EVALUATION OF CRUDE FIBRE DIGESTIBILITY IN VENDA AND ROSS 308 BROILER CHICKENS

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DECLARATION

I declare that the dissertation hereby submitted by me for the Degree of Master of Science in Agriculture (Animal Production) at the University of Limpopo is my own independent work and has not previously been submitted by me to this or another University. It is my own work in design and execution and that all materials contained therein have been duly acknowledged.

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

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DEDICATION

This work is dedicated to my late grandmother, Mokgadi Rosina Gafane, who was my role model and the pillar of my strength. I will forever remember her words of wisdom, that to be successful in life, one has to work very hard and reduce the hours of slumbering. May her soul rest in peace.

ABSTRACT

This study determined the effect of dietary crude fibre level on digestibility of Venda and Ross 308 broiler chickens aged 56 to 91 days. The digestibility and growth performances, gut organ physiology, meat quality traits and carcass characteristics of the chickens were evaluated in this study. Three hundred unsexed day-old Venda and 300 unsexed day-old Ross 308 broiler chicks were reared on similar commercial diets (starter and grower) until they were 55 days old. At day 56, one hundred and twenty female Venda and 120 female Ross 308 broiler chickens were randomly selected and blocked according to breed, then allocated to four experimental diets having different crude fibre levels of 3, 4, 5 or 7%. Each treatment had three replicates, with 10 chickens per replicate. Quadratic equations were used to determine dietary crude fibre levels for optimal live weight, ME intake, gut organ lengths and weights, meat quality traits and carcass characteristics. Linear models were used to determine the relationships between dietary crude fibre level and NDF digestibility, ADF digestibility and N-retention of the chickens. The results indicate that dietary crude fibre level did not affect *(P>0.05)* the feed intake, growth rate and live weight of Ross 308 broiler chickens aged 56 to 91 days. However, an increase in dietary crude fibre level significantly decreased *(P<0.05)* the NDF digestibility, ADF digestibility and N-retention of the chickens. The metabolisable energy intake of Ross 308 broiler chickens was optimized at a dietary crude fibre level of 4.1% (r^2 = 0.931). Dietary crude fibre level had no effect *(P>0.05)* on the villi height, crypt depths, villi height to crypt depth ratio, duodenum, jejunum, ileum, large intestine, gizzard, crop and caecal digesta pH values, weight and pH of carcass parts of Ross 308 broiler chickens. The lengths of jejunum and gastro-intestinal tracts of Ross 308 broiler chickens were optimized at dietary crude fibre levels of 5.5 (r^2 = 0.998) and 6.8 (r^2 = 0.979) %, respectively. The weights of duodenum and large intestines of Ross 308 broiler chickens were optimized at dietary crude fibre levels of 4.9 (r^2 = 0.793) and 5.2 (r^2 = 0.983) %, respectively. The L* value of breast meat of Ross 308 broiler chickens was optimized at a dietary crude fibre level of 5.6% (r^2 = 0.995). The breast meat shear force value of Ross 308 broiler chickens was optimized at a dietary crude fibre level of 4.6% (r^2 = 0.792).

Dietary crude fibre level had no effect *(P>0.05)* on feed intake, growth rate, FCR, ADF digestibility and N-retention of Venda chickens aged 56 to 91 days. The live weight of

Venda chickens was optimized at a dietary crude fibre level of 4.2% (r^2 = 0.999). An increase in dietary crude fibre level significantly increased *(P<0.05)* NDF digestibility of Venda chickens. Dietary crude fibre level did not affect *(P>0.05)* duodenum, jejunum, ileum, large intestine, gizzard, crop and caecal digesta pH values, and meat colour of Venda chickens. The jejunum, ileum and GIT lengths of Venda chickens were optimized at different dietary crude fibre levels of 5.8 (r^2 = 0.953), 3.5 (r^2 = 0.995) and 5.7 (r^2 = 0.992) %, respectively. The duodenum, caeca, large intestine and gizzard weights of Venda chickens were optimized at different dietary crude fibre levels of 5.0 (r^2 = 0.988), 4.6 (r^2 = 0.929), 5.7 (r^2 = 0.933) and 4.9 (r^2 = 0.983) %, respectively. Dietary crude fibre level did not affect *(P>0.05)* crypt depths of Venda chickens. However, the villi height and villi height to crypt depth ratio of Venda chickens were optimized at dietary crude fibre levels of 4.1 (r^2 = 0.386) and 4.5 (r^2 = 0.500) %, respectively. The thigh meat weight of Venda chickens was optimized at a dietary crude fibre level of 4.7% (r^2 = 0.959). The meat shear force and juiciness of Venda chickens were optimized at dietary crude fibre levels of 5.0 (r^2 = 0.910) and 5.5 (r^2 = 0.882) %, respectively.

Venda and Ross 308 broiler chickens had similar *(P>0.05)* ME intakes, duodenal and large intestinal lengths, crop digesta pH, villi height and crypt depth. However, Ross 308 broiler chickens had significantly higher *(P<0.05)* feed intake, growth rate, N-retention and better *(P<0.05)* FCR values than Venda chickens. Similarly, Ross 308 broiler chickens had longer *(P<0.05)* and heavier *(P<0.05)* digestive organs, higher *(P<0.05)* gizzard and caecal digesta pH values, heavier *(P<0.05)* carcass parts, higher *(P<0.05)* meat tenderness scores and redness values *(P<0.05)* than Venda chickens. Venda chickens had higher *(P<0.05)* NDF and ADF digestibility values, higher *(P<0.05)* duodenum, jejunum, ileum and large intestinal digesta pH values, higher *(P<0.05)* breast meat shear force values, better (P<0.05) meat flavour and higher *(P<0.05)* meat acceptability scores than Ross 308 broiler chickens. It is, therefore, concluded that dietary crude fibre level affected crude fibre digestibility of Venda and Ross 308 broiler chickens. The longer and heavier digestive tracts of Ross 308 broiler chickens indicate the larger surface area for more digestion and absorption to support high growth rates and live weights. The higher duodenum, jejunum, ileum and large intestinal digesta pH values of Venda chickens might have implications on crude fibre digestibility by these chickens.

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CHAPTER 1

INTRODUCTION

1.1 Background

Poultry production consists of two diverse systems, comprising commercial and traditional production systems (Gueye, 1998). Both systems engage in the domestication of various fowls such as chickens, turkeys, ducks and geese (Ogunmola *et al.,* 2013). The commercial system is mostly rearing exotic chicken breeds such as broiler chickens for meat production (John, 1995). These chickens are raised in specialized rearing systems, where they are fed specially formulated feeds to meet their nutrient requirements (Ogunmola *et al.,* 2013). They play a major role in the South African Poultry industry and the world as a whole, as sources of income and food. Traditional systems consist mainly of indigenous chickens, which are made up of different breeds such as Ovhambo, Naked neck, Venda, and Potchefstroom Koekoek chickens (John, 1995). These chicken breeds are kept by a majority of people in rural areas of South Africa (Mtileni *et al.,* 2011). They play a vital role as sources of income, nutrition and gifts to strengthen social bonding (Moreka *et al*., 2010). However, broiler chickens have rapid growth rate, which maximizes their feed consumption (Richards, 2003). Thus, high quality feeds are required to sustain their growth rates (Neves *et al.,* 2014). Conversely, indigenous chickens have slow growth rates and perform better even on feeds of lower quality (Kingori *et al.,* 2010). When compared to indigenous chickens, broiler chickens poorly digest high crude fibre feeds (Swennen *et al.,* 2010). NRC (1994) reported that dietary crude fibre in broiler feeds should be kept at levels between 3 and 4%, depending on the age of chickens. In contrast, Venda chickens had optimal crude fibre digestibility at dietary levels of 5 and 6% (Ginindza, 2014). The factors responsible for the differences in crude fibre digestibility between Venda and Ross 308 broiler chickens have not been extensively explored and the results are not conclusive.

1.2 Problem statement

Broiler and indigenous Venda chickens are economically and nutritionally very important to farmers and rural households of South Africa (Adeyemo *et al.,* 2013; Tarwireyi and Fanadzo, 2013). Broiler chickens have high growth rates (Liu *et al.,* 2011). Feeds of higher quality are, therefore, required to support their high growth rates (Neves *et al.,* 2014). These chickens poorly digest diets high in crude fibre (Sanaa *et al.,* 2014). Conversely, indigenous Venda chickens have low growth rates and do well on feeds high in course fibre fractions (Kingori *et al.,* 2010). Reasons for the differences in crude fibre digestion between the two breeds are not clear. It is, therefore, essential to determine dietary crude fibre level for optimal digestibility of Venda and Ross 308 broiler chickens.

1.3 Motivation

This study will add knowledge to the poultry farmers of South Africa and the world as a whole, in formulating rations that will enhance crude fibre digestibility of broiler and Venda chickens. Thus, an improved crude fibre digestion will increase nutrient utilization by chickens, thereby maximizing their productivity. This will improve socio-economic and nutritional status of poultry farmers and the world as whole.

1.4 Objectives

The objectives of this study were to:

i. determine the effects of dietary crude fibre level on feed intake, digestibility, feed conversion ratio and growth rates of Venda and Ross 308 broiler chickens.
ii. determine the effect of dietary crude fibre level on gastro-intestinal morphology, carcass characteristics and meat quality of Venda and Ross 308 broiler chickens.
iii. determine the optimal responses in feed intake, digestibility, feed conversion ratio, growth rates, gastro-intestinal morphology, carcass characteristics and meat quality of Venda and Ross 308 broiler chickens.

1.5 Hypotheses

The hypotheses of this study were as follows:

i. Dietary crude fibre level has no effect on feed intake, digestibility, feed conversion ratio and growth rates of Venda and Ross 308 broiler chickens.
ii. Dietary crude fibre level has no effect on gastro-intestinal morphology, carcass characteristics and meat quality of Venda and Ross 308 broiler chickens.
iii. Dietary crude fibre level has no effect on optimal responses in feed intake, digestibility, feed conversion ratio, growth rates, gastro-intestinal morphology, carcass characteristics and meat quality of Venda and Ross 308 broiler chickens.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Venda chickens are abundantly found in Limpopo Province, South Africa (Mtileni *et al.,* 2011). The production of these chickens benefits small-scale poultry farmers and rural households of South Africa and the world as a whole. They serve as their main source of income, nutrition and payments for cultural purposes (Norris and Ng'ambi, 2006). However, these chickens are known to have low growth rates, but tend to do well on feeds high in crude fibre. They are capable to convert available feeds around the house or village into highly nutritious and well-appreciated products (Mtileni *et al.,* 2009). Dietary crude fibre levels of 5 and 6% resulted in optimal diet digestibility by Venda chickens (Ginindza, 2014).

Broiler chickens are characterized by rapid growth rate and mostly attain slaughter-weight at between five to seven weeks of age (Hafez and Hauck, 2005). They are mostly bred in commercial farming and kept by the majority of households worldwide. They play vital roles as sources of income, nutrition and employment. However, these chickens have high feed consumption to support their fast growth rate (Richards, 2003). Their production potential is mostly limited by the presence of high dietary crude fibre (CF) contents in the diet. Dietary CF levels of 3-4% have been found to optimize diet digestibility in broiler chickens (González-Alvarado *et al.*, 2010; Swennen *et al.,* 2010). These CF levels are lower than 5 to 6% CF levels found in Venda chickens. Thus, there is a need to develop ways that will enhance crude fibre digestibility in broiler chickens.

2.2 Nutritional requirements of chickens

Nutrition is a crucial aspect in poultry production. It is important that diets formulated for chickens meet their nutrient requirements for optimal productivity (Mbajiorgu *et al.,* 2011; McDonald *et al.,* 2011). Most chicken diets contain maize meal for energy, soybean meal for protein and vitamin supplements (Sanaa *et al.,* 2014).

The nutritional requirements of chickens vary according to breed, age and type of production. There are nutritional requirements for chicks, egg type chickens and the meat type chickens known as broiler chickens (NRC, 1994). Six classes of nutrients are needed to sustain chicken production. These include carbohydrates, proteins, lipids, vitamins, minerals and water (NRC, 1994). Plavnik *et al.* (1997) and Nahashon *et al.* (2005) reported that the appetite in chickens depends on their nutrient requirements. Broiler chickens consume food to meet their energy requirements (NRC, 1994), whereas indigenous chickens eat to meet their limiting nutrients (Richarchs, 2003; Mbajiorgu*,* 2010). At young age, broiler chicks require diets high in crude protein, starch and fat to meet their nutrient requirements for growth (NRC, 1994).

Dietary crude fibre is one of the most important feedstuffs recommended in moderate amount in chicken diets (NRC, 1994). Naturally, chickens have an appetite for fibre and when insufficient amount is included in the diet, they have an increased consumption of litter, which includes wood shavings, papers and feathers (Hetland *et al.,* 2005). Several dietary crude fibre sources that are mostly included in poultry diets and their crude fibre contents are presented in Table 2.01.

2.3 Description and importance of dietary fibre in chickens

Fibre refers to the cell walls of plant tissues, which include cellulose, hemicelluloses and lignin (McDonald *et al.,* 2002). Dietary fibre (DF) is defined as the components of plant cell wall which are resistant to digestion by endogenous enzymes (Sharikhan *et al.,* 2010). Several studies conducted on poultry feeding considered dietary fibre as diluents of the diet (Mateos *et al.,* 2002; Rougiere and Carre, 2010). On the other hand, dietary fibre may also be described as non-starch polysaccharide (Thebaudin *et al.,* 1997). The fraction non-starch polysaccharides may be further divided into soluble and insoluble (McDonald *et al.,* 2002). The soluble fibre attracts water and turns into a gel, which slows down digestion processes (Montagne *et al.,* 2003). Soluble fibre also delays gastric emptying which in turn causes an extended feeling of fullness (Thebaudin *et al*., 1997). Insoluble fibre does not dissolve in water and provides bulking which assists in the absorption of water as digesta moves through the digestive system, thereby easing defecation (Thebaudin *et al.,* 1997).

Table 2.01 Crude fibre contents (%DM) of various feed ingredients used in poultry diets

Ingredients	Crude fibre*	Soluble NSP#	Insoluble NSP#
Wheat	3.4	2.5	7.4
Wheat bran	12.4	2.9	27.3
Lucerne meal	26.2	7.7	11.3
Peas	6.1	5.2	7.6
Oats hulls	31.2	<0.5	84.7
Maize	2.5	0.9	6.6
Barley	6.2	5.6	8.8
Soybean meal	7.9	6.3	9.2
Sunflower meal	26.7	4.5	23.1
Rapeseed meal	12.9	5.5	12.3
Oats	12.1	4.0	11.0

Authors * : NRC (1994)

\# : Knudsen (1997)

NPS : Non-starch polysaccharides

There are methods which categorise dietary fibre according to the differences in carbohydrate digestion and utilization. These include the neutral detergent fibre (NDF) and acid detergent fibre (ADF) (Van Soest *et al.,* 1991). The neutral detergent fibre measures hemicellulose, cellulose and lignin. It is the predictor of voluntary intake as it provides bulk or fill. The acid detergent fibre is a least digestible plant component and it includes cellulose and lignin. Its values are inversely related to digestibility, thus, the feedstuffs low in ADF are usually high in energy content (McDonald *et al.,* 2002).

2.4 Effect of dietary crude fibre level on nutrient digestibility of chickens

Dietary crude fibre (CF) content level has effect on digestion in chickens. Insoluble fibre in monogastric diets has been long considered a diluent of nutrients (Mateos *et al.,* 2002; Rougiere and Carre, 2010). It was observed that dietary crude fibre had negative impact on digestibility of starch and other nutrients in chickens (Choct *et al.,* 2010). However, Hetland *et al.* (2003) and Svihus *et al.* (2004) reported that moderate inclusion of dietary crude fibre resulted into increased crude fat and starch digestibility in broiler chickens and laying hens. Kalmendal *et al.* (2011) reported that the inclusion of 30% sunflower meal as a source of fibre in a pelleted maize-based diet resulted in a significant increase in digestibility of fat. Jiménez-moreno *et al.* (2011) found that a 2.5% crude fibre level in the diets of broiler chickens improved digestibility of most nutrients. Similarly, González-Alvarado *et al.* (2010) demonstrated that a 3% crude fibre level improved nutrient digestibility in broiler chickens. Nutrient digestibility in broiler chickens decreased as dietary crude fibre was increased to 7.5% (Jiménez-moreno *et al.,* 2013). On the other hand, Ginindza (2014) found that crude fibre digestibility was optimized at levels of between 5 and 6% in Venda chickens. In the experiment with layer chickens, it was found that diets containing 6.02 and 6.23% crude fibre did not affect organic matter digestibility, but decreased the digestibility of crude proteins and resulted in increased digestibility of ether extract (Abdallah *et al.,* 2015).

2.5 Effect of dietary crude fibre level on the performance of chickens

It has commonly been accepted that an increase in dietary fibre level reduces the feed intake in poultry (Mateos *et al.,* 2012). However, different authors have demonstrated that the inclusion of moderate amounts of insoluble dietary fibre does not affect voluntary feed intake in broilers (Gonzalez-Alvarado *et al*., 2007; Jimenez- Moreno *et al*., 2009; Jimenez- Moreno *et al*., 2011), growing turkeys (Sklan *et al*., 2003) or laying hens (Pérez-Bonilla *et al.,* 2011). In contrast, Sacranie *et al.* (2012) reported that feeding broiler chickens with different fibre sources and increasing fibre levels reduced the feed intake. Moreover, Castanon *et al.* (1990) reported that increasing fibre levels reduced feed intake of broiler chickens. On the other hand, González-Alvarado *et al.* (2010) reported that the inclusion of 3% soybean hulls as source of dietary fibre resulted in a reduced average daily feed intake in broiler chickens. Conversely, Hetland and Svihus (2001) observed that an inclusion of 4% oat hulls as source of fibre in the diet of broiler chickens increased feed intake.

Sarikhan *et al.* (2010) reported that weight gain was increased by the inclusion of insoluble fibre in the diet of broiler chickens. Similarly, Jiménez-Moreno *et al.* (2009) found that the inclusion of 3% of either oat hulls or sugar beet pulp as sources of fibre improved the weight gain of broiler chickens. Abdallah *et al*. (2015) found that the laying hens had increased body weight with crude fibre inclusion levels of between 4.65 and 5.9%. The results correlate with the ones observed by Incharoen and Maneechote (2013), who found that the pullets had increased final body weight and weight gain with the inclusion of 3 and 6% whole rice hulls as sources of fibre. Ahmad *et al.* (2007) and Mushtaq *et al.* (2007) found that the inclusion of 18% rapeseed meal as source of fibre had no effect on body weight gain of turkeys.

Sarikhan *et al.* (2010) found that the inclusion of insoluble fibre in the diet of broiler chickens improved the feed conversion ratio. Similarly, Abdallah *et al.* (2015) found that high levels of dietary crude fibre produced a better feed conversion ratio of laying hens. Gonzalez-Alvarado *et al.* (2007) and Jimenez-Moreno *et al.* (2009) also reported the improvements of feed conversion ratio when 2.4 and 3.3% dietary crude fibre levels were included in the diet of broiler chickens.

2.6 Effect of dietary crude fibre level on digestive organs and carcass parts of chickens

Dietary crude fibre possesses a physiological role in the digestive tract, interacting with gastrointestinal functions and nutrient utilization (Jiménez-Moreno *et al.,* 2010). Several studies reported that increasing the crude fibre content of broiler chickens' diets increases the size of the gastrointestinal tract (Hetland and Svihus, 2001; González- Alvarado *et al.,* 2008; Amerah *et al.,* 2009). Similarly, González-Alvarado *et al.* (2008) observed that high fibre diets generate physical distension of the walls of gastro-intestinal tract (GIT), increasing GIT capacity and gut fill. On the other hand, Jiménez-Moreno *et al.* (2010) reported that the presence of finely ground dietary fibre in broiler feeds increased the rate of digesta passage as well as the physical capacity of the GIT. Chickens on diets high in crude fibre levels had heavier digestive organs (Pluske *et al.,* 2003; Gonzalez-Alvarado *et al.,* 2010; Jimenez-Moreno *et al.,* 2011).

Jimenez-Moreno *et al.* (2011) also reported that the relative lengths of the small intestines and caeca were not affected by dietary crude fibre content. Amerah *et al.* (2009) and Sklan *et al.* (2003) reported that increasing the insoluble fibre content of the diet has resulted in a reduced length of the small intestines. On the contrary, Khempaka *et al.* (2009) found that the ileal and jejunal lengths were increased when insoluble fibre was included in the diets of broiler chickens.

Several studies have demonstrated that the increased dietary fibre stimulated gizzard development (Jiménez-Moreno *et al.,* 2010; Hetland and Svihus, 2001; Hetland *et al.,* 2003; Hetland *et al.,* 2005) and reduced the occurrence of spontaneous gizzard erosion and ulceration (Kaldhusdal *et al.,* 2012). Similarly, Jorgensen *et al.* (1996) reported that broiler chickens had the increased weights of proventriculus and gizzard when dietary crude fibre was increased in the diet. These authors postulated that the heavy weight of these organs might have resulted from an increased peristalsis, segmentation and mass movement due to the presence of high fibre fraction in the diets.

