C per kg DM feed

V_{1000}: Femaled chickens fed a grower diet supplemented with 1000 mg vitamin C per kg DM feed

V_{1200}: Female chickens fed a grower diet supplemented with 1200 mg vitamin C per kg DM feed

V_{2000}: Female chickens fed a grower diet supplemented with 2000 mg vitamin C per kg DM feed

3.5 Data collection

3.5.1 Live weight

The initial live weights of the birds were taken at the beginning of each experiment. Live weight per bird was measured at weekly intervals. The weekly live weights were used to calculate growth rate.

3.5.2 Feed intake

Voluntary feed intake was measured by subtracting the weight of feed leftovers from that offered per week, and the difference was divided by the total number of birds in the pen. Thus, daily feed intake per chicken was calculated.

3.5.3 Feed conversion ratio

Feed conversion ratio per pen was calculated as the total amount of feed consumed divided by the weight gain of live birds plus the weight gain of the dead or culled minus weight of all birds in the pen at the start of the experiment.

3.5.4 Apparent digestibility

Digestibility was carried out when the birds were between 36 and 42 days old in Experiment 1, and between 86 and 91 days old in Experiment 2. Digestibility was conducted in specially designed metabolic cages having separate watering and feeding troughs. Two birds were randomly selected from each replicate and transferred to metabolic cages for measurement of apparent digestibility. A three-day acclimatization period was allowed prior to a three-day collection period. Droppings voided by each bird were collected on daily basis at 11.00 hours. Apparent digestibility of nutrient was calculated according to McDonald *et al*. (2003) as follows:

$$AD\ (Decimal) = \frac{(\text{Amount of nutrient ingested} - \text{Amount of nutrient excreted})}{\text{Amount of nutrient ingested}}$$

3.5.5 Carcass characteristics

At 13 weeks of age, all remaining Venda chickens per pen were weighed on an electronic weighing scale to obtain the live weights and then slaughtered. After slaughtering, the carcass weight of an individual chicken was measured. Dressing percentage was calculated as carcass weight divided by the live weight and then multiplied by hundred. Weight of breast, thigh, drumstick and gizzard were measured. The length of the intestines was measured as from the duodenum to the cloaca. At the end of each slaughtering, meat samples from the breast part of the slaughtered chicken were stored in the refrigerator and later analyzed for nitrogen.

3.5.6 Mortality

Deaths were recorded as they occurred per pen. Mortality rate of the chickens was calculated as the total number of deaths divided by total number of chickens per pen then multiplied by 100.

3.5.7 Chemical analysis

Dry matter (DM) content of excreta was determined by drying the sample at 105 °C for 24 hours. The bomb calorimeter was used to measure gross energy values for feeds and faeces, and Semi-micro Kjeldahl method was used to analyze nitrogen contents of feeds and faeces (University of KwaZulu-Natal laboratory, Durban). Nitrogen content of the feeds and faeces were analyzed to calculate crude protein using the formula: CP = % N x 6.25 (Schroeder, 1994). High Performance Liquid Chromatography (HPLC) was used to determine the quantity of ascorbic acid contained in the experimental chickens feed (LATS, University of Limpopo, Polokwane) according to the method described by Swan-Choo and Siong (1996).

3.5.8 Statistical analysis

Effect of dietary ascorbic acid on feed intake and digestibility, growth rate, feed conversion ratio, carcass characteristics and mortality of Venda chickens were analyzed using the general linear model (GLM) procedure of the Statistical Analysis System (SAS, 2003). The Tukey test for multiple comparisons was used to test the significance of differences between treatment means ($P<0.05$). The responses in optimum intake, feed conversion ratio, growth rate and live weight changes to level of ascorbic acid supplementation were modeled using the following quadratic equation: $Y = a + b_1x + b_2x^2$

Where Y = optimum intake, feed conversion ratio, growth rate and live weight; a = intercept; b = coefficients of the quadratic equation; x = level of ascorbic acid supplementation 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, 2003). The quadratic model was used because it gave the best fit.

CHAPTER 4

RESULTS

Results of the nutrient composition of the grower diet are presented in Table 4.1. The grower diet contained 940 g DM/kg, 13.77 MJ energy/kg DM, 157.5 g protein/kg DM and 20 mg ascorbic acid/kg DM. However, after supplementation with ascorbic acid the amounts in the diets ranged from 20 to 2020 mg ascorbic acid per kg DM feed.

The effects of dietary ascorbic acid supplementation level on dry matter intake, feed conversion ratio, growth rate, intake as percentage of live weight and mortality of Venda chickens between 1 and 6 weeks old and live weight at 6 weeks old are presented in Table 4.2. Ascorbic acid supplementation level had no effect ($P>0.05$) on dry matter intake, feed conversation ratio, intake as percentage of live weight and mortality of chickens between 1 and 6 weeks old. However, level of ascorbic acid supplementation had effect ($P<0.05$) on growth rate and live weight of the Venda chickens. Venda chickens supplemented with 800, 1000, 1200 and 2000 mg of ascorbic acid per kg DM feed per day attained higher ($P<0.05$) growth rates and live weights than unsupplemented ones. Birds on 0, 100 and 400 mg of ascorbic acid per kg DM feed per day attained similar growth rates and live weights.

Table 4.1 Nutrient composition of the grower diet

	Nutrients			
Diet	Dry matter (g/kg)	Gross energy MJ/kg DM	Protein (g/kg DM)	Ascorbic acid (mg/kg DM)
V_0	940	13.77	157.5	20
V_{100}	940	13.77	157.5	120
V_{400}	940	13.77	157.5	420
V_{800}	940	13.77	157.5	820
V_{1000}	940	13.77	157.5	1020
V_{1200}	940	13.77	157.5	1220
V_{2000}	940	13.77	157.5	2020

Feed conversion ratio and growth rate of Venda chickens between 1 and 6 weeks old and live weight at 6 weeks old were optimized at different ascorbic acid supplementation levels of 1050, 1301 and 1500 mg per kg DM feed, respectively. However, dietary ascorbic acid supplementation level did not effectively predict optimum feed conversion ratio because of the low regression coefficient value (Table 4.3 and Figures 4.1, 4.2 and 4.3).