Dietary crude fibre level has effect on the pH of digestive organs of the chickens. Jiménez-Moreno *et al.* (2009) indicated that the inclusion of oat hulls and sugar beet pulp as sources of dietary fibre significantly reduced gizzard pH. Studies indicated that there were no differences in the duodenal pH when dietary crude fibre levels were added to broiler chicken diets (Jiménez-Moreno *et al.,* 2009). A decreased gizzard pH was observed in response to a coarse particle size of the diet and this improved the gut health of chickens (Engberg *et al.,* 2004).

The intestinal villi are the important tubular projections responsible for the absorption of nutrients in the small intestines (Caspary, 1992). The longer the intestinal villi, the higher the surface area for absorption of nutrients (Montagne *et al.,* 2003). They are consisting of crypt depths, which are the regions in which the division of stem cells takes place, allowing for the replacement of the epithelial cells (Iji *et al.,* 2001). Deeper crypts are necessary for the greater production of enterokinase, which is the precursor for the production of trypsin. Trypsin is an enzyme responsible for the digestion of protein, which culminates into increased availability of amino acids vital for chickens' performance (Agboola *et al.,* 2016). Dietary crude fibre level has effect on the villi height and crypt depths of chickens. Sarikhan *et al.* (2010) reported that the inclusion of 0.75% crude fibre level in the diet of broiler chickens increased the villi height and resulted in increased surface area for absorption of nutrients. Jimenez-Moreno *et al.* (2011) and Mateos *et al.* (2012) reported that the dietary crude fibre levels of 4.4% did not affect the villi height, but affected crypt depth and the villi height to crypt depth ratio of broiler chickens aged one to 42 days. Kalmendal *et al.* (2011) reported that an increase in dietary crude fibre level resulted in a decreased villi length of broiler chickens aged 42 days.

Shahin and Abdelazim (2005) indicated that broiler chickens fed a high fibre diet of 5.0% had lower carcass weights than those fed low fibre diets of 1.6%. Sarikhan *et al.* (2010) found that the inclusion of 3.8% dietary crude fibre in the diet of broiler chickens resulted in higher carcass weights and breast meat yield. However, this level (3.8%) did not influence the relative thigh percentage. Shahin and Abdelazim (2005) demonstrated that the inclusion of 8% dietary fibre in broiler chicken diets reduced carcass weight of the chickens. Mourao *et al.* (2008) indicated that broiler chickens fed oat hulls as sources of fibre had lower carcass weights and carcass relative live weights due to a more developed gastrointestinal tract. Iyayi *et al.* (2005) found that dietary crude fibre level had no effect on the weights of thigh, drumstick and wings.

2.7 Effect of dietary crude fibre level on meat quality of chickens

Meat quality is one of the most economic traits in chickens (Motsepe, 2016). It describes the properties and perceptions of meat (Maltin *et al.,* 2003). The major determinants of meat quality consist of aroma, tenderness, colour, juiciness and flavour (Mekchay *et al.,* 2010).

2.7.1 Effect on meat colour and pH

Meat colour is an important quality attribute for consumer's selection of fresh meat at the retail level and for the consumer's final evaluation and acceptance of a meat product at time of consumption (Fletcher *et al.,* 2000; Owens *et al.,* 2000; Bell and Weaver, 2002; Woelfel *et al.,* 2002; Teye *et al.,* 2015). Colour is determined by using the instrumental (Lovibond tintometer/Hunter colour Labs) aids and it is expressed as L*-value which indicates the lightness of the meat, a*-value for redness and b*-value for yellowness. The red colour of meat indicates the high content of myoglobin, which is a protein of the meat (Mancini and Hunt, 2005). The remaining colour comes from the haemoglobin, which occurs, mainly in the circulating blood, but a small amount can be found in the tissues after slaughter (Fanatico *et al.,* 2007). Meat colour is mostly influenced by breed, diet, age, sex or exercise of animals (Xiong *et al.,* 1999). The indigenous chicken muscles tend to be lighter, redder, and yellower than the broiler chicken muscles (Wattanachant, 2004). This result was probably related to the differences in muscle pH between the breeds. Fletcher (1999) indicated that meat pH and meat colour are highly correlated. Meat high in pH values is mostly dark, firm and dry, whereas the one with low pH is often pale, soft and exudative (Wattanachant, 2008). It was found that the inclusion of 10% dehydrated pasture as source of fibre significantly increased the yellowness of broiler breast skin (Mourão *et al*., 2008). The authors also reported that the inclusion level of 10% of citrus pectin as source of fibre reduced intramuscular pH of poultry breast meat. There is limited information on the effect of dietary crude fibre levels on meat colour and pH in chickens.

2.7.2 Effect on sensory attributes

Palatability of meat products depends mainly on aroma, flavour, tenderness, juiciness, *etc*. Consumer studies showed that flavour and texture are the most important amongst all the quality attributes (Chrystall, 1994; Dransfield and Sosnicki, 1999). Tenderness and juiciness of the meat are the two important factors generally preferred by the consumers (Biswas *et al.,* 2011). Both factors are influenced by several factors such as breed, age, type of feed given to animals, the cut of meat chosen, the duration of cooking, *etc* (Takahashi, 1996). Fanatico *et al.* (2007) reported that indigenous chicken meat possesses better taste than meat of fast-growing genotypes such as broiler chickens. Similarly, Wattanachant (2004) found that indigenous chicken meat had a unique taste and texture. The inclusion of dietary crude fibre in the diet of large white turkey resulted in the improved flavour and juiciness, but decreased tenderness (Schonfeldt *et al.,* 1993). Iyayi *et al.* (2005) reported that the increased dietary crude fibre levels did not affect the meat juiciness, but decreased tenderness and increased flavour in broiler chickens. Data on the effect of dietary crude fibre level on sensory attributes of chickens is limited and not extensive.

2.7.3 Effect on shear force

Shear force indicates the maximum force required to cut through a sample and it represents meat tenderness, i.e., a higher shear force value indicates poor tenderness or tougher meat (Cavitt *et al.,* 2004). Meat tenderness is the sum total of the mechanical strength of skeletal muscle tissue and its weakening during the post-mortem aging of meat (Muchenje *et al*., 2009). It is, also, a function of the collagen content, heat stability and the myofibrillar structure of the muscle and is the most important sensory characteristic of meat (Strydom *et al.,* 2000; Sebsibe, 2006). Tenderness varies with the animal species (Muchenje *et al.,* 2008). Differences in muscle fibre size affect the shear force property of meat. Mahon (1999) reported that fast-growing chickens possess longer fibre diameters as compared to slow-growing chickens. Tang *et al.* (2009) demonstrated that longer fibre diameters are often associated with the higher shear force and meat toughening. Iyayi *et al.* (2005) found that the increased dietary crude fibre levels increased the shear force values of broiler chickens' meat. Kung *et al.* (2008) found that the inclusion of 0.15% and 30% dietary fibre in the diet of geese did not affect the meat shear force. However, data on the effect of dietary crude fibre on meat shear force of chickens is limited.

2.8 Conclusion

Numerous studies have been conducted on the effect of dietary crude fibre level on productivity performance of broiler chickens. Few studies were found on the effect of dietary crude fibre level on productivity of Venda chickens. However, these studies are inconclusive and not extensive. It was found that Venda chickens digest crude fibre better than broiler chickens. There is a lack of information on the factors that contribute to the differences in crude fibre digestibility between these two chicken breeds. Thus, it is essential to explore the biological reasons responsible for the variations in crude fibre digestibility between Venda and Ross 308 broiler chickens.

CHAPTER 3

METHODOLOGY

3.1 Study site

The study was conducted at the Animal Unit, University of Limpopo, South Africa. The ambient temperature around the study area ranges between 20 and 36°C during summer and between 10 and 25°C during winter season (Kutu and Asiwe, 2010). University of Limpopo lies at latitude 27.55°S and longitude 24.77°E (Kutu and Asiwe, 2010).

3.2 Preparation of the house

The experimental house was cleaned with water and disinfected with Jeyes fluid (high boiling tar acid with poly-alkylphenol fraction). Thereafter, the house was left to dry for seven days, to break the life cycles of disease-causing organisms that were not killed by the disinfectant. All the equipment such as drinkers, feeders and the partitions were cleaned. The house was heated 24 hours before the arrival of the chicks. Fresh water with a disinfectant was prepared daily for the footbath.

3.3 Acquisition of materials and chickens

Feed ingredients for the experimental diet were purchased from UPS Verspreiders Milling Company, located in Mokopane, South Africa. They were mixed at the University of Limpopo, following the ration formulation using Java computer program (opti-kuckeliku, optimal feed formulation for poultry) to produce grower diets for the experiment. The commercial starter and grower diets were purchased from NTK Company in Polokwane, South Africa. The medicines, vaccines and chemicals for the experiment were purchased in advance prior to the commencement of the experiment. Day-old broiler chicks used in the experiment were obtained from Lufafa Hatchery in Letsitele, South Africa, whereas day-old Venda chicks were obtained from the University of Limpopo Hatchery Unit.

3.4 Experimental procedures, dietary treatments and design

Three hundred unsexed day-old Venda and 300 unsexed day-old Ross 308 broiler chicks were reared on similar commercial diets (starter and grower) until they were 55 days old. The experiment was commenced when the chickens were aged 56 days and terminated at 91 days of age. At the commencement of the experiment, one hundred and twenty female chickens per breed were randomly selected, then allocated to four experimental diets having different crude fibre levels of 3, 4, 5 or 7%. Thus, a 2 (breeds) x 4 (Crude fibre levels) factorial arrangement in a completely randomized design was used. Each treatment had three replicates, with 10 chickens per replicate. A total number of 24 pens were used, each pen measuring 2.5m^2. Each pen was equipped with one feeder and two drinkers. The floor pen was covered with saw dust of 6cm thickness which was changed whenever wet. Light was provided 24 hours throughout the experimental period (natural light during the day and artificial light during the night). Feed and water were offered *ad libitum.* The vaccination programme for the chicks was done according to the procedures used at the University of Limpopo Experimental Farm (appendix A). The treatments for the experiment and the feed ingredients of the experimental diets are presented in Tables 3.01 and 3.02, respectively.

Table 3.01 Dietary treatments for the experiment

Diet code	Diet description
FVC_3	Female Venda chickens fed a grower diet containing 3% crude fibre, 20% crude protein and 11.5 ME/kg DM
FVC_4	Female Venda chickens fed a grower diet containing 4% crude fibre, 20% crude protein and 11.5 ME/kg DM
FVC_5	Female Venda chickens fed a grower diet containing 5% crude fibre, 20% crude protein and 11.5 ME/kg DM
FVC_7	Female Venda chickens fed a grower diet containing 7% crude fibre, 20% crude protein and 11.5 ME/kg DM
FRC_3	Female Ross 308 broiler chickens fed a grower diet containing 3% crude fibre, 20% crude protein and 11.5 ME/kg DM
FRC_4	Female Ross 308 broiler chickens fed a grower diet containing 4% crude fibre, 20% crude protein and 11.5 ME/kg DM
FRC_5	Female Ross 308 broiler chickens fed a grower diet containing 5% crude fibre, 20% crude protein and 11.5 ME/kg DM
FRC_7	Female Ross 308 broiler chickens fed a grower diet containing 7% crude fibre, 20% crude protein and 11.5 ME/kg DM

FVC: Female Venda chickens.

FRC: Female Ross 308 broiler chickens.

Table 3.02 Ingredients and nutrient composition of experimental diets

	Experimental diet			
Ingredient	**3% CF**	**4% CF**	**5% CF**	**7% CF**
Maize meal (%)	63.63	63.59	62.82	64.05
Wheat bran (%)	8.42	8.90	9.35	10.00
Maize gluten meal	3.40	3.87	3.37	3.40
Soya bean meal (44% CP)	13.38	12.46	13.30	11.34
Fish meal (2- 8% fat) (%)	5.00	5.00	5.00	5.00
Sunflower oil (%)	2.50	2.50	2.50	2.50
Limestone (%)	1.25	1.25	1.25	1.25
Dicalcium Phosphate (%)	1.30	1.30	1.30	1.30
DL- Methionine (%)	0.18	0.18	0.19	0.19
L- Lysine (%)	0.21	0.20	0.22	0.23
Vitamin/Trace Element Premix (%)	0.23	0.25	0.20	0.24
Salt (%)	0.50	0.50	0.50	0.50
Total (%)	100	100	100	100
Nutrient analysis (calculated)				
Metabolisable energy (MJ/kg)	11.50	11.50	11.50	11.50
Crude protein (%)	20.00	20.00	20.00	20.00
Crude fibre (%)	3.00	4.00	5.00	7.00
Lysine (%)	1.10	1.10	1.10	1.10
Methionine (%)	0.56	0.54	0.54	0.54
Methionine + Cysteine (%)	0.84	0.84	0.84	0.84
Threonine (%)	0.81	0.75	0.73	0.73
Calcium (%)	0.90	0.90	0.90	0.90
Potassium (%)	0.67	0.64	0.64	0.64
Sodium (%)	0.25	0.25	0.25	0.25
Available Phosphorus (%)	0.65	0.45	0.45	0.45

CF : Crude fibre

3.5 Data collection

3.5.1 Performance

Live weight per bird was measured at the commencement of the experiment and, thereafter, at weekly intervals using an electronic weighing balance. Daily feed intake per bird was measured by subtracting the weight of feed leftover from that offered per day and the difference was divided by the total number of chickens in the pen. Feed conversion ratio per bird was calculated as the total amount of feed consumed divided by the weight gain of the chickens.

Digestibility was determined when the chickens were between 84 and 91 days old. Two birds were randomly selected from each replicate and transferred to metabolic cages for the measurement of digestibility. The trial was conducted in the specially designed metabolic cages, which were fitted with automated and separated feed and water troughs. A three-day acclimatization period was allowed prior to a four-day collection period. Faeces voided by the chickens were collected daily at 09h30. Care was taken to ensure that the droppings were not contaminated with feathers, scales, feeds and debris. Apparent digestibility (AD) was calculated using the following formula:

$$AD\ (\%) = \frac{\text{Amount of nutrient ingested} - \text{Amount of nutrient excreted}}{\text{Amount of nutrient ingested}} \times 100$$

3.5.2 Carcass characteristics

At 91 days, two chickens per replicate were weighed and slaughtered by the method of cervical dislocation in accordance with the standards that comply with the animal welfare requirements of the University of Limpopo Animal Research Ethics Committee (Ethical certificate: AREC/02/2017: PG). The digestive tract with its contents was removed from the abdominal cavities of the chickens. The length and weight of the whole gastro-intestinal tract, comprising the crop, gizzard, small intestines, large intestines and caeca were measured. The digesta pH was measured at each gut segment using a digital pH meter (Crison, Basic 20 pH meter). Samples of the ileum were taken for villi height determination. The samples (2.5cm) were cut approximately 5cm from the Meckel’s diverticulum prior to the opening for cleaning. The samples were then cut lengthwise along the line of mesentery, pinned at four corners to a piece of cardboard and then transferred into containers with formalin. Samples were transferred into alcohol with various concentrations and then embedded in liquid paraffin to make blocks (Hamedi *et al.,* 2011). Each sample was cut longitudinally into a cross-section (6.0µm) using rotary microtome (Accu-Cut®) and stained with hematoxylin and eosin, then transferred onto glass slides. Slides were examined using an optical microscope (Eclipse E600) fitted with a video camera (XC77E, Sony Corp) and the images were captured at 4x magnitude and analysed using an image analysis software (Visilog 5.2) to measure the villi height and crypt depths. The carcass weights, together with the weights of various cuts (breast, drumstick and thigh) were measured using an electronic sensitive weighing balance.

3.5.3 Meat quality

Meat colour was determined using Minolta (CR-100) Chroma Meter. Three measurements were taken from the breast, thigh and drumstick and the colours were recorded as L* to indicate lightness, a* for redness and b* for yellowness of the meat (Norouzi *et al.,* 2014; Sharbati *et al.,* 2015).

The measurement of muscles' pH was done by making a small incision on the breast, thigh and drumstick regions and the pH measuring electrode was inserted. The readings were taken at approximately 1 minute after the insertion of electrode (Wattanachant *et al.,* 2005).

Sensory evaluation was done according to Wattanachant *et al.* (2004). Thigh muscles with bones and skins still attached were placed in roasting pans (eight thighs per pan per treatment) and cooked at 176ºC in a conventional preheated electric oven to 80ºC internal muscle temperature. The cooked portions were then removed from the oven, allowed to cool for 10 minutes, deboned, and then sliced into uniform sizes (about 2cm) and wrapped with coded aluminium foils and presented to the trained panellists. A total of forty (40) panellists aged between 25 and 30 years (17males and 23 females) were randomly selected to evaluate the products. Each panellist was provided with two cubes of meat per replicate and unsweetened lemon juice to serve as neutralizer between the chewings of meat cubes. They were instructed to score each sample for tenderness, juiciness, flavour and overall acceptability. A five-point category scale was used to evaluate the sensory characteristics of the products as illustrated in Table 3.03.

Table 3.03 Evaluation scores used by the sensory panel

	Meat sensory attribute			
Score	Tenderness	Juiciness	Flavour	Overall acceptability
1	Too tough	Much too dry	Very bad flavour	Strongly dislike
2	Tough	Dry	Poor flavour	Dislike
3	Neither tough nor tender	Neither dry nor juicy	Neither bad nor good flavour	Neither dislike nor like
4	Tender	Juicy	Good flavour	Like
5	Too tender	Too juicy	Very good flavour	Strongly like

Source: Wattanachant *et al.* (2004)

Shear force values were determined according to Dawson *et al.* (1991). One breast per replicate was cut into equal halves and the right breasts were boiled for 30 minutes in the separated pots. Thereafter, the meat was allowed to cool for 20 minutes and chilled overnight at 5°C. The following day, three round cores of 1.3cm in diameter were removed parallel to the longitudinal orientation of the muscle fibres of each chilled breast meat using a hand-held coring device. The Warner-Bratzler shear device was mounted on a Universal Instron Apparatus and the cross-head speed was set to 200mm/min and a 10-kg load cell was used. The cross-head was applied perpendicularly to the muscle fibre axis of each sample and the peak of the shear force value profile was recorded.

3.6 Chemical analysis

Dry matter of the feeds and faeces were determined by drying the feeds and faeces in the oven for 24 hours at a temperature of 105^{o}C. Neutral and acid detergent fibre contents of feeds and faeces were determined according to Van Soest *et al*. (1991). Ash content of the feeds and faeces were determined by ashing the samples at 600^{o}C in a muffle furnace overnight. Nitrogen contents of the feeds and faeces were determined by Kjeldahl method (AOAC, 2012). Amino acid and fatty acid contents of feeds were analysed by ion-exchange chromatography at the University of Limpopo.

Gross energy of the feeds and faeces was determined using a bomb calorimeter (AOAC, 2012).

3.7 Data analysis

Data on the effect of dietary crude fibre level on feed intake, digestibility, feed conversion ratio, growth rate, live weight, carcass characteristics, meat quality and gastro-intestinal morphology of Venda and Ross 308 broiler chickens was subjected to ANOVA using General Linear Model procedures of Statistical Analysis system (SAS, 2014). The model $Y_{ij} = \mu + T_i + e_{ij}$ was applied, where Y_{ij} = feed intake, digestibility, feed conversion ratio, growth rate, live weight, carcass characteristics, meat quality and gastro-intestinal morphology; μ = the overall mean; T_i = dietary treatments (FVC_3, FVC_4, FVC_5, FVC_7, FRC_3, FRC_4, FRC_5, FRC_7) and e_{ij} = random error. Where there were significant differences ($P<0.05$) between treatment means, Tukey's honestly significant difference test (HSD) was used for mean separations. The responses in productivity parameters to crude fibre level were modelled using the following quadratic equation:

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

Where Y = ME intake, live weight, gut organ physiology, carcass parts and meat quality; a = intercept; b_1 and b_2 = coefficients of the quadratic equation; x = crude fibre level and $-b_1/2b_2$ = x value for optimal response. The quadratic model was fitted to the experimental data by means of the NLIN procedure of SAS (2014). The quadratic model was used because it gave the best fit.

The linear relationships between dietary crude fibre level and NDF digestibility, ADF digestibility and N-retention of Venda and Ross 308 broiler chickens were modelled using the following linear regression equation:

$$Y = a + bx$$

Where Y = NDF digestibility, ADF digestibility and N-retention; a = intercept; b = coefficient of the linear equation; x = dietary crude fibre level.

CHAPTER 4

RESULTS

4.1 The nutrient composition of experimental diets

The results of nutrient composition of experimental diets are presented in Table 4.01. The experimental diets were formulated to meet the nutrient requirements of chickens as recommended by the National Research Council (NRC, 1994). The diets contained similar crude protein and energy levels. All the nutrients in the diets were of the same levels, but with various dietary crude fibre levels of 3, 4, 5 or 7%.