Feed intake was not optimized within the ascorbic acid values used in this experiment. Ascorbic acid level of supplementation had no effect (P>0.05) on dietary intake, digestibility, metabolisable energy and nitrogen retention in Venda chickens at 7 weeks of age (Table 4.4).

Table 4.2 Effect of dietary ascorbic acid supplementation level on dry matter intake (g/bird/day), feed conversion ratio, growth rate (g/bird/day), intake as % of live weight and mortality (%) of Venda chickens between 1 and 6 weeks old, and live weight (g/bird) at 6 weeks old

	Variables					
Treatment	DM intake	FCR	Growth rate	Live weight	Intake as % of live weight	Mortality
V_0	19.0	4.7	4.0^c	127.6^c	15.0	5
V_{100}	19.0	4.7	4.1^c	144.0^{bc}	13.2	5
V_{400}	19.4	4.5	4.3^{bc}	146.6^{abc}	13.2	5
V_{800}	20.0	4.5	4.4^{ab}	160.0^{ab}	12.5	0
V_{1000}	18.2	3.9	4.7^a	164.2^a	11.1	0
V_{1200}	18.8	4.2	4.5^{ab}	158.6^{ab}	11.9	5
V_{2000}	20.6	4.6	4.4^{ab}	161.8^{ab}	12.7	0
SE	1.18	0.31	0.12	6.89	1.07	4.07

^{abc}: Means in the same column sharing a common superscript are not significantly different (P>0.05)

SE: Standard error

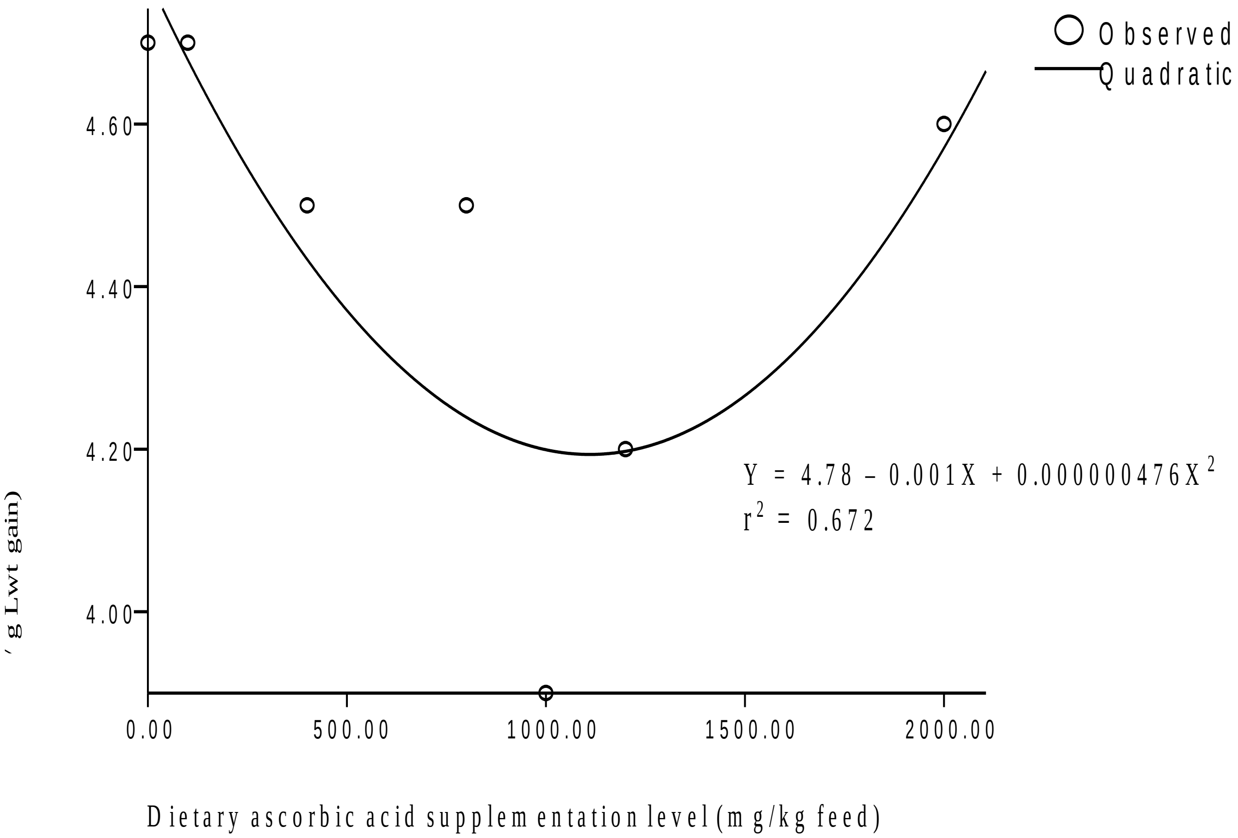

Figure 4.1 Effect of dietary ascorbic acid supplementation level on feed conversion ratio of Venda chickens between 1 and 6 weeks of age