Table 4.01 Analysed nutrient composition of the experimental diets for Venda and Ross 308 broiler chickens aged 56 to 91 days

Diet Code*	Dry matter (%)	Energy (MJ/kg DM)	Crude Protein (%)	Crude fibre level (%)
FRC_3 & FVC_3	94	17	20	3
FRC_4 & FVC_4	94	17	20	4
FRC_5 & FVC_5	94	17	20	5
FRC_7 & FVC_7	94	17	20	7

FRC : Female Ross 308 broiler chickens

FVC : Female Venda chickens

CF : Crude fibre

DM : Dry matter

MJ : Megajoules

* : diet codes are 3%, 4%, 5% and 7% CF

4.2 Growth performance and digestibility

The results of the effect of dietary crude fibre level on diet dry matter (DM) intake, growth rate, feed conversion ratio (FCR), live weight, digestibility, metabolisable energy (ME) intake and nitrogen (N) retention of Venda and Ross 308 broiler chickens aged 56 to 91 days are presented in Table 4.02. Dietary crude fibre level had no effect ($P>0.05$) on diet DM intake, growth rate, FCR and live weight of Ross 308 broiler chickens. Similarly, dietary crude fibre level had no effect ($P>0.05$) on DM intake, growth rate, FCR, acid detergent fibre digestibility (ADFD) and nitrogen (N) retention of Venda chickens. However, dietary crude fibre level had an effect ($P<0.05$) on NDF and ADF digestibility, ME intake and N-retention of broiler chickens. Similarly, dietary crude fibre level had effect ($P<0.05$) on the live weight, NDFD, ADFD and ME intake of Venda chickens.

Broiler chickens on diets having 3 or 4% crude fibre (CF) contents had higher ($P<0.05$) NDF digestibility values than those on diets having 5 or 7% CF. However, broiler chickens on diets having 3 or 4% CF had similar ($P>0.05$) NDF digestibilities. Similarly, broiler chickens on diets having 5 or 7% CF had the same ($P>0.05$) NDF digestibilities. Broiler chickens offered a diet containing 3% CF had a higher ($P<0.05$) ADF digestibility value than those on diets having 4, 5 or 7% CF. Similarly, broiler chickens on a diet having 4% CF had a higher ($P<0.05$) ADF digestibility value than those on diets having 5 or 7% CF. However, broiler chickens on diets having 5 or 7% CF had similar ADF digestibilities. Broiler chickens on diets having 3, 4 or 5% CF had higher ($P<0.05$) ME intakes than those on a diet having 7% CF. However, broiler chickens on diets having 3, 4 or 5% CF had similar ($P>0.05$) ME intakes. Broiler chickens on a diet having 3% CF had a higher ($P<0.05$) N-retention value than those on diets having 4, 5 or 7% CF. Similarly, broiler chickens on a diet containing 4% CF had a higher ($P<0.05$) N-retention value than those on diets having 5 or 7% CF. However, broiler chickens on diets having 5 or 7% CF had the same ($P>0.05$) N-retention values.

Strong and negative relationships were observed between dietary crude fibre level and neutral detergent fibre digestibility (r^2 = 0.805), acid detergent fibre digestibility (r^2 = 0.798) and nitrogen retention (r^2 = 0.686) of Ross 308 broiler chickens (Figures 4.01, 4.02 and 4.04, respectively and Table 4.03). The metabolisable energy intake of Ross 308 broiler chickens was optimized at a dietary crude fibre level of 4.1% (r^2 = 0.931) (Figure 4.03).

Venda chickens on diets having 4 or 5 % CF had higher ($P<0.05$) live weights than those on a diet having 7% CF. However, Venda chickens on diets having 3, 4 or 5% CF had similar ($P>0.05$) live weights. Similarly, Venda chickens on diets having 3 or 7% CF had the same ($P>0.05$) live weights. Venda chickens on a diet containing 7% CF had a higher ($P<0.05$) NDF digestibility value than those on diets having 3 or 4% CF. Similarly, Venda chickens on a diet having 5% CF had a higher NDF digestibility value than those on diets having 4% CF. However, Venda chickens on diets having 5 or 7% CF had similar ($P>0.05$) NDF digestibilities. Similarly, Venda chickens on diets having 3 or 4% CF had the same ($P>0.05$) NDF digestibilities. Venda chickens on diets having 3 or 5% CF had the same ($P>0.05$) NDF digestibility values. Venda chickens on a diet having 7% CF had a higher ($P<0.05$) ME intake than those on a diet having

5% CF. However, Venda chickens fed diets containing 3, 4 or 7% CF had similar (P>0.05) ME intakes. Similarly, Venda chickens on diets having 3, 4 or 5% CF had the same (P>0.05) ME intakes.

The live weight of Venda chickens was optimized at a dietary crude fibre level of 4.2% (r^2 = 0.999) (Figure 4.05). There was a strong and positive relationship between dietary crude fibre level and neutral detergent fibre digestibility (r^2 = 0.738) of Venda chickens (Figure 4.06 and Table 4.03).

Chicken breed had no effect (P>0.05) on the ME intake. However, Ross 308 broiler chickens had higher (P<0.05) diet DM intake, growth rate, live weight and N-retention values than Venda chickens. Similarly, broiler chickens had better (P<0.05) FCR values than Venda chickens. However, Venda chickens had higher (P<0.05) NDF and ADF digestibility values than Ross 308 broiler chickens (Table 4.02). No deaths of chickens were recorded during this study.

4.3 Gastro-intestinal tract

The results of the effect of dietary crude fibre level on the length of gut organs of Ross 308 broiler and Venda chickens aged 91 days are presented in Table 4.04. Dietary crude fibre level had no effect (P>0.05) on the lengths of duodenum, ileum, large intestines and caeca of Ross 308 broiler chickens. Similarly, dietary crude fibre level had no effect (P>0.05) on the lengths of large intestines and caeca of Venda chickens. However, dietary crude fibre level had effect (P<0.05) on the lengths of jejunum and gastro-intestinal tract (GIT) of broiler chickens. Similarly, dietary crude fibre level had effect (P<0.05) on the lengths of duodenum, jejunum, ileum and GIT of Venda chickens.

Broiler chickens offered a diet containing 5% CF had a higher (P<0.05) jejunal length value than those on a diet having 3, 4 or 7% CF. Similarly, broiler chickens offered diets having 5 or 7% CF had higher (P<0.05) jejunal length values than those on a diet having 3% CF. However, broiler chickens on diets having 5 or 7% CF had similar (P>0.05) jejunal lengths. Broiler chickens fed a diet having 7% CF had a higher (P<0.05) GIT value than those on diets having 3 or 4% CF. Similarly, broiler chickens on a diet having 4% CF had a higher (P<0.05) GIT value than those on a diet having

3% CF. However, broiler chickens on diets having 5 or 7% CF had similar (P>0.05) GIT values. Similarly, broiler chickens offered diets containing 3 or 4% CF had the same (P>0.05) GIT values. The lengths of jejunum and gastro-intestinal tracts of Ross 308 broiler chickens were optimized at dietary crude fibre levels of 5.5 (r^2 = 0.998) and 6.8 (r^2 = 0.979) %, respectively (Figures 4.07 and 4.08, respectively, and Table 4.05).

Venda chickens on a diet having 4% CF had a higher (P<0.05) duodenal length value than those on a diet having 3% CF. However, Venda chickens offered diets having 4, 5 or 7% CF had similar (P>0.05) duodenal length values. Similarly, Venda chickens on diets having 3, 5 or 7% CF had the same (P>0.05) duodenal lengths. Venda chickens on diets having 5 or 7% CF had higher (P<0.05) jejunal length values than those on diets having 3 or 4% CF. Similarly, Venda chickens on a diet having 4% CF had a higher (P<0.05) jejunal length value than those on a diet having 3% CF. However, Venda chickens fed diets containing 5 or 7% CF had similar (P>0.05) jejunal length values. Venda chickens on diets having 3, 4 or 5% CF had higher (P<0.05) ileal length values than those on a diet having 7% CF. However, Venda chickens on diets having 3, 4 or 5% CF had similar (P>0.05) ileal lengths. Venda chickens on diets having 5 or 7% CF had higher GIT values than those offered a diet having 3% CF. However, Venda chickens on diets having 4, 5 or 7% CF had similar (P>0.05) GIT values. Similarly, Venda chickens on diets having 3 or 4% CF had the same (P>0.05) GIT values. The lengths of jejunum, ileum and GIT of Venda chickens were optimized at dietary crude fibre levels of 5.8 (r^2 = 0.953), 3.5 (r^2 = 0.995) and 5.7 (r^2 = 0.992) %, respectively (Figures 4.09, 4.10 and 4.11, respectively, and Table 4.05).

Chicken breed had no effect (P>0.05) on the lengths of duodenum and large intestines. However, Ross 308 broiler chickens had longer (P<0.05) jejunum, ileum, caeca and GIT than Venda chickens (Table 4.04).

Table 4.02 Effect of dietary crude fibre level (%) on feed intake (g DM/bird/day), growth rate (g/bird/day), feed conversion ratio (FCR) (g DM feed/g live weight gain), live weight (g/bird aged 91 days), metabolisable energy (MJ/kg DM), nitrogen retention (g/bird/day), neutral detergent fibre digestibility (NDFD) and acid detergent fibre digestibility (ADFD) of Venda and Ross 308 broiler chickens aged 56 to 91 days

Treatment*	DM intake	Growth rate	FCR	Live weight	NDFD (%)	ADFD (%)	ME intake	N-retention
Ross 308 broiler chickens								
FRC_3	$152^a \pm 6.8$	$44^a \pm 1.6$	$3.5^a \pm 0.16$	$4750^a \pm 162.3$	$59^a \pm 0.9$	$42^a \pm 0.6$	$14^a \pm 0.3$	$2.8^a \pm 0.35$
FRC_4	$149^a \pm 6.5$	$43^a \pm 1.6$	$3.5^a \pm 0.17$	$4645^a \pm 172.1$	$60^a \pm 0.9$	$37^b \pm 0.6$	$15^a \pm 0.3$	$2.6^b \pm 0.03$
FRC_5	$155^a \pm 11.6$	$43^a \pm 1.7$	$3.6^a \pm 0.17$	$4410^a \pm 164.8$	$54^b \pm 1.0$	$34^c \pm 0.6$	$14^a \pm 0.5$	$2.5^c \pm 0.06$
FRC_7	$156^a \pm 6.6$	$44^a \pm 1.7$	$3.5^a \pm 0.22$	$4696^a \pm 233.3$	$52^b \pm 1.0$	$33^c \pm 0.6$	$12^b \pm 0.3$	$2.5^c \pm 0.03$
Venda chickens								
FVC_3	$72^a \pm 11.2$	$17^a \pm 1.2$	$4.3^a \pm 0.55$	$1864^{ab} \pm 83.9$	$63^{bc} \pm 1.1$	$47^a \pm 1.9$	$13^{ab} \pm 0.7$	$1.9^a \pm 0.30$
FVC_4	$77^a \pm 8.9$	$16^a \pm 1.3$	$4.7^a \pm 0.57$	$1923^a \pm 89.1$	$61^c \pm 1.2$	$47^a \pm 2.0$	$14^{ab} \pm 0.5$	$2.1^a \pm 0.24$
FVC_5	$76^a \pm 15.7$	$18^a \pm 1.2$	$4.2^a \pm 0.64$	$1906^a \pm 85.5$	$68^{ab} \pm 1.11$	$46^a \pm 2.0$	$12^b \pm 0.9$	$2.0^a \pm 0.42$
FVC_7	$67^a \pm 26.3$	$16^a \pm 1.3$	$4.2^a \pm 0.63$	$1565^b \pm 110.7$	$70^a \pm 1.13$	$47^a \pm 2.0$	$14^a \pm 0.5$	$1.9^a \pm 0.71$
Chicken breed								
Ross	$153^a \pm 21.5$	$44^a \pm 3.2$	$3.5^b \pm 2.84$	$4625^a \pm 505.2$	$56^b \pm 2.8$	$37^b \pm 3.2$	$14^a \pm 1.1$	$2.6^a \pm 0.44$
Venda	$73^b \pm 85.2$	$17^b \pm 0.8$	$4.3^a \pm 1.71$	$1815^b \pm 429.4$	$65^a \pm 0.5$	$47^a \pm 0.8$	$13^a \pm 4.5$	$2.0^b \pm 1.71$
Significance								
Breed	0.0001	0.0001	0.024	0.0001	0.0001	0.001	0.064	0.0002
Treatment	0.937	0.897	0.945	0.045	0.0001	0.037	0.038	0.041
Breed x Treatment	0.690	0.784	0.873	0.174	0.024	0.045	0.007	0.424

$^{a, b, c}$: Means in the same column not sharing a common superscript are significantly different ($P<0.05$)
CF : Crude fibre
FRC : Female Ross 308 broiler chickens
FVC : Female Venda chickens
* : Treatments are 3%, 4%, 5% and 7% CF

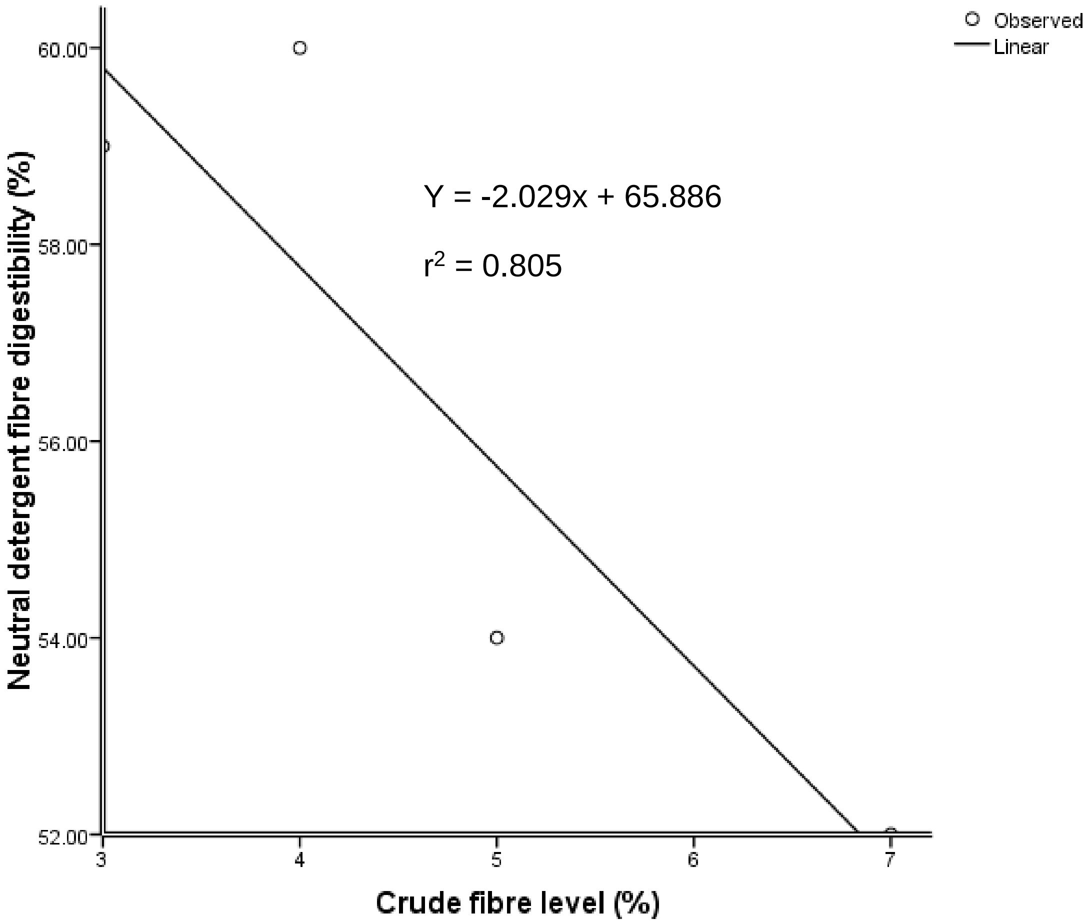

Figure 4.01 Relationship between dietary crude fibre level and neutral detergent fibre digestibility of Ross 308 broiler chickens aged 56 to 91 days

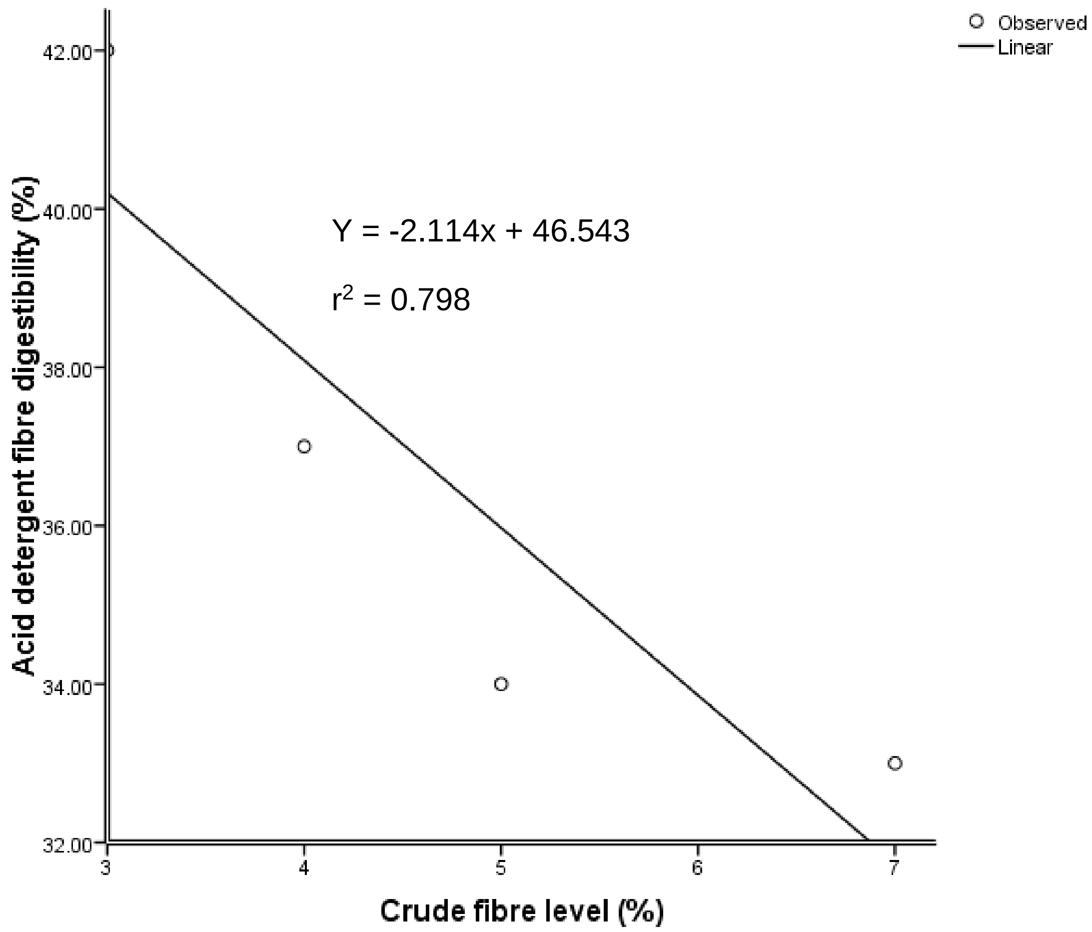

Figure 4.02 Relationship between dietary crude fibre level and acid detergent fibre digestibility of Ross 308 broiler chickens aged 56 to 91 days

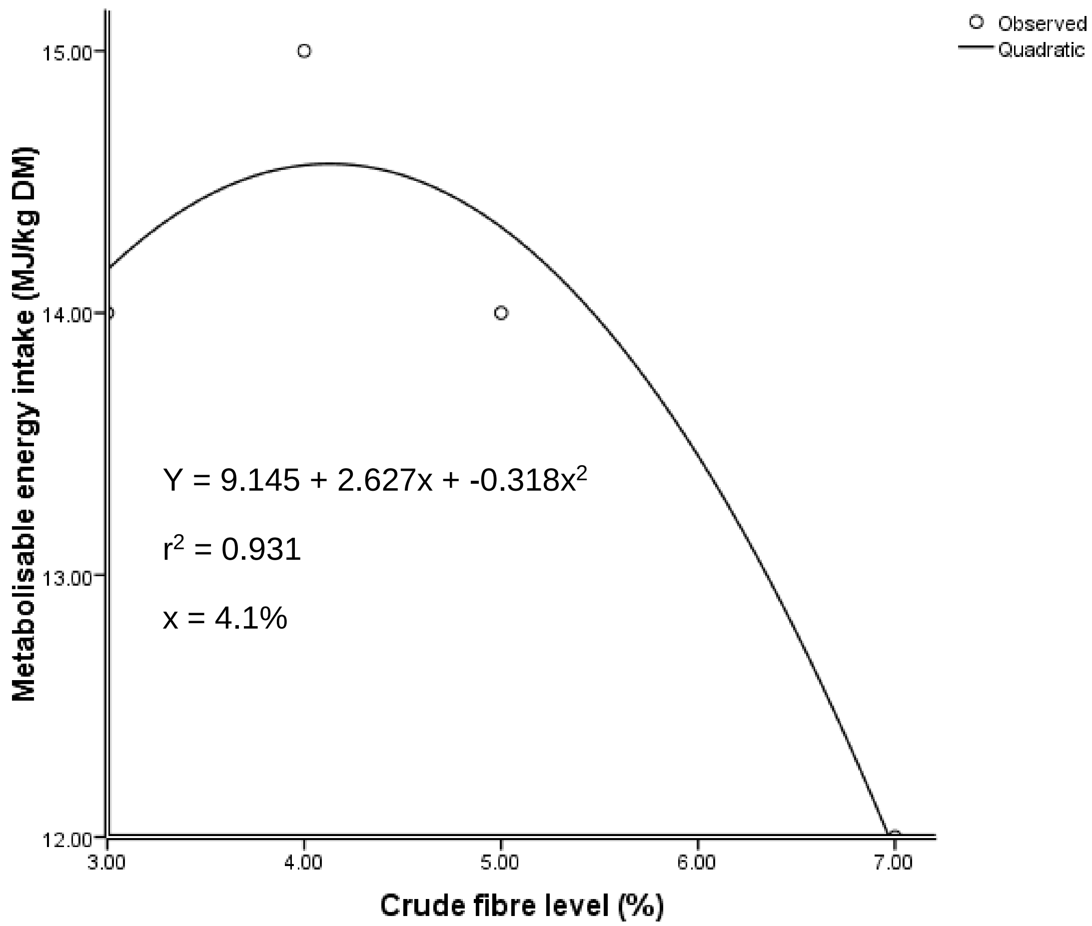

Figure 4.03 Effect of dietary crude fibre level on metabolisable energy intake of Ross 308 broiler chickens aged 56 to 91 days

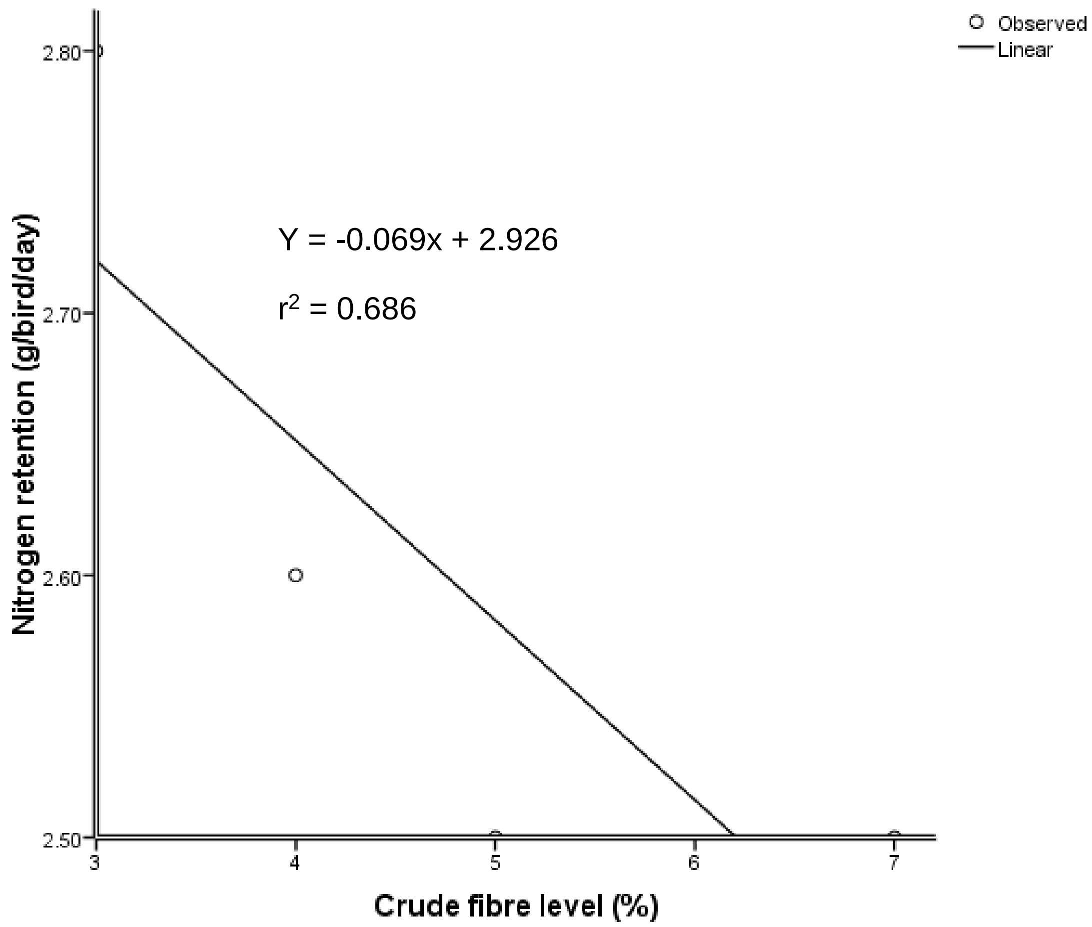

Figure 4.04 Relationship between dietary crude fibre level and nitrogen retention of Ross 308 broiler chickens aged 56 to 91 days

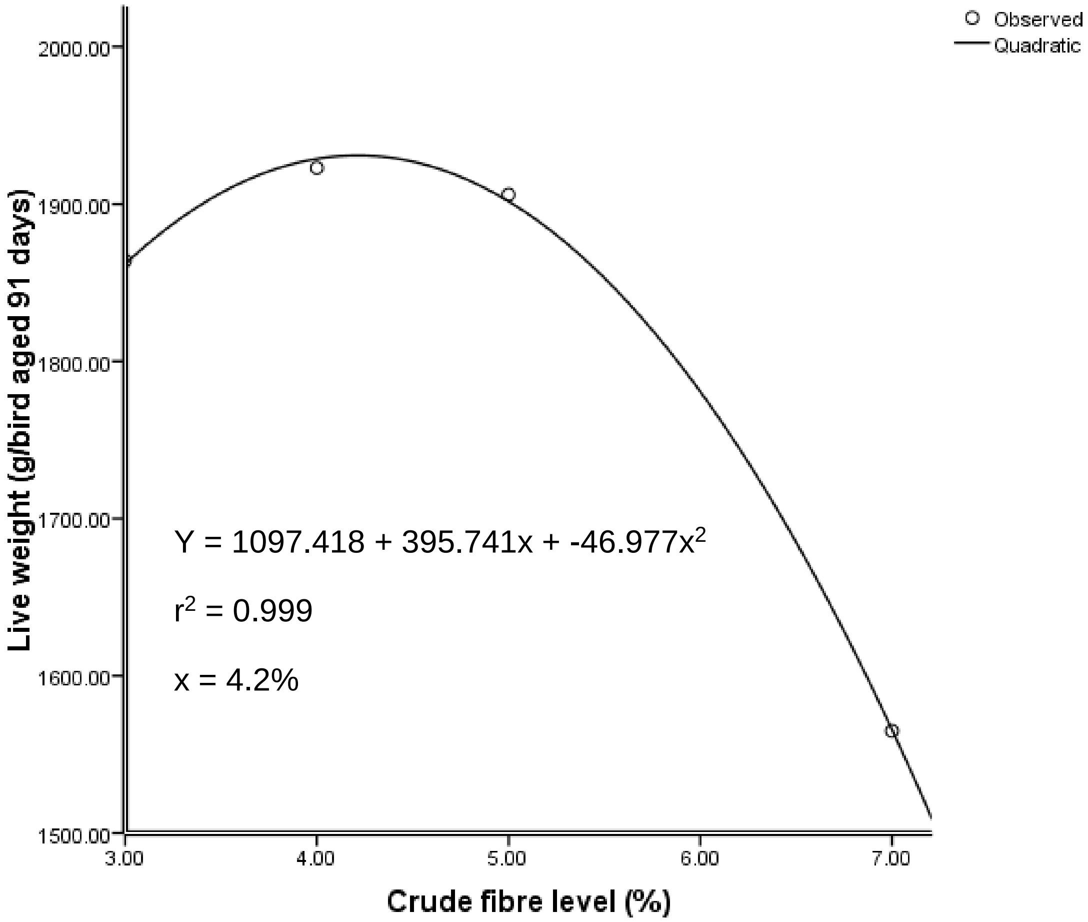

Figure 4.05 Effect of dietary crude fibre level on the live weight of Venda chickens aged 91 days

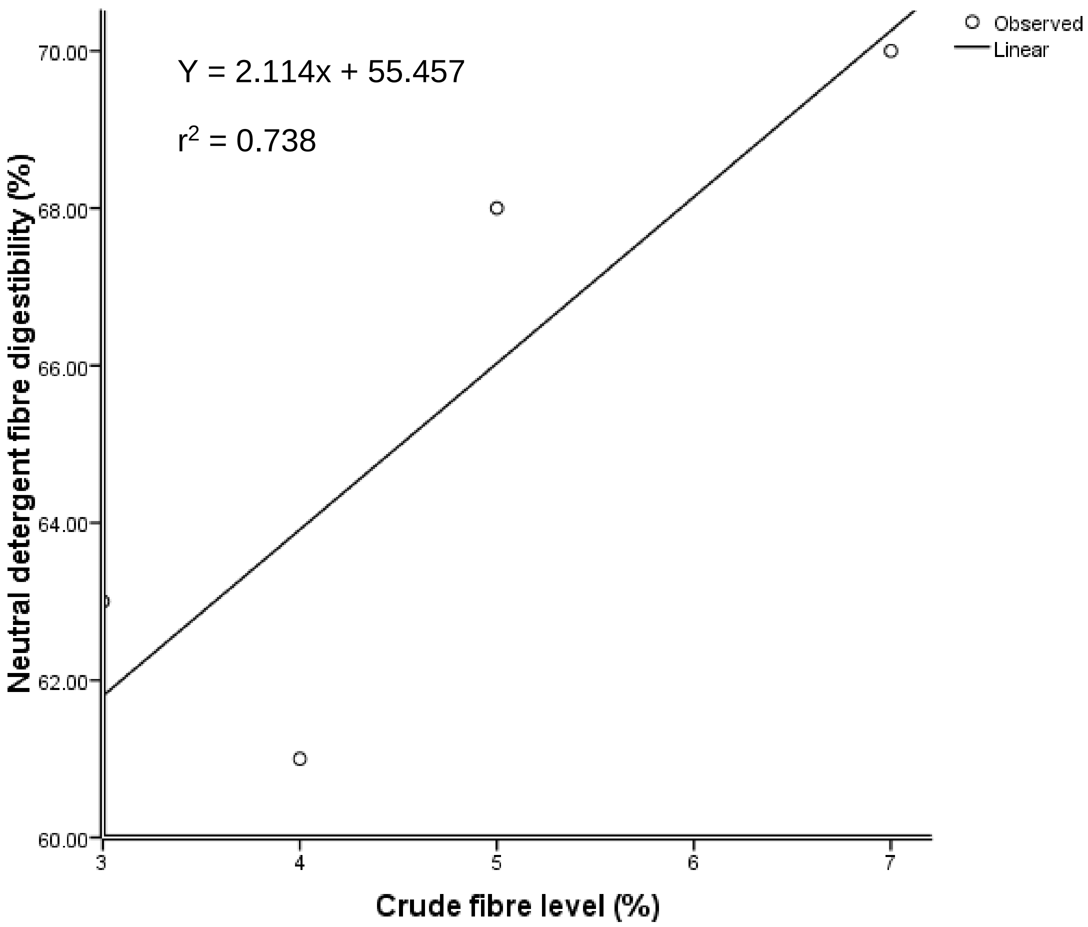

Figure 4.06 Relationship between dietary crude fibre level and neutral detergent fibre digestibility of Venda chickens aged 56 to 91 days

Table 4.03 Relationships between dietary crude fibre level (%) and Neutral detergent fibre digestibility (%), acid detergent fibre digestibility (%) and nitrogen retention (g/bird/day) of Venda and Ross 308 broiler chickens aged 56 to 91 days

Variable	Formula	r^2	Probability
Ross 308 broiler chickens			
Neutral detergent fibre digestibility	Y = -2.029x + 65.886	0.805	0.103
Acid detergent fibre digestibility	Y = -2.114x + 46.543	0.798	0.107
Nitrogen retention	Y = -0.069x + 2.926	0.686	0.172
Venda chickens			
Neutral detergent fibre digestibility	Y = 2.114x + 55.457	0.738	0.141

r^2 : Coefficient of determination

The results of the effect of dietary crude fibre level on the weights of gut organs of Ross 308 broiler and Venda chickens aged 91 days are presented in Table 4.06. Dietary crude fibre level had no effect (P>0.05) on the weights of jejunum, ileum, caeca, gizzard and crop of Ross 308 broiler chickens.

Dietary crude fibre level had no effect (P>0.05) on the weights of ileum and crops of Venda chickens. However, dietary crude fibre level had effect (P<0.05) on the weights of duodenum and large intestines of broiler chickens. Broiler chickens on a diet having 4% CF had a higher (P<0.05) duodenal weight value than those on diets having 3 or 7% CF. However, broiler chickens on diets having 4 or 5% CF had similar (P>0.05) duodenal weights. Similarly, broiler chickens fed diets having 3, 5 or 7% CF had similar (P>0.05) duodenal weights. Broiler chickens fed a diet containing 5% CF had a higher (P<0.05) large intestinal weight value than those offered diets having 3 or 7% CF. Similarly, broiler chickens on a diet having 4% CF had a higher large intestinal weight value than those on a diet having 3% CF. However, broiler chickens on diets having 4 or 5% CF had similar (P>0.05) large intestinal weights. Similarly, broiler chickens on diets having 3 or 7% CF and those on diets having 4 or 7% CF had the same (P>0.05) large intestinal weights. The weights of duodenum and large intestines of Ross 308 broiler chickens were optimized at dietary crude fibre levels of 4.9 (r^2 = 0.793) and 5.2 (r^2 = 0.983) %, respectively (Figures 4.12 and 4.13, respectively, and Table 4.07).

Venda chickens on diets having 4 or 5% CF had higher ($P<0.05$) duodenal weights than those on diets having 3 or 7% CF. However, Venda chickens fed diets containing 4 or 5% CF had the same ($P>0.05$) duodenal weights. Similarly, Venda chickens on diets having 3 or 7% CF had the same ($P>0.05$) duodenal weights. Venda chickens on a diet having 4% CF had a higher ($P<0.05$) jejunal weight value than those on diets having 3, 5 or 7% CF. However, Venda chickens on diets having 3, 5 or 7% CF had similar ($P>0.05$) jejunal weights. Venda chickens on a diet having 4% CF had a higher ($P<0.05$) caecal weight value than those on diets having 3 or 7% CF. Similarly, Venda chickens offered a diet having 5% CF had a higher ($P>0.05$) caecal weight value than those on a diet having 7% CF. However, Venda chickens on diets having 4 or 5% CF had similar ($P>0.05$) caecal weights. Similarly, Venda chickens offered diets having 3 or 5% CF and those on diets having 3 or 7% CF had the same ($P>0.05$) caecal weights. Venda chickens on a diet having 5% CF had a higher ($P<0.05$) large intestinal weight value than those on diets having 3 or 4% CF. Similarly, Venda chickens on a diet having 7% CF had a higher ($P<0.05$) large intestinal weight value than those on a diet having 3% CF. However, Venda chickens on diets having 5 or 7% CF had similar ($P>0.05$) large intestinal weights. Similarly, Venda chickens offered diets having 4 or 7% CF had the same ($P>0.05$) large intestinal weights. Venda chickens on a diet having 5% CF had a higher ($P<0.05$) gizzard weight value than those offered diets having 3 or 7% CF. Similarly, Venda chickens on a diet having 4% CF had a higher ($P<0.05$) gizzard weight value than those offered diets having 7% CF. However, Venda chickens on diets having 4 or 5% CF had similar ($P>0.05$) gizzard weights. Similarly, Venda chickens on diets having 3 or 4% CF and those on diets having 3 or 7% CF had the same ($P>0.05$) gizzard weights. The weights of duodenum, caeca, large intestines and gizzards of Venda chickens were optimized at dietary crude fibre levels of 5.0 ($r^2 = 0.988$), 4.6 ($r^2 = 0.929$), 5.7 ($r^2 = 0.933$) and 4.9 ($r^2 = 0.983$) %, respectively (Figures 4.14, 4.15, 4.16 and 4.17, respectively, and Table 4.07). Ross 308 broiler chickens had larger ($P<0.05$) duodenum, jejunum, ileum, caeca, large intestines, gizzard and crop weights than Venda chickens (Table 4.06).

Table 4.04 Effect of dietary crude fibre level on the length of gut organs of Ross 308 broiler and Venda chickens aged 91 days

Treatment*	Duodenum (cm)	Jejunum (cm)	Ileum (cm)	Large Intestines (cm)	Caeca (cm)	GIT (cm)
Ross 308 broiler chickens						
FRC_3	$17.1^a \pm 1.95$	$80.5^c \pm 1.21$	$85.4^a \pm 7.87$	$12.3^a \pm 1.00$	$21.7^a \pm 1.92$	$234.8^c \pm 4.18$
FRC_4	$21.6^a \pm 1.85$	$89.6^b \pm 1.15$	$91.8^a \pm 7.48$	$12.8^a \pm 0.85$	$22.6^a \pm 1.83$	$254.6^b \pm 3.98$
FRC_5	$19.8^a \pm 3.31$	$95.00^a \pm 2.06$	$78.3^a \pm 13.35$	$13.2^a \pm 1.52$	$23.7^a \pm 3.26$	$260.5^{ab} \pm 7.10$
FRC_7	$20.9^a \pm 2.00$	$89.9^b \pm 1.18$	$83.7^a \pm 7.66$	$13.8^a \pm 0.87$	$24.3^a \pm 1.87$	$270.7^a \pm 4.07$
Venda chickens						
FVC_3	$14.8^b \pm 4.07$	$64.6^c \pm 1.37$	$60.7^a \pm 3.05$	$12.0^a \pm 3.43$	$18.3^a \pm 1.58$	$160.6^b \pm 10.85$
FVC_4	$25.6^a \pm 3.23$	$69.9^b \pm 1.09$	$60.2^a \pm 2.43$	$12.7^a \pm 2.73$	$17.8^a \pm 1.26$	$185.6^{ab} \pm 8.62$
FVC_5	$19.8^{ab} \pm 5.71$	$76.6^a \pm 1.93$	$59.4^a \pm 4.28$	$11.2^a \pm 4.81$	$18.3^a \pm 2.22$	$194.7^a \pm 15.23$
FVC_7	$24.7^{ab} \pm 9.54$	$73.8^a \pm 3.23$	$51.6^b \pm 7.16$	$7.7^a \pm 8.05$	$15.3^a \pm 3.71$	$189.6^a \pm 25.45$
Chicken breed						
Ross	19.8a ± 7.12	$83.3^a \pm 20.03$	$84.8^a \pm 17.20$	$13.0^a \pm 5.25$	$23.0^a \pm 4.65$	$248.7^a \pm 29.61$
Venda	21.2a ± 28.17	$65.6^b \pm 79.20$	$58.0^b \pm 68.01$	$11.0^a \pm 20.76$	$17.4^b \pm 18.40$	$184.8^b \pm 117.06$
Significance						
Breed	0.414	0.004	0.0001	0.113	0.0001	0.0001
Treatment	0.035	0.020	0.044	0.667	0.858	0.006
Breed x Treatment	0.481	0.015	0.599	0.305	0.341	0.027