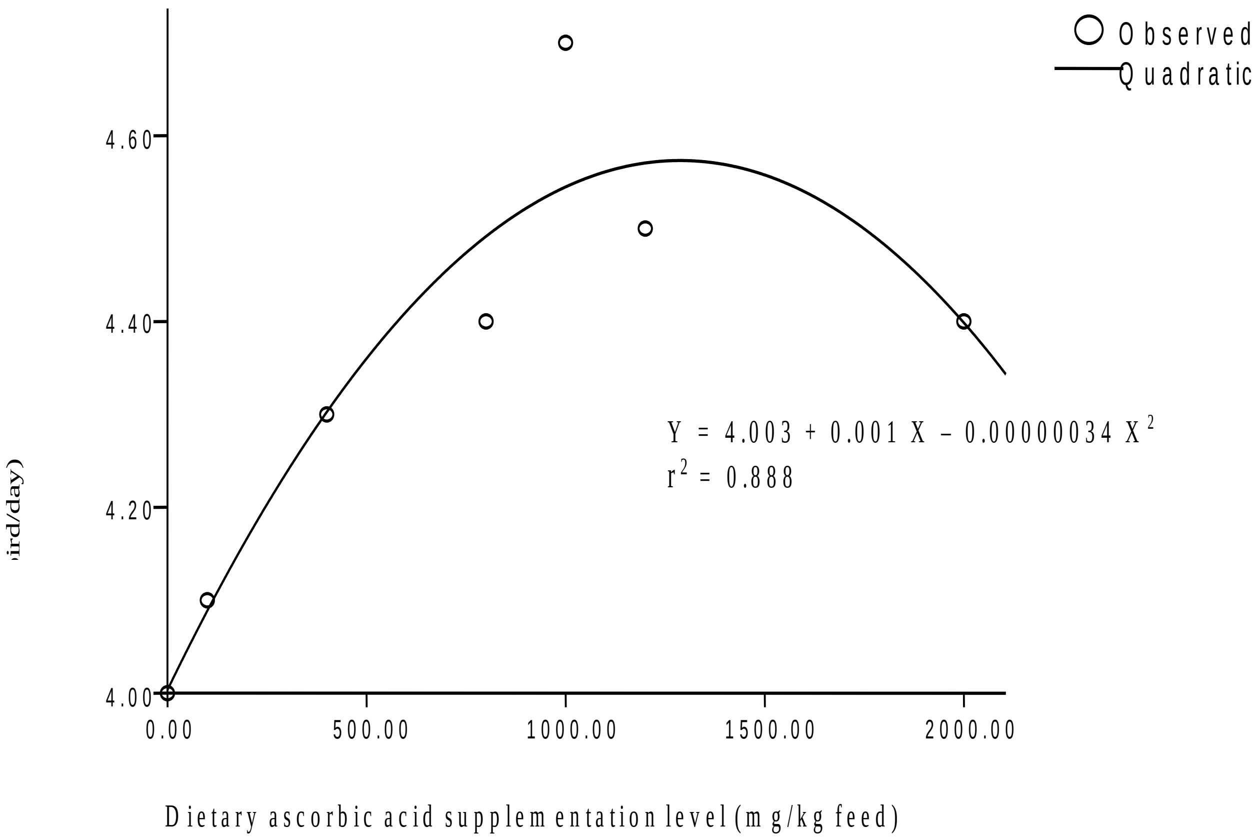

Figure 4.2 Effect of dietary ascorbic acid supplementation level on growth rate of Venda chickens between 1 and 6 weeks of age

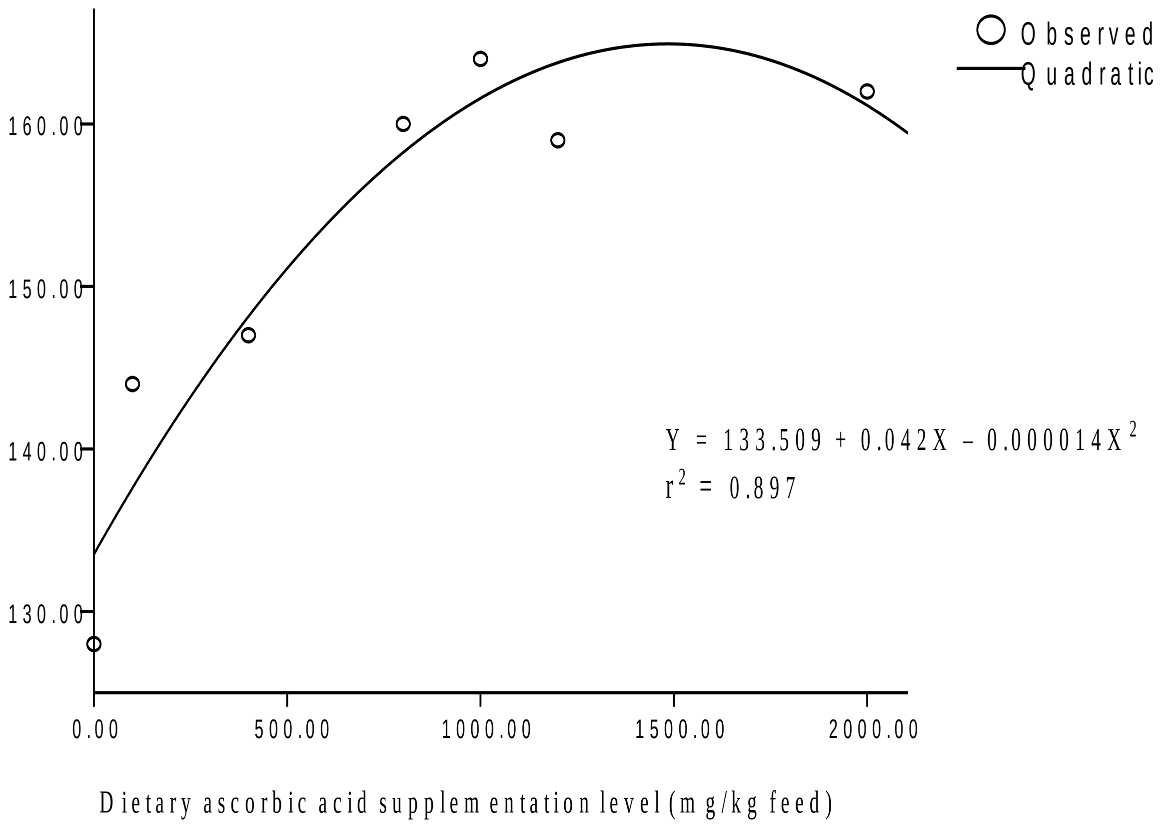

Figure 4.3 Effect of dietary ascorbic acid supplementation level on live weight of Venda chickens at 6 weeks of age