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

FRC : Female Ross 308 broiler chickens

FVC : Female Venda chickens

CF : Crude fibre

GIT : Gastro-intestinal tract

* : Treatments are 3%, 4%, 5% and 7% CF

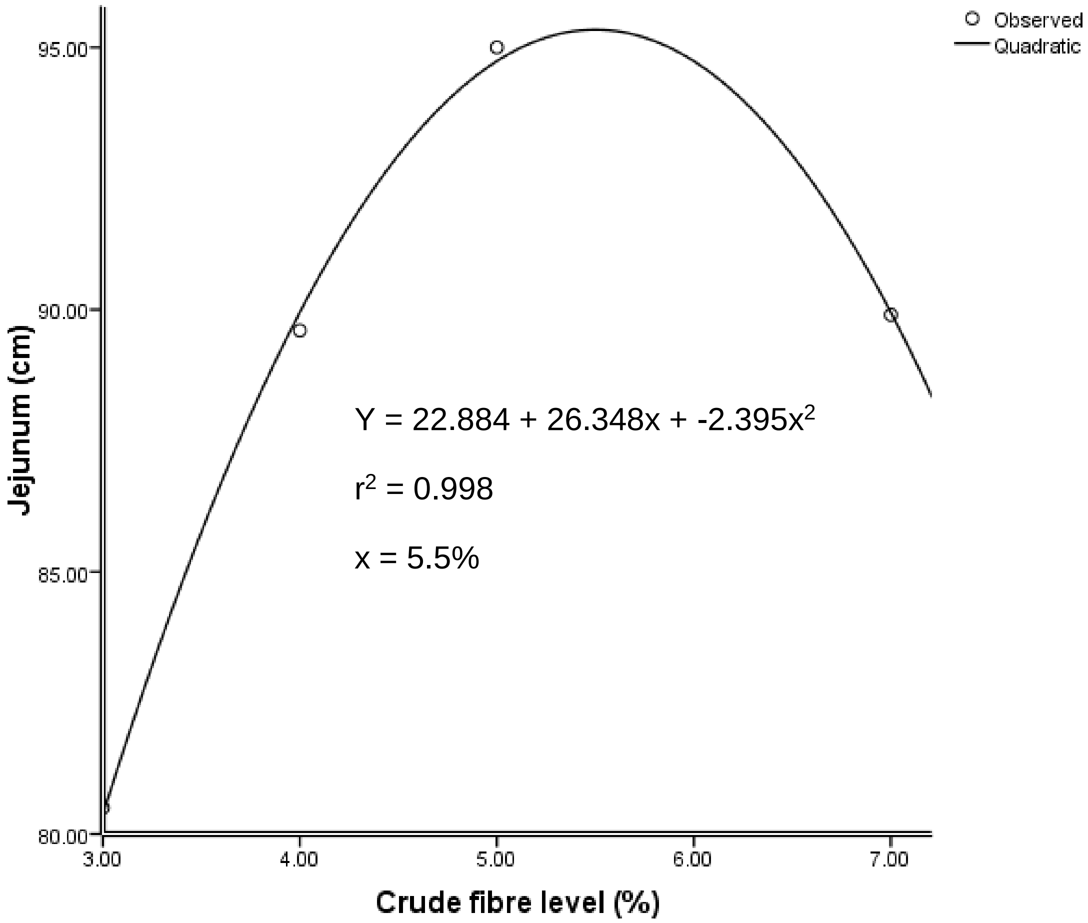

Figure 4.07 Effect of dietary crude fibre level on jejunal length of Ross 308 broiler chickens aged 91 days

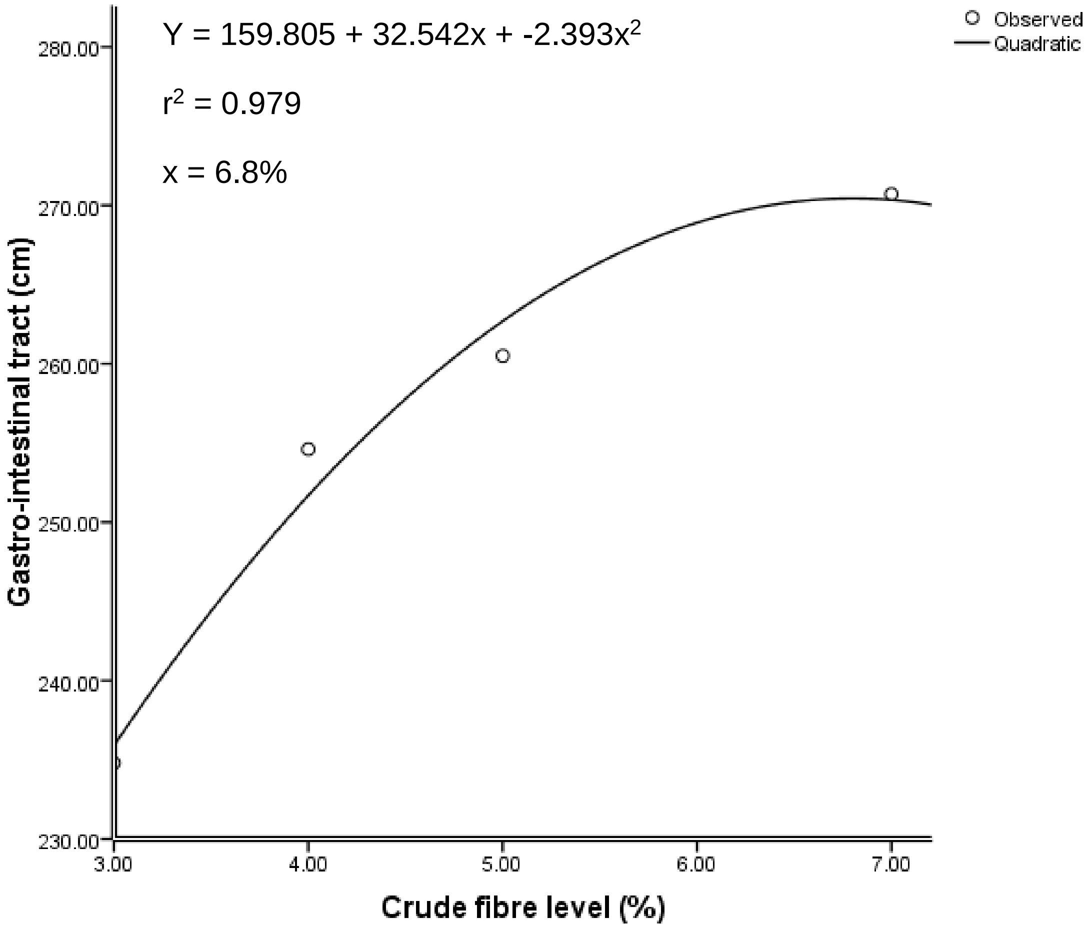

Figure 4.08 Effect of dietary crude fibre level on the length of gastro-intestinal tract of Ross 308 broiler chickens aged 91 days

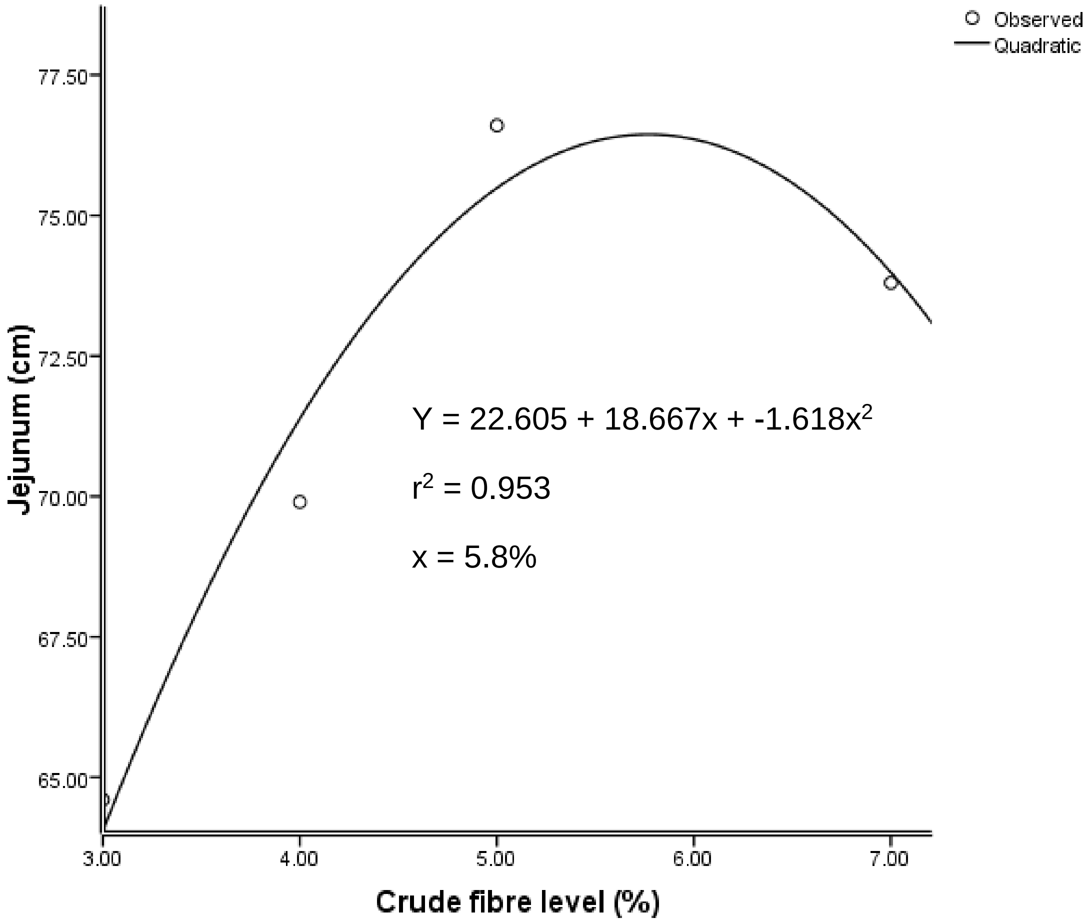

Figure 4.09 Effect of dietary crude fibre level on jejunal length of Venda chickens 91 days

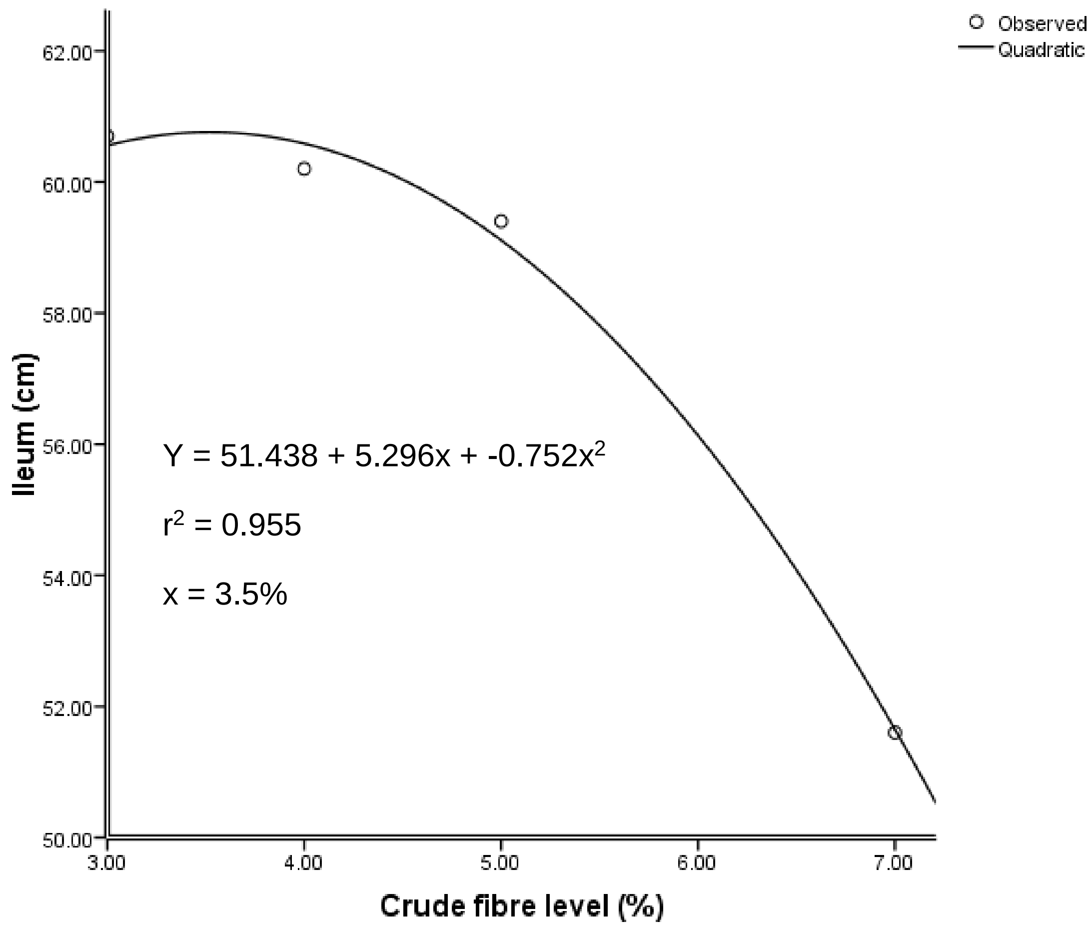

Figure 4.10 Effect of dietary crude fibre level on the ileal length of Venda chickens aged 91 days

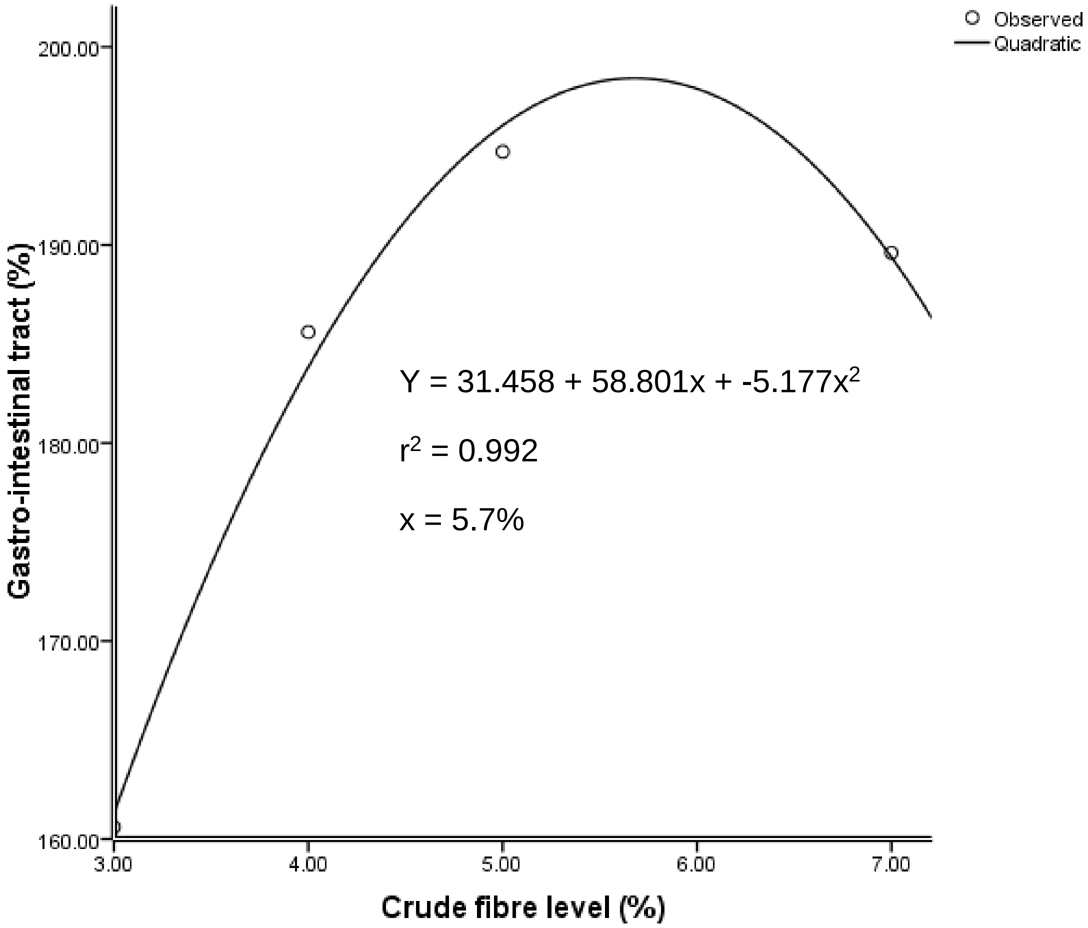

Figure 4.11 Effect of dietary crude fibre level on gastro-intestinal tract of Venda chickens aged 91 days

Table 4.05 Dietary crude fibre levels for optimal gut organ lengths of Venda and Ross 308 broiler chickens aged 91 days

Variable	Formula	r^2	Optimal CF level (%)	Optimal Y-level (cm)
Ross 308 Broiler chickens				
Jejunum	$Y = 22.884 + 26.348x + -2.395x^2$	0.998	5.5	95.35
GIT	$Y = 159.805 + 32.542x + -2.393x^2$	0.979	6.8	270.44
Venda chickens				
Jejunum	$Y = 22.605 + 18.667x + -1.618x^2$	0.953	5.8	76.45
Ileum	$Y = 51.438 + 5.296x + -0.752x^2$	0.995	3.5	60.76
GIT	$Y = 31.458 + 58.801x + -5.177x^2$	0.992	5.7	198.43

r^2 : Coefficient of determination

CF : Crude fibre

GIT : Gastro-intestinal tract

The results of the effect of dietary crude fibre level on pH of gut organ digesta of Ross 308 broiler and Venda chickens aged 91 days are presented in Table 4.08. Dietary crude fibre level had no effect (P>0.05) on duodenum, jejunum, ileum, large intestine, gizzard, crop and caecal digesta pH of the chickens. However, Ross 308 broiler chickens had higher (P<0.05) gizzard and caecal digesta pH values than Venda chickens. Similarly, Venda chickens had higher (P<0.05) duodenum, jejunum, ileum and large intestinal digesta pH values than Ross 308 broiler chickens (Table 4.08).

The results of the effect of dietary crude fibre level on ileal villi height, crypt depth and villi height to crypt depth ratio of Ross 308 broiler and Venda chickens are presented in Table 4.09. Dietary crude fibre level had no effect (P>0.05) on the villi height, crypt depth and villi height to crypt depth ratio of Ross 308 broiler chickens. Similarly, dietary crude fibre level had no effect (P>0.05) on the crypt depths of Venda chickens. However, dietary crude fibre level had effect (P<0.05) on the villi height and villi height to crypt depth ratio of Venda chickens. Venda chickens offered a diet having 4% CF had a higher (P<0.05) villi height value than those on diets having 5 or 7% CF. However, Venda chickens offered diets containing 3 or 4% CF had similar (P>0.05) villi height values. Similarly, Venda chickens on diets having 3, 5 or 7% CF had the same (P>0.05) villi height values.

Chicken breed had no effect (P>0.05) on the villi height and crypt depths. However, Ross 308 broiler chickens had a higher (P<0.05) villi height to crypt depth ratio value than Venda chickens (Table 4.09).

4.4 Carcass parts and meat quality

The results of the effect of dietary crude fibre level on the weights of carcass parts of Ross 308 broiler and Venda chickens aged 91 days are presented in Table 4.10. Dietary crude fibre level had no effect (P>0.05) on the carcass, breast, thigh and drumstick meat weights of Ross 308 broiler chickens. Similarly, dietary crude fibre level had no effect (P>0.05) on the carcass, breast and drumstick meat weights of Venda chickens. However, dietary crude fibre level had effect (P<0.05) on thigh meat weights of Venda chickens. Venda chickens offered a diet having 5% CF had a higher (P<0.05) thigh meat weight than those on diets having 7% CF. However, Venda chickens on diets having 3, 4 or 5% CF had similar (P>0.05) thigh meat weights. Similarly, Venda chickens on diets having 3, 4 or 7% CF had the same (P>0.05) thigh meat weights. The thigh meat weight of Venda chickens was optimized at a dietary crude fibre level of 4.725% (r^2 = 0.959) (Figure 4.18). Ross 308 broiler chickens had heavier (P<0.05) carcass, breast, thigh and drumstick meat than Venda chickens (Table 4.10).

The results of the effect of dietary crude fibre level on breast meat colour of Ross 308 broiler and Venda chickens aged 91 days are presented in Table 4.11. Dietary crude fibre level had no effect (P>0.05) on the redness (a*) and yellowness (b*) of breast meat of Ross 308 broiler chickens. Similarly, dietary crude fibre level had no effect (P>0.05) on the lightness (L*), redness (a*) and yellowness (b*) of breast meat of Venda chickens. However, dietary crude fibre level had effect (P<0.05) on the L* value of breast meat of Ross 308 broiler chickens. Broiler chickens on diets having 4, 5 or 7% CF had higher (P<0.05) L* values of breast meat than those on a diet having 3% CF. However, broiler chickens on diets having 4, 5 or 7% CF had similar (P>0.05) L* values of breast meat. The L* value of breast meat of Ross 308 broiler chickens was optimized at a dietary crude fibre level of 5.6% (r^2 = 0.995) (Figure 4.19). Chicken breed had no effect (P>0.05) on the L* and b* values of breast meat. However, Ross 308 broiler chickens had a higher (P<0.05) a* value of breast meat than Venda chickens (Table 4.11).

The results of the effect of dietary crude fibre level on meat tenderness, juiciness, flavour, acceptability and shear force of Ross 308 broiler and Venda chickens aged 91 days are presented in Table 4.12. Dietary crude fibre level had no effect (P>0.05) on meat tenderness, juiciness, flavour and acceptability of Ross 308 broiler chickens. Similarly, dietary crude fibre level had no effect (P>0.05) on meat tenderness, flavour and acceptability of Venda chickens. However, dietary crude fibre level had effect (P<0.05) on meat shear force of Ross 308 broiler chickens. Similarly, dietary crude fibre level had effect (P<0.05) on meat shear force and juiciness of Venda chickens.

Broiler chickens on a diet having 4% CF had a higher (P<0.05) shear force value than those on a diet having 7% CF. However, broiler chickens on diets having 3, 4 or 5% CF had similar (P>0.05) shear force values. Similarly, broiler chickens offered diets having 3, 5 or 7% CF had the same (P>0.05) shear force values. The shear force value of Ross 308 broiler chickens was optimized at a dietary crude fibre level of 4.6% (r^2 = 0.792) (Figure 4.20 and Table 4.13).