Table 4.3 Dietary ascorbic acid supplementation levels (mg/kg DM feed) for optimal feed conversion ratio (g DM feed/g live weight gain) and growth rate (g/bird/day) in Venda chickens between 1 and 6 weeks old and live weight (g/bird) at 6 weeks old

Trait	Formula	r^2	Ascorbic acid level	Optimal Y level
FCR	$Y = 4.78 - 0.001X + 0.000000476X^2$	0.672	1050	4.25
Growth rate	$Y = 4.003 + 0.001X - 0.00000034X^2$	0.888	1301	4.6
Live weight	$Y = 133.509 + 0.042X - 0.000014X^2$	0.897	1500	165

r^2: Regression coefficient

X : Level of ascorbic acid supplementation

Table 4.4 Effect of dietary ascorbic acid level of supplementation (mg/kg DM) on dietary intake, digestibility, metabolisable energy (ME) and nitrogen (N) retention in Venda chickens at 7 weeks old

Variables	Ascorbic acid supplementation level							SE
	V_0	V_{100}	V_{400}	V_{800}	V_{1000}	V_{1200}	V_{2000}	
Intake (g/bird/day)								
DM	51	46	45	45	51	44	47	22.00
N	1.29	1.17	1.15	1.14	1.29	1.12	1.20	0.100
Energy (MJ/bird/day)	0.70	0.63	0.62	0.62	0.70	0.61	0.65	0.030
Digestibility (decimal)								
DM	0.81	0.84	0.86	0.81	0.84	0.87	0.84	0.024
N	0.75	0.70	0.76	0.67	0.74	0.71	0.69	0.040
ME (MJ/kg DM)	11.18	11.52	11.78	11.11	11.57	12.05	11.49	0.770
N retention (g/bird/day)	0.97	0.81	0.87	0.76	0.96	0.97	0.83	0.056

SE: Standard error

Results of the effects of dietary ascorbic acid supplementation level on dietary dry matter intake, feed conversion ratio, growth rate and mortality of female Venda chickens between 8 and 13 weeks old, and live weight at 13 weeks old are presented in Table 4.5. Ascorbic acid supplementation level had no effect (P>0.05) on dry matter intake, feed conversion ratio, growth rate and mortality of chickens between 8 and 13 weeks old, and live weight at 13 weeks old. Dietary feed conversion ratio and growth rate of female Venda chickens between 8 and 13 weeks, live weight and breast meat yield at 13 weeks old were optimized at different ascorbic acid supplementation levels of 1000, 1250, 1482 and 769 mg per kg DM feed, respectively. However, feed intake was not optimized within the range of values of ascorbic acid supplementation level used in the experiment. Optimum feed conversion ratio and breast meat yield were not effectively predicted by dietary ascorbic acid supplementation levels, because of low regression coefficient value (Table 4.6 and Figures 4.4, 4.5, 4.6, 4.7 and 4.8).

Ascorbic acid level of supplementation had no effect (P>0.05) on dietary intake, digestibility, metabolisable energy and nitrogen retention in female Venda chickens at 13 weeks of age (Table 4.7). Similarly, supplemental ascorbic acid level had no effect (P>0.05) on the carcass weight, dressing percentage and carcass parts of female Venda chickens at 13 weeks of age (Table 4.8)

Table 4.5 Effect of dietary ascorbic acid supplementation level on DM intake (g/bird/day), feed conversion ratio, growth rate (g/bird/day) and mortality (%) of female Venda chickens between 8 and 13 weeks old, and live weight (g/bird) at 13 weeks old

	Variables				
Treatment	DM intake	FCR	Growth rate	Live weight	Mortality
V_0	51.6	63	0.62	431.00	2.8
V_{100}	54.2	74	0.74	381.20	2.4
V_{400}	52.8	166	0.58	385.00	2.4
V_{800}	52.2	61	0.86	455.40	0.8
V_{1000}	52.2	114	0.66	446.00	0.8
V_{1200}	55.4	73	0.84	473.60	2.4
V_{2000}	53.6	93	0.72	441.40	0.0
SE	2.030	35.30	0.142	26.330	1.069

SE: Standard error

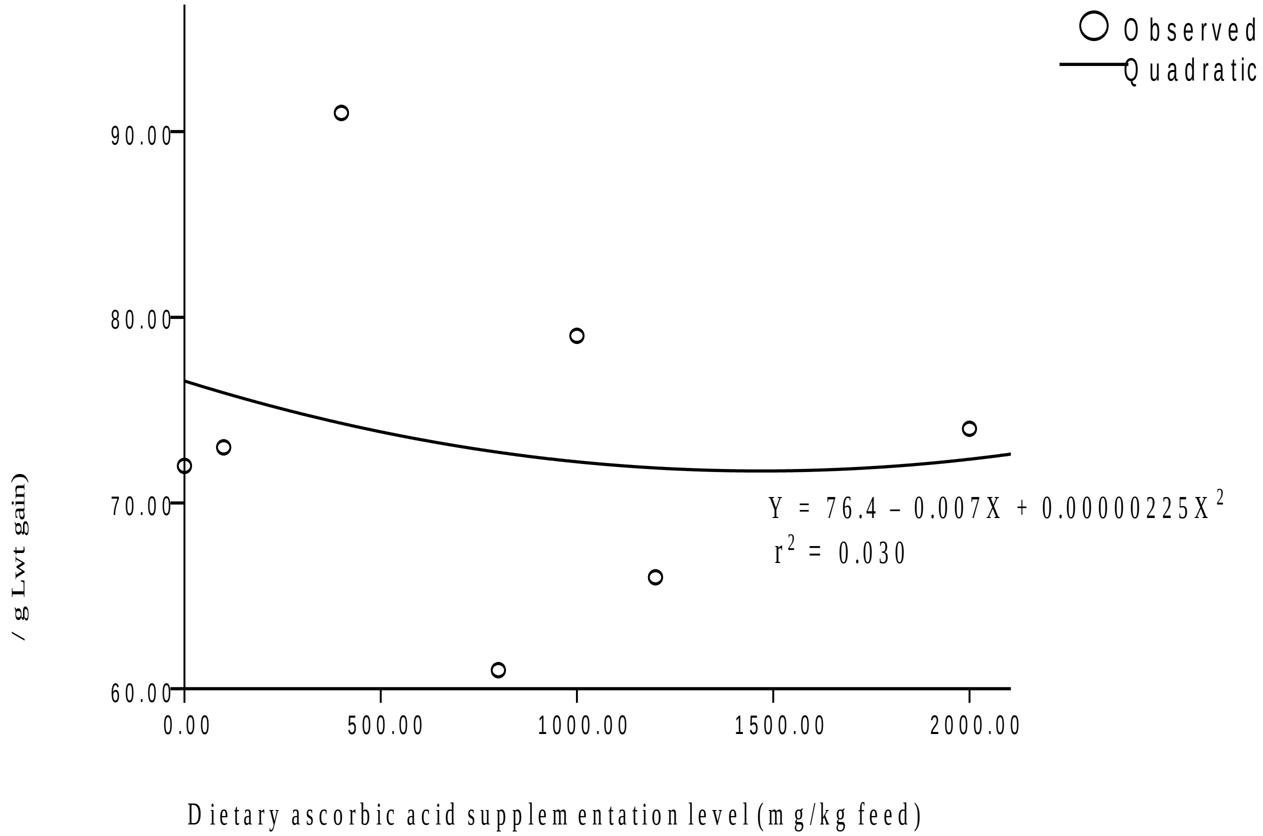

Figure 4.4 Effect of dietary ascorbic acid supplementation level on feed conversion ratio of female Venda chickens between 8 and 13 weeks of age

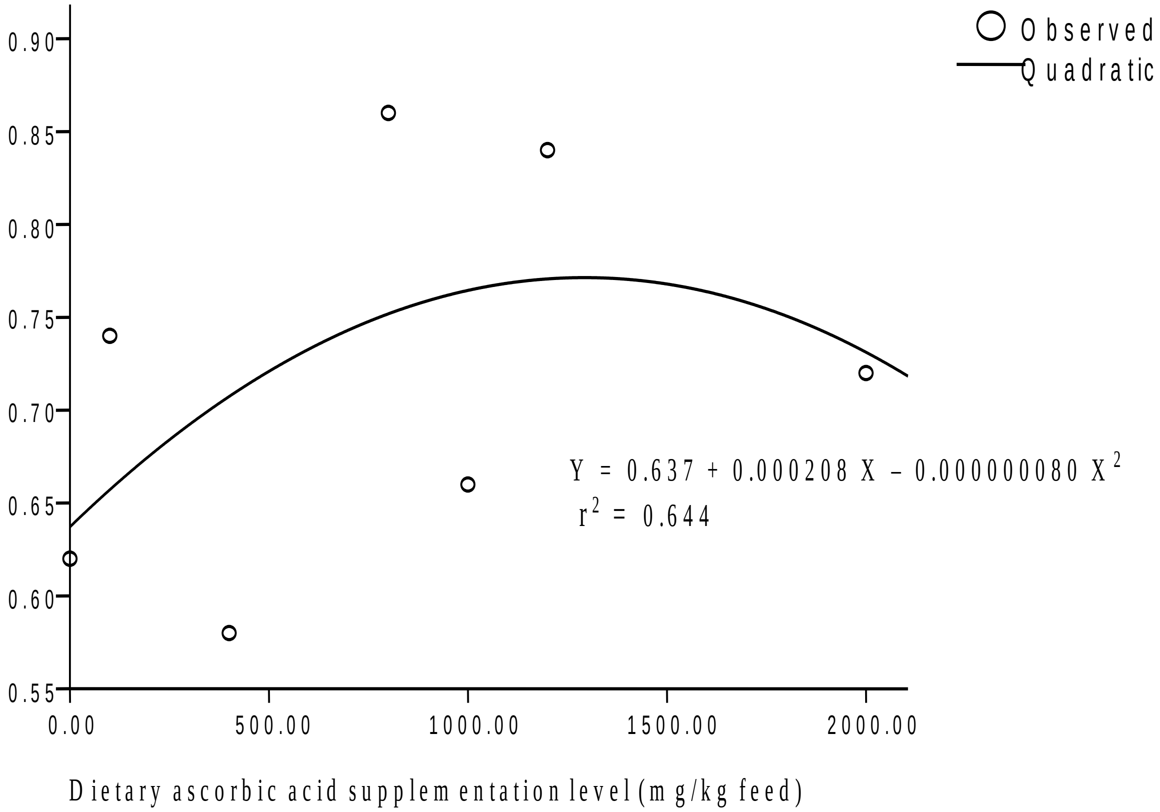

Figure 4.5 Effect of dietary ascorbic acid supplementation level on growth rate of female Venda chickens between 8 and 13 weeks of age