Venda chickens offered diets having 4 or 5% CF had higher (P<0.05) meat shear force values than those on diets having 3 or 7% CF. However, Venda chickens on diets having 4 or 5% CF had similar (P>0.05) meat shear force values. Similarly, Venda chickens on diets having 3 or 7% CF had the same (P>0.05) meat shear force values. Venda chickens offered a diet having 5% CF had a higher (P<0.05) meat juiciness value than those on diets having 3, 4 or 7% CF. Similarly, Venda chickens offered a diet having 7% CF had a higher (P<0.05) meat juiciness value than those on a diet having 3% CF. However, Venda chickens on diets having 4 or 7% CF had similar (P>0.05) meat juiciness values. Similarly, Venda chickens on diets having 3 or 4% CF had the same (P>0.05) meat juiciness values. The meat shear force and juiciness of Venda chickens were optimized at dietary crude fibre levels of 5.0 (r^2 = 0.910) and 5.5 (r^2 = 0.882) %, respectively (Figures 4.21 and 4.22, respectively, and Table 4.13).

Chicken breed had no effect (P>0.05) on meat juiciness. However, Ross 308 broiler chickens had a higher (P<0.05) meat tenderness value than Venda chickens. Similarly, Venda chickens had higher (P<0.05) meat shear force, flavour and acceptability values than Ross 308 broiler chickens (Table 4.12).

The results of the effect of dietary crude fibre level on the pH of breast, thigh and drumstick meat of Ross 308 broiler and Venda chickens aged 91 days are presented in Table 4.14. Dietary crude fibre level had no effect (P>0.05) on the pH of breast, thigh and drumstick meat of Ross 308 broiler chickens. Similarly, dietary crude fibre level had no effect (P>0.05) on the pH of breast and drumstick meat of Venda chickens. However, dietary crude fibre level had effect (P<0.05) on the pH of thigh meat of Venda chickens.

Venda chickens offered a diet having 7% CF had a higher (P<0.05) pH value of thigh meat than those fed diets containing 3 or 5% CF. However, Venda chickens offered diets having 4 or 7% CF had similar (P>0.05) pH values of thigh meat. Similarly, Venda chickens on diets having 3, 4 or 5% CF had the same (P>0.05) pH values of thigh meat. Chicken breed had no effect (P>0.05) on the pH of breast, thigh and drumstick meat (Table 4.14).

Table 4.06 Effect of dietary crude fibre level on the weights of gut organs of Ross 308 broiler and Venda chickens aged 91 days

Treatment*	Duodenum (g)	Jejunum (g)	Ileum (g)	Caeca (g)	Large Intestines (g)	Gizzard (g)	Crop (g)
Ross 308 broiler chickens							
FRC_3	$35.5^b \pm 1.24$	$50.6^a \pm 8.17$	$49.6^a \pm 7.80$	$22.0^a \pm 2.40$	$3.7^c \pm 0.64$	$104.4^a \pm 14.36$	$51.1^a \pm 9.00$
FRC_4	$39.9^a \pm 1.04$	$53.1^a \pm 7.76$	$53.8^a \pm 7.41$	$24.5^a \pm 2.29$	$7.0^{ab} \pm 0.60$	$130.6^a \pm 13.65$	$42.0^a \pm 8.55$
FRC_5	$38.4^{ab} \pm 1.85$	$44.3^a \pm 13.86$	$39.5^a \pm 13.23$	$22.2^a \pm 4.08$	$7.6^a \pm 1.08$	$136.8^a \pm 24.37$	$26.2^a \pm 15.27$
FRC_7	$35.6^b \pm 1.06$	$52.9^a \pm 7.95$	$48.1^a \pm 7.59$	$20.4^a \pm 2.34$	$5.0^{bc} \pm 0.62$	$126.6^a \pm 13.98$	$26.8^a \pm 8.76$
Venda chickens							
FVC_3	$15.5^b \pm 0.34$	$33.5^b \pm 3.98$	$29.7^a \pm 11.71$	$8.9^{bc} \pm 0.57$	$3.4^c \pm 0.26$	$71.0^{bc} \pm 5.58$	$18.5^a \pm 7.26$
FVC_4	$20.0^a \pm 0.27$	$44.0^a \pm 3.16$	$31.2^a \pm 9.30$	$10.4^a \pm 0.46$	$4.1^b \pm 0.21$	$83.0^{ab} \pm 4.43$	$29.6^a \pm 5.77$
FVC_5	$20.6^a \pm 0.48$	$31.6^b \pm 5.59$	$26.0^a \pm 16.43$	$9.8^{ab} \pm 0.80$	$5.1^a \pm 0.37$	$90.6^a \pm 7.83$	$30.1^a \pm 10.18$
FVC_7	$15.5^b \pm 0.80$	$23.9^b \pm 9.34$	$32.0^a \pm 27.47$	$7.8^c \pm 1.344$	$4.60^{ab} \pm 0.61$	$67.3^c \pm 13.08$	$21.0^a \pm 17.02$
Chicken breed							
Ross	$37.4^a \pm 2.36$	$50.2^a \pm 18.19$	$47.7^a \pm 23.48$	$22.3^a \pm 5.15$	$5.9^a \pm 2.57$	$124.6^a \pm 31.41$	$36.5^a \pm 21.63$
Venda	$17.9^b \pm 9.32$	$33.3^b \pm 71.91$	$29.7^b \pm 92.84$	$9.2^b \pm 20.37$	$3.3^b \pm 10.17$	$78.0^b \pm 124.17$	$24.1^b \pm 85.52$
Significance							
Breed	<0.0001	<0.0003	0.009	<0.0001	0.002	<0.0002	0.033
Treatment	0.0004	0.029	0.615	0.029	0.036	0.012	0.351
Breed x Treatment	0.021	0.391	0.930	0.950	0.046	0.543	0.100

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

CF : Crude fibre

FRC : Female Ross 308 broiler chickens

FVC : Female Venda chickens

GIT : Gastro-intestinal tract

* : Treatments are 3%, 4%, 5% and 7% CF

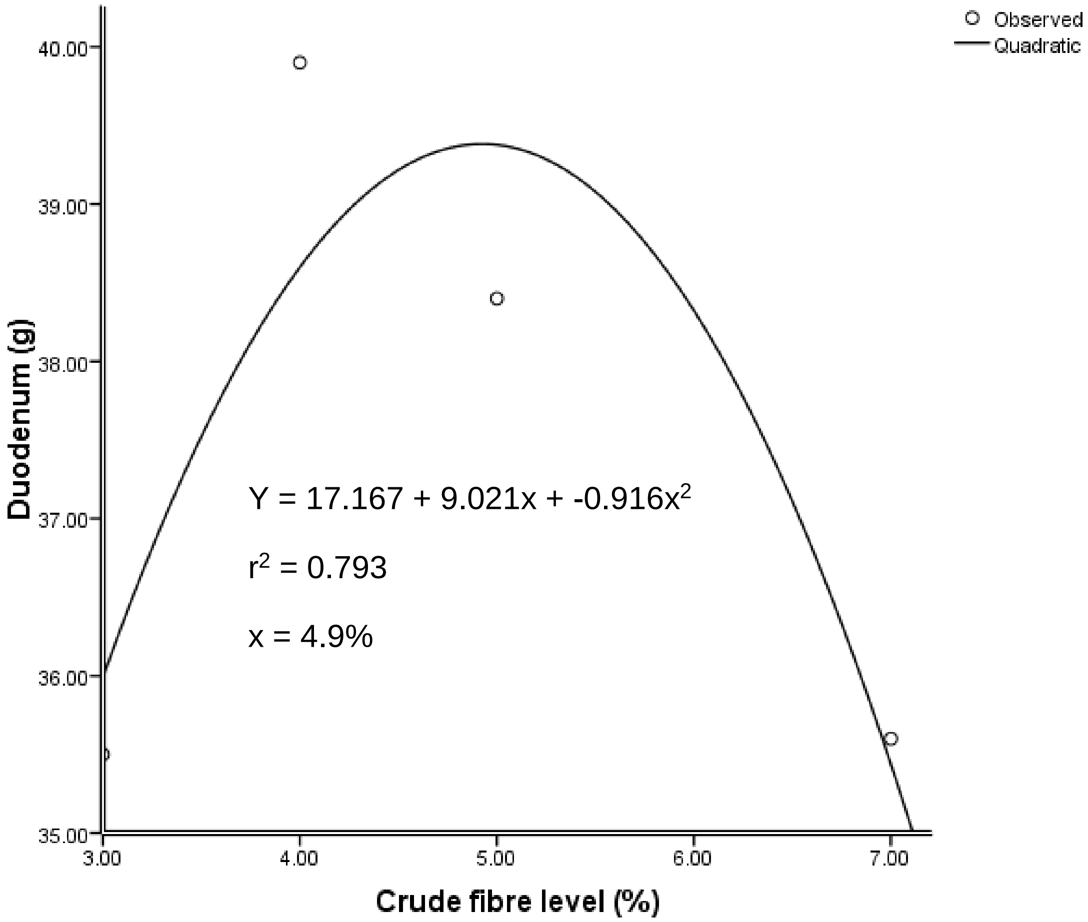

Figure 4.12 Effect of dietary crude fibre level on duodenal weight of Ross 308 broiler chickens aged 91 days

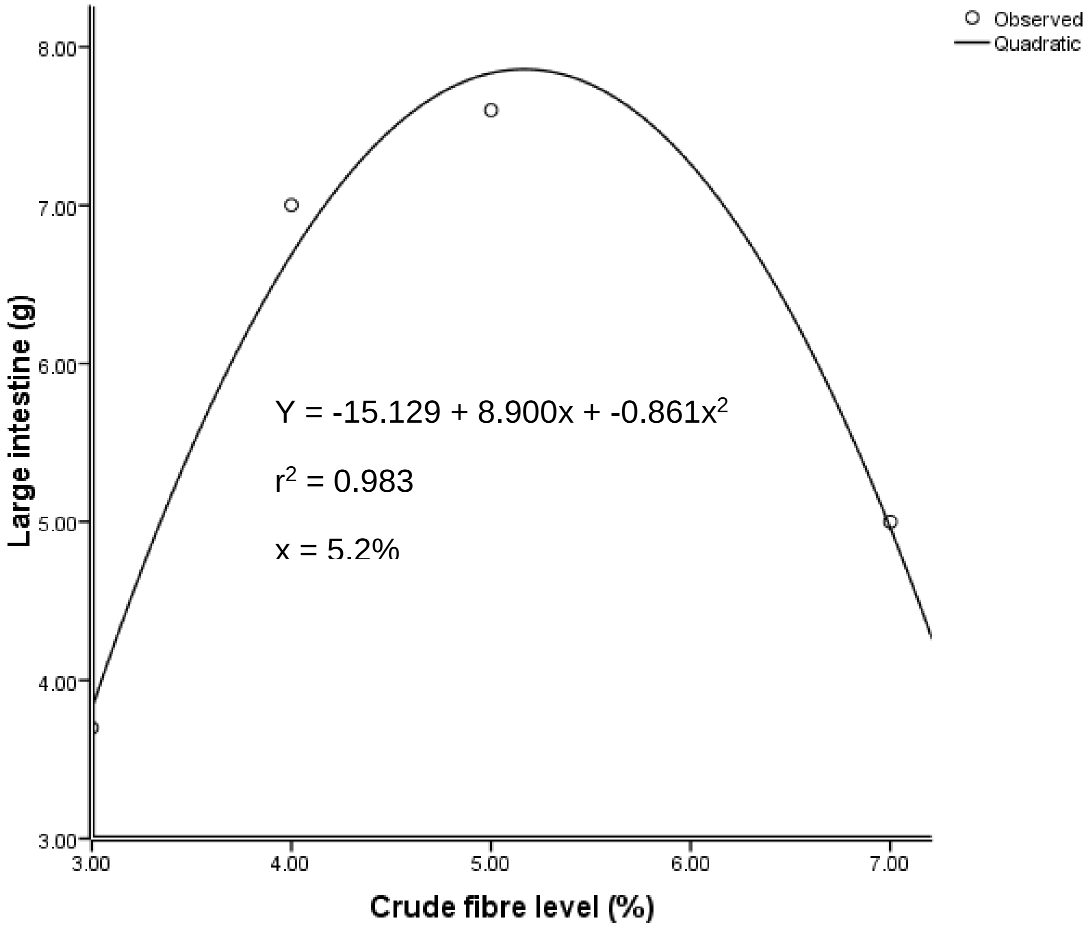

Figure 4.13 Effect of dietary crude fibre level on large intestinal weight of Ross 308 broiler chickens aged 91 days

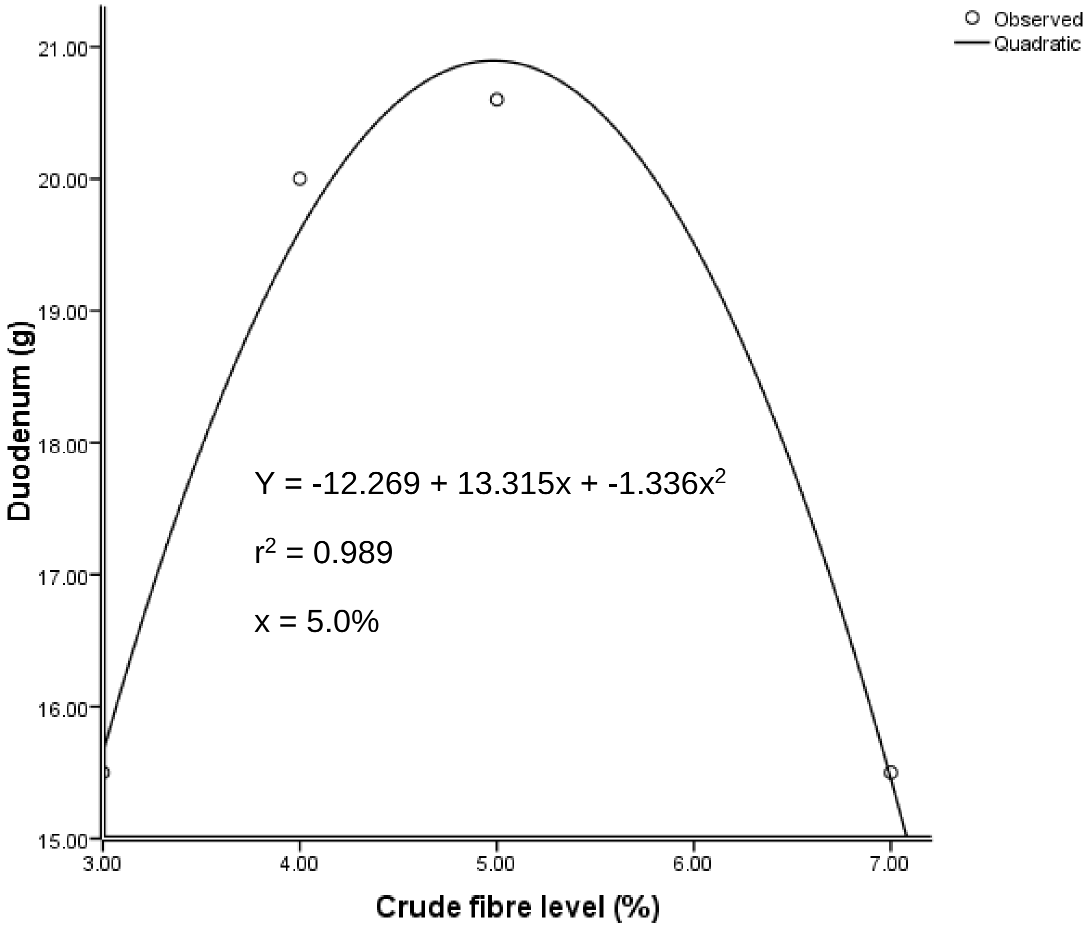

Figure 4.14 Effect of dietary crude fibre level on duodenal weight of Venda chickens aged 91 days

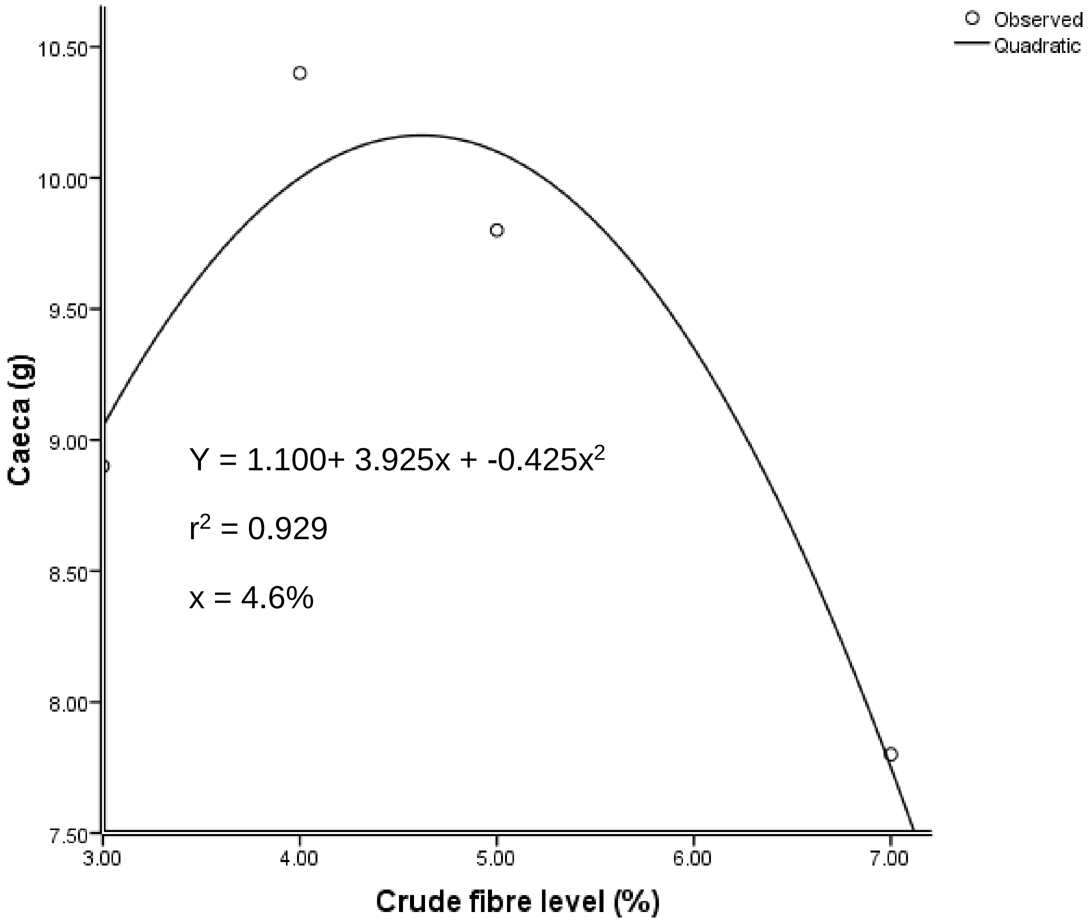

Figure 4.15 Effect of dietary crude fibre level on caecal weight of Venda chickens aged 91 days

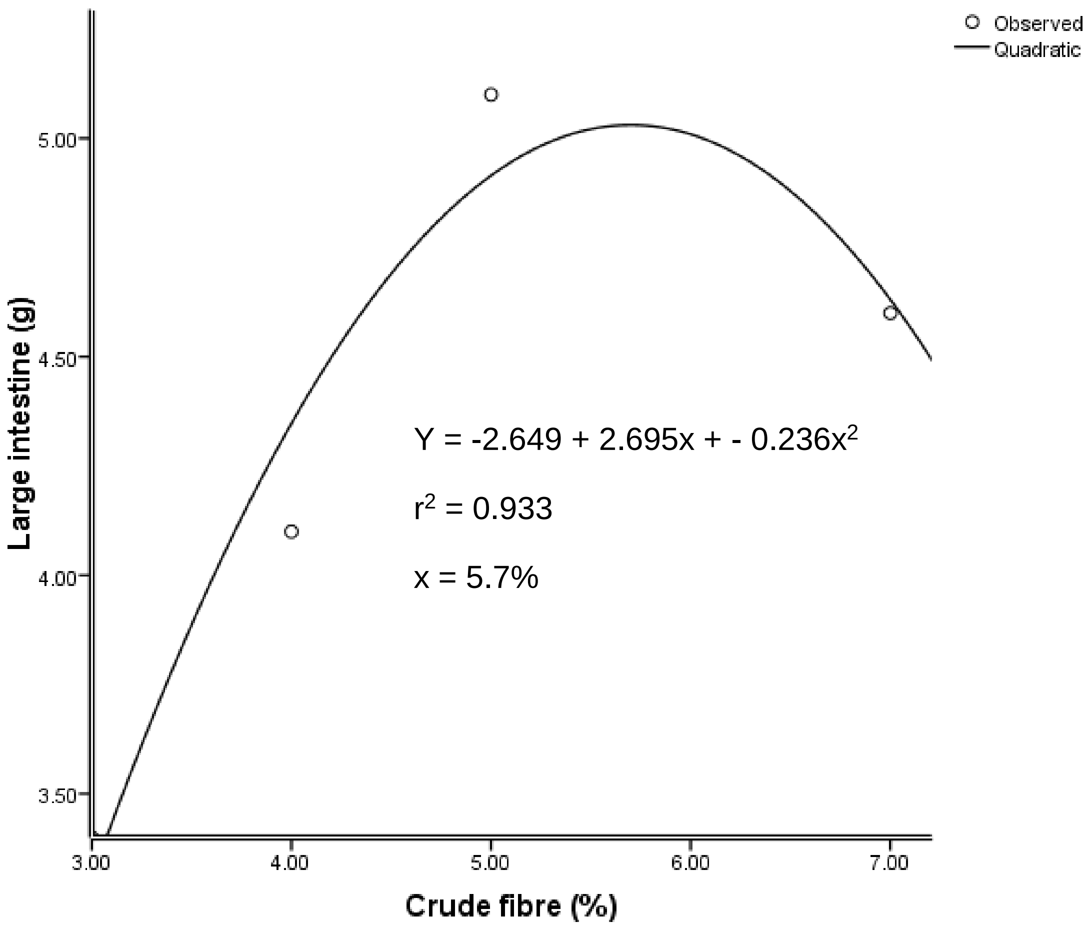

Figure 4.16 Effect of dietary crude fibre level on large intestinal weight of Venda chickens aged 91 days