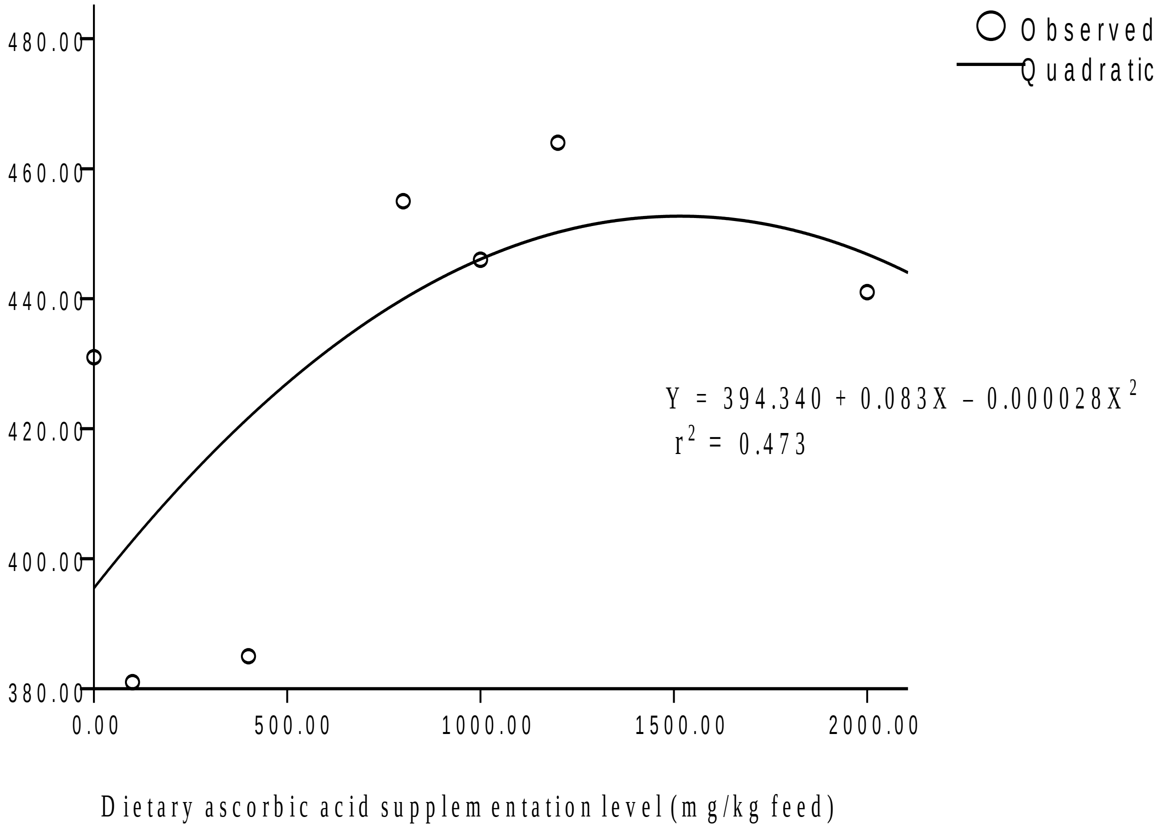

Figure 4.6 Effect of dietary ascorbic acid supplementation level on live weight of female Venda chickens at 13 weeks of age

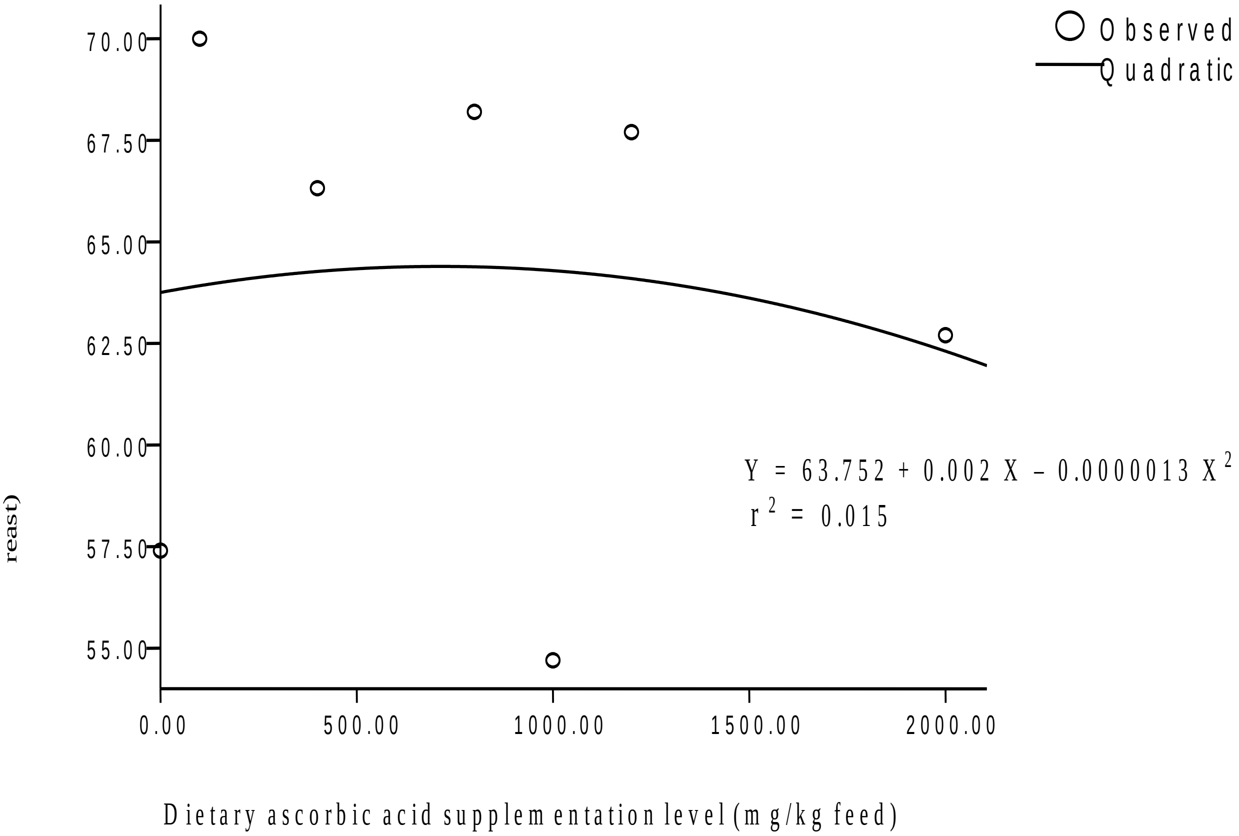

Figure 4.7 Effect of dietary ascorbic acid supplementation level on breast meat yield of Venda chickens at 13 weeks of age