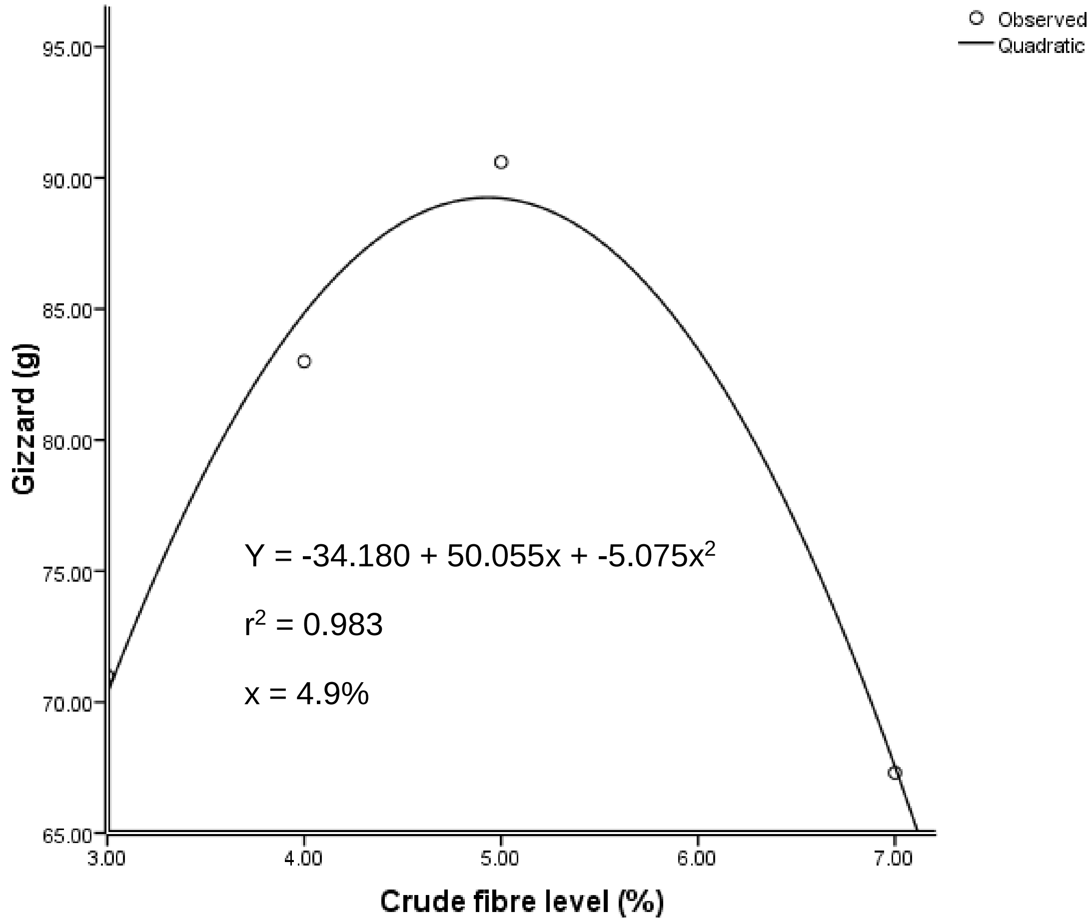

Figure 4.17 Effect of dietary crude fibre level on gizzard weight of Venda chickens aged 91 days

Table 4.07 Dietary crude fibre levels (%) for optimal gut organ weights (g) of Venda and Ross 308 broiler chickens aged 91 days

Variable	Formula	r^2	Optimal CF level (%)	Optimal Y-level (g)
Ross 308 Broiler chickens				
Duodenum	$Y = 17.167 + 9.021x + -0.916x^2$	0.793	4.9	39.38
Large intestine	$Y = -15.129 + 8.900x + -0.861x^2$	0.983	5.2	7.87
Venda chickens				
Duodenum	$Y = -12.269 + 13.315x + -1.336x^2$	0.989	5.0	20.91
Large intestine	$Y =-2.649+ 2.695x + -0.236x^2$	0.933	5.7	5.05
Gizzard	$Y = -34.180 + 50.055x + -5.075x^2$	0.983	4.9	89.24
Caeca	$Y = 1.100 + 3.925x + -0.425x^2$	0.929	4.6	10.16

r^2 : Coefficient of determination

CF : Crude fibre

GIT : Gastro-intestinal tract

Table 4.08 Effect of dietary crude fibre level (%) on the pH of gut organ digesta of Ross 308 broiler and Venda chickens aged 91 days

Treatment*	Duodenum	Jejunum	Ileum	Large Intestines	Gizzard	Crop	Caeca
Ross 308 broiler chickens							
FRC_3	$5.64^a \pm 0.075$	$4.86^a \pm 0.184$	$5.62^a \pm 0.249$	$5.72^a \pm 0.548$	$3.56^a \pm 0.408$	$4.29^a \pm 0.144$	$6.27^a \pm 0.230$
FRC_4	$5.52^a \pm 0.069$	$4.80^a \pm 0.182$	$5.21^a \pm 0.315$	$5.66^a \pm 0.335$	$3.74^a \pm 0.272$	$4.29^a \pm 0.091$	$6.39^a \pm 0.257$
FRC_5	$5.69^a \pm 0.095$	$4.75^a \pm 0.226$	$5.53^a \pm 0.661$	$5.84^a \pm 0.184$	$3.86^a \pm 0.294$	$4.60^a \pm 0.104$	$6.41^a \pm 0.223$
FRC_7	$5.62^a \pm 0.067$	$4.90^a \pm 0.210$	$5.46^a \pm 0.242$	$5.73^a \pm 0.504$	$3.64^a \pm 0.254$	$4.46^a \pm 0.140$	$6.23^a \pm 0.258$
Venda chickens							
FVC_3	$5.80^a \pm 0.380$	$5.55^a \pm 0.191$	$5.66^a \pm 0.272$	$5.75^a \pm 0.316$	$2.84^a \pm 0.546$	$4.35^a \pm 2.367$	$5.56^a \pm 0.153$
FVC_4	$5.85^a \pm 0.185$	$5.41^a \pm 1.026$	$5.59^a \pm 0.289$	$5.99^a \pm 0.211$	$3.03^a \pm 0.507$	$4.51^a \pm 0.242$	$5.98^a \pm 0.512$
FVC_5	$5.73^a \pm 0.387$	$5.60^a \pm 0.193$	$6.30^a \pm 0.302$	$5.98^a \pm 0.528$	$2.72^a \pm 0.647$	$4.29^a \pm 0.262$	$6.10^a \pm 0.152$
FVC_7	$5.75^a \pm 0.336$	$5.51^a \pm 0.669$	$5.74^a \pm 0.276$	$6.05^a \pm 0.167$	$2.78^a \pm 0.650$	$4.41^a \pm 0.245$	$6.00^a \pm 0.688$
Chicken breed							
Ross	$5.62^b \pm 0.263$	$4.83^b \pm 0.272$	$5.45^b \pm 0.213$	$5.74^b \pm 0.179$	$3.70^a \pm 0.280$	$4.41^a \pm 0.120$	$6.33^a \pm 0.354$
Venda	$5.78^a \pm 0.595$	$5.52^a \pm 0.420$	$5.82^a \pm 0.258$	$5.94^a \pm 0.222$	$2.84^b \pm 0.575$	$4.39^a \pm 0.873$	$5.91^b \pm 1.409$
Significance							
Breed	0.006	0.0007	0.007	0.063	0.007	0.842	0.015
Treatment	0.937	0.933	0.320	0.578	0.940	0.851	0.367
Breed x Treatment	0.240	0.898	0.579	0.628	0.906	0.430	0.613

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

FRC : Female Ross 308 broiler chickens

FVC : Female Venda chickens

CF : Crude fibre

* : Treatments are 3%, 4%, 5% and 7% CF

Table 4.09 Effect of dietary crude fibre level (%) on ileal villi height (µm), crypt depth (µm) and villi height to crypt depth ratio of Ross 308 broiler and Venda chickens aged 91 days

Treatment*	Villi height (µm)	Crypt depth (µm)	Villi height to crypt depth ratio
Ross 308 broiler chickens			
FRC_3	606.7[a] ± 108.27	143.3[a] ± 20.14	4.2[a] ± 0.28
FRC_4	360.0[a] ± 137.17	100.0[a] ± 25.52	3.6[a] ± 0.36
FRC_5	463.3[a] ± 287.50	100.0[a] ± 53.49	4.6[a] ± 0.75
FRC_7	350.0[a] ± 105.45	93.3[a] ± 19.62	3.8[a] ± 0.27
Venda chickens			
FVC_3	393.3[ab] ± 110.03	130.0[a] ± 25.10	3.0[b] ± 0.37
FVC_4	770.0[a] ± 116.68	150.0[a] ± 26.61	5.1[a] ± 0.39
FVC_5	313.3[b] ± 121.80	96.67[a] ± 27.78	3.2[b] ± 0.41
FVC_7	243.3[b] ± 111.66	100.0[a] ± 25.47	2.4[b] ± 0.37
Chicken breed			
Ross	445.0[a] ± 89.09	109.2[a] ± 18.62	4.1[a] ± 0.27
Venda	430.0[a] ± 107.94	119.2[a] ± 22.56	3.4[b] ± 0.32
Significance			
Breed	0.849	0.548	0.037
Treatment	0.040	0.275	0.013
Breed x Treatment	0.068	0.544	0.004

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

µm : Micrometre

FRC : Female Ross 308 broiler chickens

FVC : Female Venda chickens

CF : Crude fibre

* : Treatments are 3%, 4%, 5% and 7% CF

Table 4.10 Effect of dietary crude fibre level (%) on the weights (g) of carcass parts of Ross 308 broiler and Venda chickens aged 91 days

	Carcass parts			
Treatment*	Carcass (g)	Breast (g)	Thigh (g)	Drumstick (g)
Ross 308 broiler chickens				
FRC_3	$3372.5^a \pm 167.51$	$1367.2^a \pm 62.39$	$515.9^a \pm 30.83$	$407.2^a \pm 27.08$
FRC_4	$3297.8^a \pm 159.21$	$1322.4^a \pm 59.30$	$490.4^a \pm 29.31$	$382.3^a \pm 25.74$
FRC_5	$3304.2^a \pm 284.30$	$1342.5^a \pm 105.90$	$514.7^a \pm 52.33$	$407.8^a \pm 45.10$
FRC_7	$3354.9^a \pm 163.07$	$1468.3^a \pm 60.74$	$482.2^a \pm 30.02$	$380.9^a \pm 26.36$
Venda chickens				
FVC_3	$939.1^a \pm 155.74$	$224.7^a \pm 35.10$	$141.4^{ab} \pm 14.58$	$115.2^a \pm 14.34$
FVC_4	$904.3^a \pm 123.74$	$240.2^a \pm 27.89$	$152.5^{ab} \pm 11.58$	$126.3^a \pm 11.39$
FVC_5	$954.9^a \pm 218.60$	$276.0^a \pm 49.26$	$163.7^a \pm 20.47$	$128.6^a \pm 20.12$
FVC_7	$746.5^a \pm 365.41$	$207.8^a \pm 82.35$	$123.5^b \pm 34.21$	$100.6^a \pm 33.64$
Chicken breed				
Ross	$3332.3^a \pm 418.39$	$1375.1^a \pm 141.20$	$500.8^a \pm 68.47$	$394.5^a \pm 60.85$
Venda	$883.9^b \pm 1654.20$	$237.2^b \pm 558.25$	$145.3^b \pm 270.73$	$117.7^b \pm 240.57$
Significance				
Breed	<0.0001	<0.0001	<0.0001	<0.0001
Treatment	0.877	0.642	0.032	0.558
Breed x Treatment	0.789	0.201	0.461	0.821

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

FRC : Female Ross 308 broiler chickens

FVC : Female Venda chickens

CF : Crude fibre

* : Treatments are 3%, 4%, 5% and 7% CF

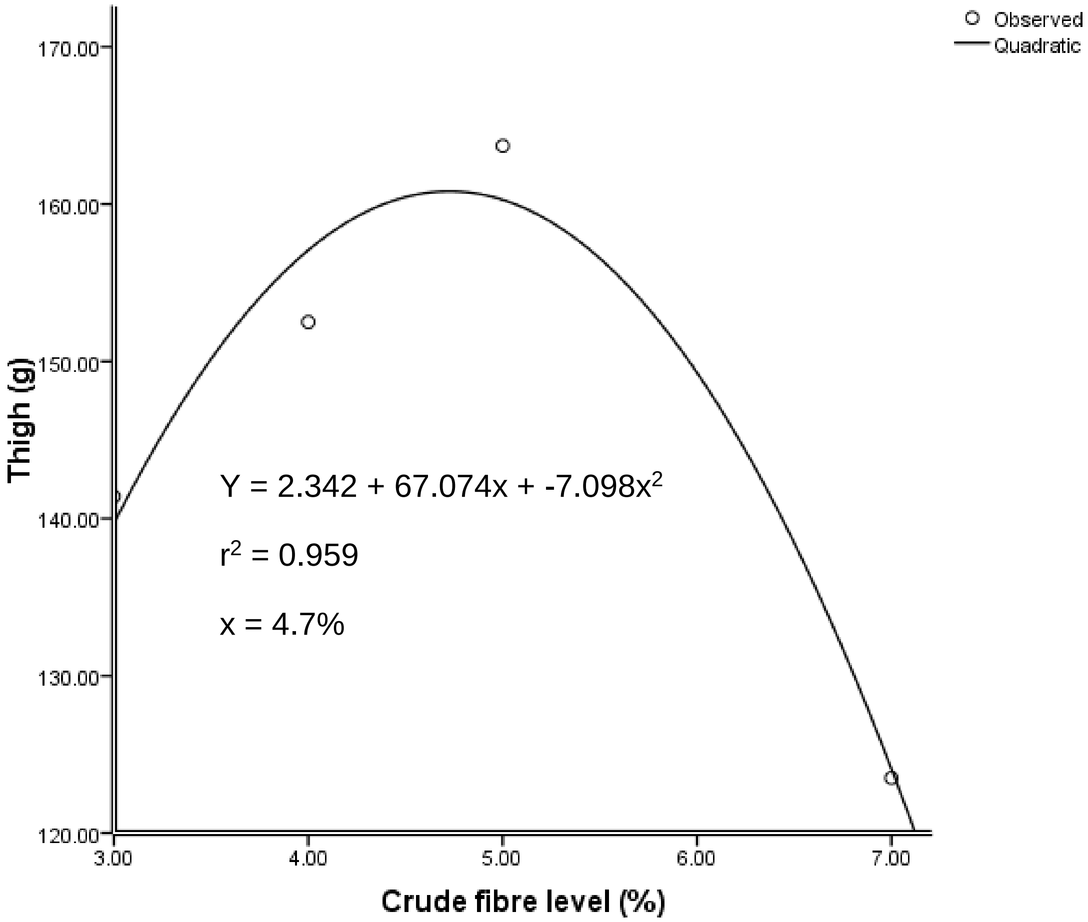

Figure 4.18 Effect of dietary crude fibre level on thigh weight of Venda chickens aged 91 days

Table 4.11 Effect of dietary crude fibre level (%) on the breast meat colour of Ross 308 broiler and Venda chickens aged 91 days

Treatment[#]	Breast meat colour		
	L*	a*	b*
Ross 308 broiler chickens			
FRC_3	$47.68^b \pm 1.007$	$6.19^a \pm 0.915$	$12.15^a \pm 2.264$
FRC_4	$51.73^a \pm 1.095$	$4.75^a \pm 0.995$	$12.15^a \pm 2.876$
FRC_5	$53.31^a \pm 1.044$	$5.74^a \pm 0.948$	$15.56^a \pm 2.742$
FRC_7	$52.04^a \pm 1.493$	$4.25^a \pm 0.356$	$9.36^a \pm 3.921$
Venda chickens			
FVC_3	$52.38^a \pm 1.303$	$2.02^a \pm 0.606$	$12.81^a \pm 1.063$
FVC_4	$51.50^a \pm 1.416$	$3.00^a \pm 0.660$	$11.67^a \pm 1.558$
FVC_5	$50.09^a \pm 1.350$	$3.83^a \pm 0.629$	$11.99^a \pm 1.102$
FVC_7	$51.39^a \pm 1.931$	$2.83^a \pm 0.900$	$10.19^a \pm 1.576$
Chicken Breed			
Ross	$51.19^a \pm 0.578$	$5.23^a \pm 0.543$	$12.31^a \pm 1.177$
Venda	$51.34^a \pm 0.680$	$2.92^b \pm 0.574$	$11.67^a \pm 1.265$
Significance			
Breed	0.858	0.003	0.662
Treatment	0.029	0.462	0.311
Breed x Treatment	0.058	0.329	0.677

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

FRC : Female Ross 308 chickens

FVC : Female Venda chickens

CF : Crude fibre

L* : Lightness of meat

a* : Redness of meat

b* : Yellowness of meat

[#] : Treatments are 3%, 4%, 5% and 7% CF

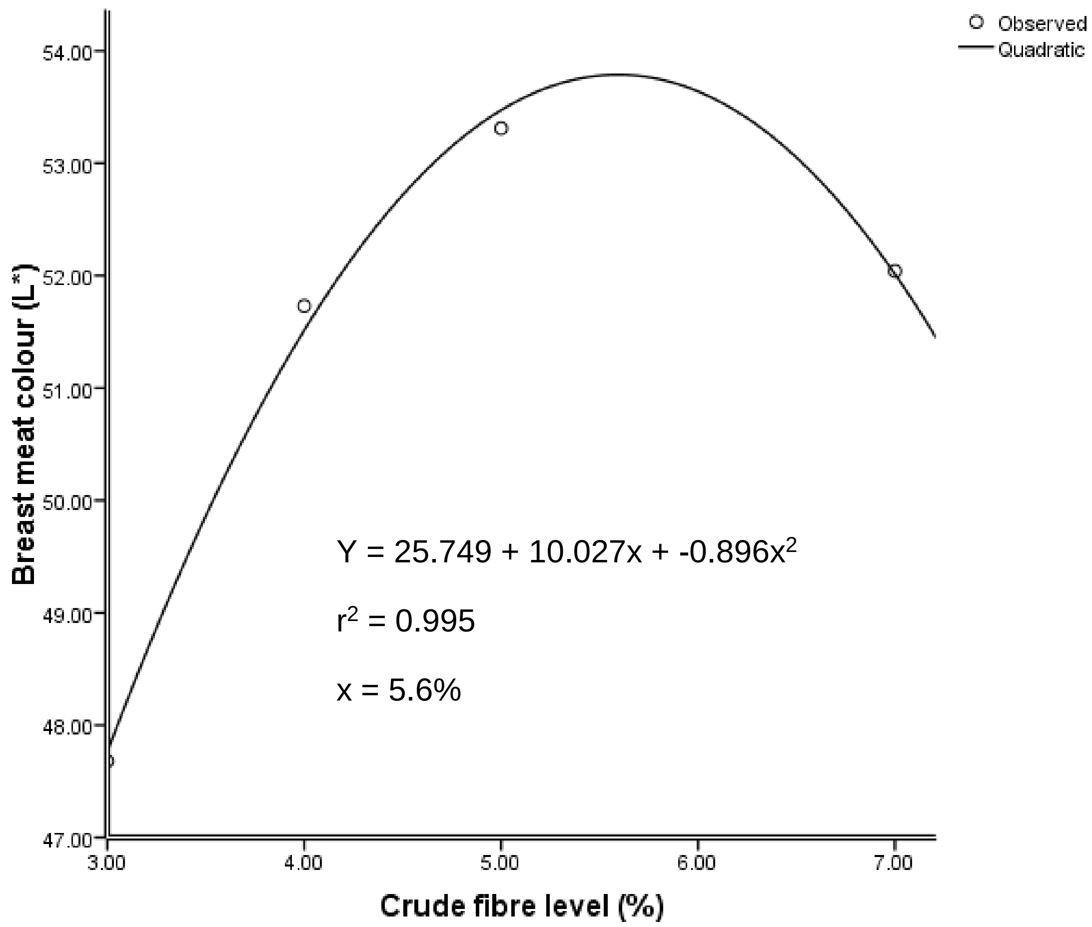

Figure 4.19 Effect of dietary crude fibre level on breast meat colour of Ross 308 broiler chickens aged 91 days