Table 4.6 Dietary ascorbic acid supplementation levels for optimal feed conversion ratio (g DM feed/g live weight gain) and growth rate (g/bird/day) of female Venda chickens between 8 and 13 weeks, live weight (g/bird) and breast meat yield (g/breast) at 13 weeks old

Trait	Formula	r^2	Ascorbic acid level	Optimal Y level
FCR	$Y = 76.573 - 0.007X + 0.00000225X^2$	0.030	1000	71.8
Growth rate	$Y = 0.637 + 0.000208X - 0.000000080X^2$	0.644	1250	0.77
Live weight	$Y = 394.340 + 0.083X - 0.000028X^2$	0.473	1482	456
Breast meat yield	$Y = 63.752 + 0.002X - 0.0000013X^2$	0.015	769	65

r^2: Regression coefficient

X : Level of ascorbic acid supplementation

Table 4.7 Effect of dietary ascorbic acid supplementation (mg/kg DM) on dietary intake, digestibility, metabolisable energy (ME) and nitrogen retention (N) in female Venda chickens at 13 weeks old

Variables	Ascorbic acid supplementation level							SE
	V_0	V_{100}	V_{400}	V_{800}	V_{1000}	V_{1200}	V_{2000}	
Intake (g/bird/day)								
DM	43.80	39.40	45.60	45.20	51.40	43.80	39.60	4.435
N (g/bird/day)	1.00	0.84	0.98	1.06	1.20	1.00	0.86	0.102
Energy (MJ/bird/day)	0.60	0.54	0.63	0.62	0.71	0.60	0.55	0.062
Digestibility (decimal)								
DM	0.85	0.86	0.86	0.80	0.84	0.84	0.82	0.04
N (g/bird/day)	0.76	0.76	0.78	0.70	0.76	0.78	0.80	0.044
ME (MJ/kg DM)	11.71	11.93	11.84	11.06	11.48	11.64	11.36	0.532
N retention (g/decimal/day)	0.30	0.16	0.26	0.36	0.36	0.38	0.14	0.076

SE: Standard error

Table 4.8 Effect of dietary ascorbic acid supplementation level on carcass weight (g), dressing percentage and carcass parts (g) of female Venda chickens at 13 weeks of age

Diet	Carcass Weight	Dressing %	Gizzard	Breast yield	Thigh	Drum stick
V_0	330	77	26	57	22	21
V_{100}	301	79	37	69	22	24
V_{400}	328	85	33	66	28	25
V_{800}	359	79	40	66	26	26
V_{1000}	356	80	30	65	27	23
V_{1200}	377	80	39	68	22	19
V_{2000}	351	80	28	63	22	22
SE	30.267	9.227	2.833	6.934	2.090	2.377

SE: Standard error

CHAPTER 5

DISCUSSION, CONCLUSIONS AND RECOMMENDATION

5.1 Discussion

This study examined the effect of seven different levels of dietary ascorbic acid supplementation for optimum productivity and reduced mortality in Venda chickens between 1 and 6, and between 6 and 13 weeks of age. Results showed that ascorbic acid supplementation affected growth rate of Venda chickens between 1 and 6 weeks of age, and live weight of chickens at 6 weeks of age. Higher growth rate and live weight were observed as level of ascorbic acid supplementation increased. Supplementation above 800 mg/kg DM feed improved both growth rate and live weight. These results are similar to the findings of Whitehead and Keller (2003), Mbajiorgu *et al*. (2007) and Kadim *et al*. (2008) in broiler chickens. Sahin *et al*. (2003) indicated that ascorbic acid alleviates the negative effects of stress in chickens by decreasing synthesis and secretion of corticosteroids, thus increasing growth and live weight of chickens. However, the present results are different from the findings of Sifri *et al*. (1977) and Pardue *et al*. (1985) which showed that dietary ascorbic acid supplementation had no effect on growth rate of broiler chickens. The results of the present study show that ascorbic acid supplementation had no effect on growth rate of female Venda chickens between 6 and 13 weeks of age, and live weight at 13 weeks of age. Pardue *et al*. (1985) found similar results in broiler chickens. However, these results are different from the findings of Whitehead and Keller (2003), Mbajiorgu *et al*. (2007) and Kadim *et al*. (2008) in broiler chickens.

In this study, ascorbic acid supplementation had no effect on feed intake, feed conversion ratio, and intake as percentage of live weight of Venda chickens between 1 and 6 weeks old, and feed intake and feed conversion ratio of Venda chickens between 8 and 13 weeks old. Similarly, al-Taweil and Kassab (1990) and Lohakare *et al*. (2005) observed that supplementation with ascorbic acid had no effect on feed intake and feed conversion ratio in broiler chickens. Contrary to the above results, McKee and Harrison (1995), Blaha and Kreosna (1997), Whitehead and Keller (2003), Sahin *et al*. (2003), Asli *et al*. (2007) and Konca *et al*. (2008) observed that dietary ascorbic acid supplementation had an effect on feed intake and feed conversion ratio in broiler chickens. These authors observed a higher feed intake and improved feed conversion ratio with increased ascorbic acid supplementation. During stressful conditions, feed intake is compromised and micronutrient consumption is insufficient to support optimum performance. Therefore, ascorbic acid is important in facilitating utilization of nutrients under stressful conditions by bringing non-enzymatic scission of plant cell wall polysaccharides to induce hydroxyl radicals, which may lead to better nutrient digestion (Kadim *et al*., 2008). Ascorbic acid is implicated in feed conversion ratio because it is associated with the conversion of body proteins and fat into energy for production and survival through increased corticosterone secretion (Vathana *et al*., 2002).

Results of the present study indicate that although ascorbic acid supplementation had no significant effect on mortality of Venda chickens between 1 and 6 weeks, and between 8 and 13 weeks of age, mortality tended to decrease with increased levels of ascorbic acid supplementation. Similarly, results of Gross (1988) showed that as the dose of ascorbic acid increased from 0 to 330 mg/kg feed, mortality of leghorn type chickens reduced from 40 to 0 %. However, Vathana *et al.* (2002) showed that ascorbic acid supplementation level had no effect on mortality of broiler chickens supplemented with 40 mg/bird/day in drinking water during acute heat stress. Pardue *et al.* (1985) and Giang and Doan (1998) also observed reduced mortality in 1 to 4 weeks old broiler chicks. Ascorbic acid plays a role in the synthesis of leukocytes, especially phagocytes and neutrophilles, which play a part in the defence systems of the chickens (Null, 2001). Thus, dietary supplementation of ascorbic acid has been shown to provide resistance against infections and minimization of loss of productivity (Wu *et al.*, 2000).

The present study indicates that ascorbic acid supplementation had no effect on dietary intake, digestibility, metabolisable energy and nitrogen retention in Venda chickens between 7 and 13 weeks of age. Similarly, Mckee *et al.* (1997) and Mbajourgu *et al.* (2007) observed no effect of ascorbic acid supplementation level on dry matter intake, nutrient digestibility, nitrogen retention and metabolisable energy in broiler chickens. McKee *et al.* (1997) concluded that both reduced dry matter intake and blood flow to the gastrointestinal tract decreased metabolic energy input. These factors contribute to the depressed performance characteristic of birds (Mckee *et al.*, 1997). Spinu and Degen (1993) also observed no effect of ascorbic acid supplementation in nutrient digestibility of chickens reared during low temperatures. However, Sahin *et al.* (2001) and Seyrek *et al.* (2004) indicated that ascorbic acid supplementation had an effect on digestibility of nutrients. In the present study, metabolisable energy was approximately 11.00 MJ/kg DM. Nitrogen retention was very low, possibly contributing to poor growth rate and feed conversion ratio values.

Results of the current study indicate that different dietary ascorbic acid supplementation levels of 1050 and 1000 mg/kg DM feed optimized feed conversion ratio of Venda chickens between 1 and 6, and between 8 and 13 weeks of age, respectively. This study indicates that between 1 and 6, and between 8 and 13 weeks of age, dietary ascorbic acid supplementation levels of 1301 and 1250 mg/kg DM feed, respectively, optimized growth rate of Venda chickens. Live weight at 6 and 13 weeks of age were optimized on ascorbic acid supplementation levels of 1500 and 1482 mg/kg DM feed, respectively. Breast meat yield of female Venda chickens was optimized at ascorbic acid supplementation level of 769 mg/kg DM feed.

These results are in agreement with Sahin *et al*. (2002), Whitehead and Keller (2003) and Nameghi *et al*. (2007) who reported that optimum feed conversion ratio, growth rate, live weight and breast meat yield may be achieved by supplementation of ascorbic acid. Ascorbic acid supplementation levels for optimum feed conversion ratio and growth rate of Venda chickens between 1 and 6, and live weight at 6 weeks old were higher than levels that optimized feed conversion ratio and growth rate of female chickens between 8 and 13, and live weight at 13 weeks old. Supplementation level for optimized productivity decreased with age of the chickens. This can be explained by the chicks' higher requirements for ascorbic acid at younger age. Mbajourgu *et al*. (2007) detected improved growth rate and live weight in the ascorbic acid supplemented birds in comparison with those not supplemented with ascorbic acid. However, the optimum level of ascorbic acid supplementation was not calculated because of the short range of values used in their experiment. In the present study, ascorbic acid supplementation for optimum feed intake was not reached. It is possible that ascorbic acid supplementation level required for optimum feed intake in this study was higher than the range of values used in the study. However, the results show that at each growth phase, feed conversion ratio, growth rate, and live weight of Venda chickens were optimized at different ascorbic acid levels of supplementation. These findings have a lot of implications on ration formulation for indigenous chickens. No previous study on this issue regarding indigenous chickens was found.

Dietary ascorbic acid supplementation had no effect on carcass weight, carcass parts and dressing percentage of female Venda chickens at 13 weeks of age. Similar results were observed by Konca *et al*. (2008), who reported that supplemental ascorbic acid had no effect on carcass weight and carcass parts of broiler chickens. However, these results are different from the findings of Kutlu (2001), Sahin and Kucuk (2001), Sahin *et al*. (2002) and Lohakare *et al*. (2005), who showed that supplemental ascorbic acid had an effect on carcass weight, parts and dressing percentage in broiler chickens. Mbajiorgu *et al*. (2007) observed that dietary ascorbic acid supplementation had a significant effect on dressing percentage and breast meat yield of broiler chickens. Quarks and Adrian (1988) observed similar results when they supplemented broiler chickens with ascorbic acid before slaughter.

5.2 Conclusions

Dietary ascorbic acid supplementation level optimized feed conversion ratio, growth rate, live weight and breast meat yield of Venda chickens during starter and grower phases. However, the above parameters were optimized at different supplementation levels. Dietary ascorbic acid supplementation levels of 1050, 1301 and 1500 mg/kg DM feed optimized feed conversion ratio, growth rate and live weight at starter phase; and supplementation levels of 1000, 1250, 1482 and 769 mg/kg DM feed optimized feed conversion ratio, growth rate, live weight and breast meat yield, respectively, at grower phase. Levels for optimum live weights at both phases were higher than those of feed conversion ratio, growth rate and breast meat yield. However, feed intake was not optimized within the ascorbic acid values used in this experiment.

5.3 Recommendation

More studies should be done to ascertain levels of ascorbic acid supplementation for optimum feed intake, growth, live weight and meat yield in Venda chickens.

CHAPTER 6

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