Table 4.12 Effect of dietary crude fibre level (%) on the meat tenderness, juiciness, flavour, acceptability and shear force values (g) of Ross 308 broiler and Venda chickens aged 91 days

Treatment*	Shear force (g)	Tenderness	Juiciness	Flavour	Acceptability
Ross 308 broiler chickens					
FRC_3	$14.6^{ab} \pm 1.25$	$4.0^{a} \pm 0.13$	$3.1^{a} \pm 0.04$	$3.2^{a} \pm 0.09$	$3.0^{a} \pm 0.40$
FRC_4	$18.5^{a} \pm 1.19$	$3.9^{a} \pm 0.12$	$3.1^{a} \pm 0.3$	$3.4^{a} \pm 0.09$	$2.9^{a} \pm 0.40$
FRC_5	$16.1^{ab} \pm 2.13$	$4.0^{a} \pm 0.22$	$3.1^{a} \pm 0.04$	$3.4^{a} \pm 0.10$	$3.3^{a} \pm 0.46$
FRC_7	$12.7^{b} \pm 1.22$	$4.1^{a} \pm 0.13$	$3.2^{a} \pm 0.04$	$3.1^{a} \pm 0.10$	$2.9^{a} \pm 0.43$
Venda chickens					
FVC_3	$17.2^{b} \pm 2.42$	$2.1^{a} \pm 0.58$	$2.5^{c} \pm 0.88$	$4.1^{a} \pm 1.49$	$4.1^{a} \pm 2.61$
FVC_4	$28.3^{a} \pm 1.92$	$2.8^{a} \pm 0.46$	$2.8^{bc} \pm 0.13$	$3.8^{a} \pm 0.22$	$4.2^{a} \pm 0.39$
FVC_5	$26.7^{a} \pm 3.39$	$3.3^{a} \pm 0.82$	$3.7^{a} \pm 0.20$	$4.0^{a} \pm 0.33$	$3.7^{a} \pm 0.58$
FVC_7	$17.6^{b} \pm 5.67$	$2.7^{a} \pm 0.36$	$3.1^{b} \pm 0.18$	$3.9^{a} \pm 0.30$	$3.9^{a} \pm 0.53$
Chicken breed					
Ross	$15.5^{b} \pm 4.35$	$4.0^{a} \pm 0.87$	$3.1^{a} \pm 0.05$	$3.3^{b} \pm 0.09$	$3.0^{b} \pm 0.22$
Venda	$22.4^{a} \pm 17.20$	$2.7^{b} \pm 3.45$	$3.0^{a} \pm 0.14$	$4.0^{a} \pm 0.25$	$4.0^{a} \pm 0.58$
Significance					
Breed	0.0001	0.0002	0.192	0.0003	0.007
Treatment	0.0007	0.280	0.001	0.795	0.959
Breed x Treatment	0.046	0.235	0.001	0.476	0.692

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

FRC : Female Ross 308 broiler chickens

FVC : Female Venda chickens

CF : Crude fibre

* : Treatments are 3%, 4%, 5% and 7% CF

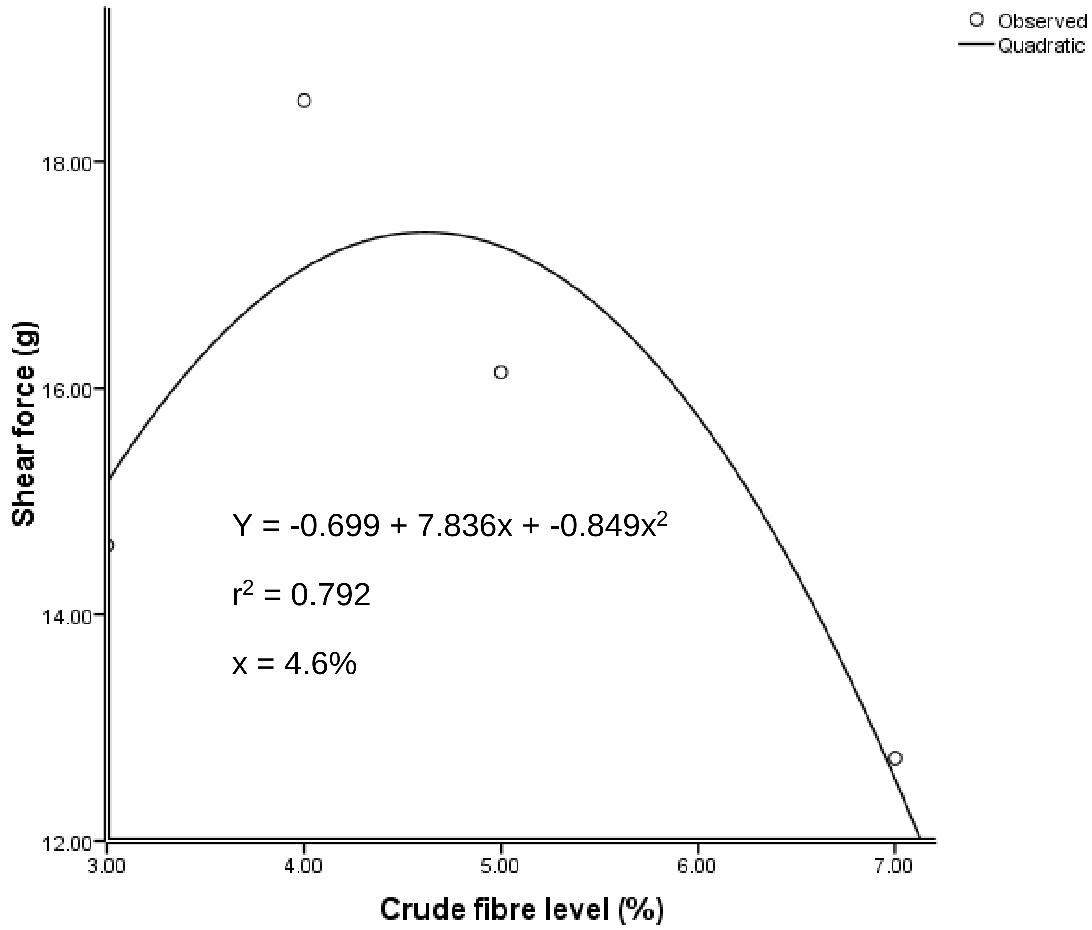

Figure 4.20 Effect of dietary crude fibre level on shear force values of Ross 308 broiler chickens aged 91 days

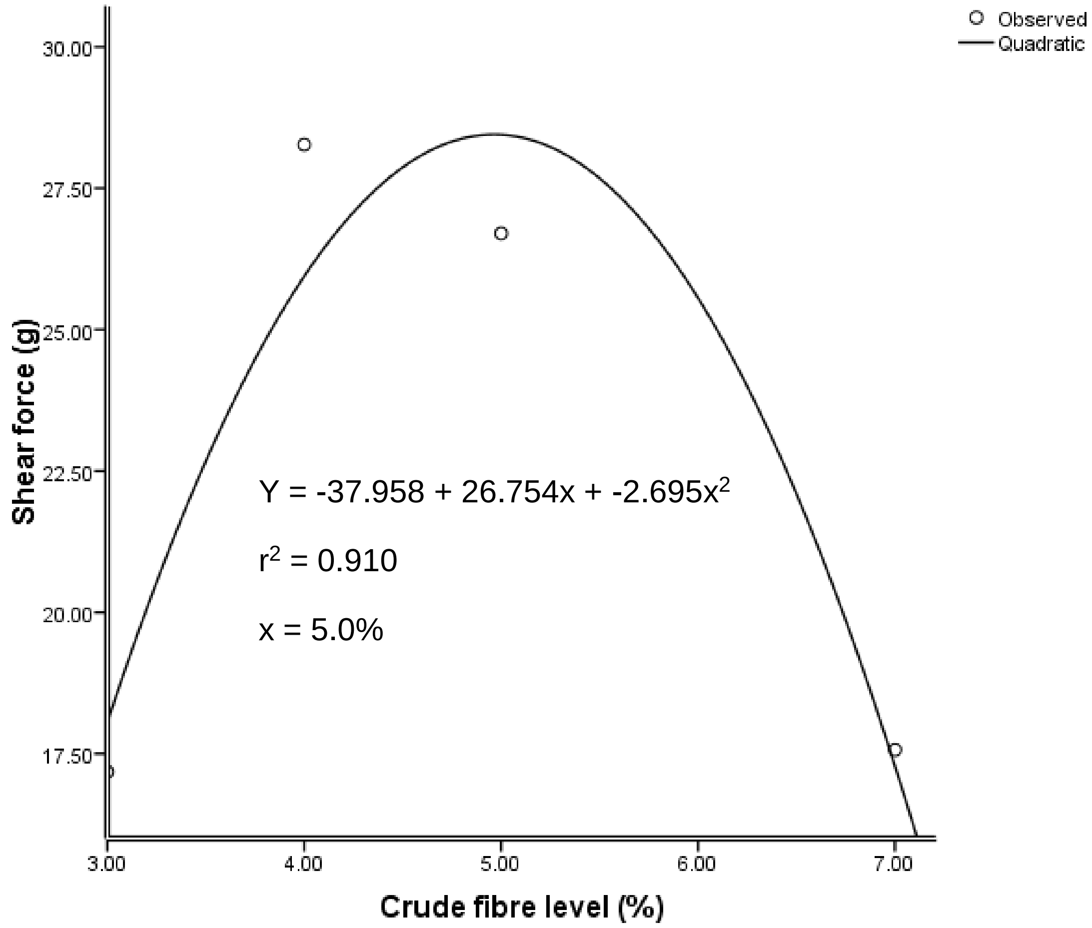

Figure 4.21 Effect of dietary crude fibre level on shear force values of Venda chickens aged 91 days

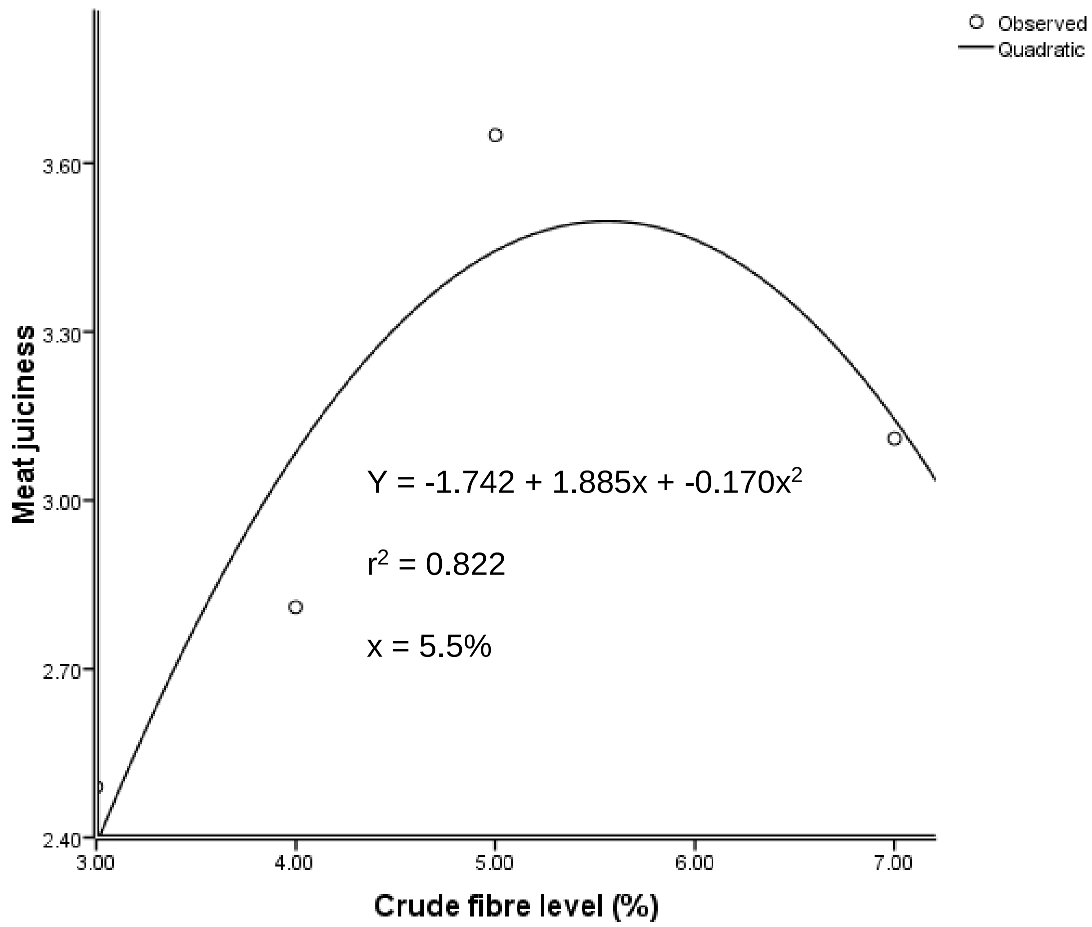

Figure 4.22 Effect of dietary crude fibre level on meat juiciness of Venda chickens aged 91 days

Table 4.13 Dietary crude fibre levels (%) for optimal shear force values (g) and meat juiciness of Venda and Ross 308 broiler chickens aged 91 days

Variable	Formula	r^2	Optimal CF level (%)	Optimal Y-level
Ross 308 broiler chickens				
Shear force	$Y = -0.699 + 7.836x + -0.849x^2$	0.792	4.6	17.38
Venda chickens				
Shear force	$Y = -37.953 + 26.716x + -2.691x^2$	0.910	5.0	28.36
Juiciness	$Y = -1.902 + 1.961x + -0.177x^2$	0.822	5.5	3.48

r^2 : Coefficient of determination

CF : Crude fibre

Table 4.14 Effect of dietary crude fibre level (%) on the pH of breast, thigh and drumstick meat of Ross 308 broiler and Venda chickens aged 91 days

Treatment*	Breast	Thigh	Drumstick
Ross 308 broiler chickens			
FRC_3	$5.66^a \pm 0.152$	$5.78^a \pm 0.041$	$5.85^a \pm 0.044$
FRC_4	$5.67^a \pm 0.056$	$5.79^a \pm 0.039$	$5.86^a \pm 0.047$
FRC_5	$5.66^a \pm 0.054$	$5.77^a \pm 0.040$	$5.85^a \pm 0.045$
FRC_7	$5.58^a \pm 0.062$	$5.83^a \pm 0.041$	$5.87^a \pm 0.053$
Venda chickens			
FVC_3	$5.64^a \pm 0.076$	$5.74^b \pm 0.047$	$5.79^a \pm 0.062$
FVC_4	$5.60^a \pm 0.072$	$5.86^{ab} \pm 0.051$	$5.83^a \pm 0.069$
FVC_5	$5.58^a \pm 0.114$	$5.75^b \pm 0.071$	$5.80^a \pm 0.079$
FVC_7	$5.63^a \pm 0.101$	$5.97^a \pm 0.089$	$5.91^a \pm 0.106$
Chicken breed			
Ross	$5.64^a \pm 0.152$	$5.79^a \pm 0.081$	$5.86^a \pm 0.133$
Venda	$5.61^a \pm 0.571$	$5.83^a \pm 0.267$	$5.83^a \pm 0.277$
Significance			
Breed	0.527	0.272	0.475
Treatment	0.912	0.030	0.580
Breed x Treatment	0.766	0.230	0.824

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

FRC : Female Ross 308 broiler chickens

FVC : Female Venda chickens

CF : Crude fibre

* : Treatments are 3%, 4%, 5% and 7% CF

CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Growth performance and digestibility

The results of the present study indicate that different levels of dietary crude fibre did not affect DM intake, growth rate, feed conversion ratio and live weight of Ross 308 broiler chickens aged 56 to 91 days. This is despite decreasing NDF and ADF digestibilities with the increased dietary crude fibre levels. The results are in agreement with those of Alshelmani *et al.* (2016), who noted the decreased NDF and ADF digestibility values when high (15%) dietary crude fibre level was included in the diet of broiler chickens aged 22 to 42 days. Conversely, Krás *et al.* (2013) found that an increased dietary crude fibre level (14%) resulted in increased ADF digestibility in broiler chickens aged 31 to 41 days. These authors reported that an increased fibre fraction in the diet of broiler chickens speeds up the rate of digesta passage, increasing the excreta output and decreasing the digestibility of most nutrients (Jiménez-Moreno *et al.,* 2010; Georgieva *et al.,* 2014). In the present study, dietary crude fibre level affected ME intake of Ross 308 broiler chickens aged 56 to 91 days, and it was optimized at a dietary CF level of 4.1%. This is similar to the findings of Krás *et al.* (2013), who noted a significant increase in ME intake when a diet containing 4% CF was fed to broiler chickens aged 22 to 42 days. There was a strong and negative relationship between dietary crude fibre level and N-retention in Ross 308 broiler chickens aged 56 to 91 days. Several studies considered dietary fibre as diluents of the diet (Mateos *et al.,* 2002; Rougiere and Carre, 2010). Thus, the reason for the reduction in N-retention with an increase in dietary CF level, in the current study, may be due to the high levels of indigestible fibre in the diets of chickens, which might have limited the exposure of proteins and carbohydrates to digestion processes, resulting in decreased N-retention (Hernandez *et al.,* 2011; Jiménez-moreno *et al.,* 2013).

The results of the present study indicate that dietary crude fibre level did not affect DM intake, growth rate, feed conversion ratio, ADF digestibility and N-retention of Venda chickens aged 56 to 91 days. However, live weight, NDF digestibility and ME intake of the chickens were affected by dietary crude fibre level. The live weight of Venda chickens was optimized at a dietary crude fibre level of 4.2%. This level is higher than 3.2% observed by Ginindza (2014) in indigenous Venda chickens aged 50 to 91days. The present study indicates a strong and positive relationship between dietary crude fibre level and NDF digestibility of Venda chickens aged 56 to 91 days. This finding is contrary to the observations of Ginindza (2014), who reported that an increased dietary crude fibre level resulted in decreased crude fibre digestibility.

Ross 308 broiler chickens had higher DM intake, growth rate, live weight, ME intake and N-retention than Venda chickens. Similarly, broiler chickens had better FCR values than Venda chickens. These responses were expected since Ross 308 broiler chickens are known to have faster growth rates as compared to indigenous chickens (Kamali *et al.,* 2007). Thus, their diet intakes are generally high to sustain their faster growth rates (Nguyen *et al.,* 2010). The current findings are supported by Krás *et al*. (2013), who reported that broiler chickens presented better FCR and higher weight gain as compared to slow growing chickens. Yang and Jiang (2005) and Moujahed and Haddad (2013) found that the indigenous chickens have lower growth rates than broiler chickens. The present study indicates that Venda chickens had higher NDF and ADF digestibility values than Ross 308 broiler chickens. The difference might be genetic (Rondelli *et al.,* 2003). No studies were found comparing the effect of dietary crude fibre level on digestibility of Venda and Ross 308 broiler chickens.

5.1.2 Gastro-intestinal tract

Dietary crude fibre level had no effect on the lengths of duodenum, ileum, large intestines and caeca of Ross 308 broiler chickens aged 56 to 91 days. However, the lengths of jejunum and GIT were significantly affected and were optimized at dietary crude fibre levels of 5.5 and 6.8%, respectively. The results are in line with the findings of Mossami (2011), who found that different dietary crude fibre levels had no effect on the lengths of large intestines and caeca of broiler chickens aged 22 to 35 days. Jimenez-Moreno *et al.* (2011) and Incharoen (2013), also, observed no significant differences in the lengths of small intestines and caeca of broiler chickens aged 22 to 42 days, when different dietary crude fibre levels were included in the diet. However, the authors did not indicate their optimal levels. In contrast to the current study, Amera *et al.* (2009) found that the increased levels of dietary crude fibre significantly decreased the lengths of small intestines of broiler chickens aged 22 to 42 days. Jorgensen *et al.* (1996) reported that the increased dietary crude fibre levels resulted in increased length of GIT in broiler chickens aged 22 to 42 days. They indicated that this was meant to increase the surface area for digestion and absorption.

In the present study, dietary crude fibre level significantly affected the lengths of duodenum, jejunum and GIT of Venda chickens aged 56 to 91 days. However, the lengths of large intestines and caeca were not affected by dietary crude fibre level. The lengths of jejunum, ileum and GIT of Venda chickens were optimized at dietary crude fibre levels of 5.8, 3.5 and 5.7%, respectively. These findings vary with the observations of Ginindza (2014), who observed that dietary crude fibre level did not affect the lengths of small intestines and GIT of Venda chickens aged 50 to 91 days. The author observed a positive relationship between dietary crude fibre level and caecal length of the chickens. Furthermore, the author noted a negative relationship between dietary crude fibre level and large intestinal lengths in Venda chickens.

Ross 308 broiler chickens had longer jejunum, ileum, caeca and GIT than Venda chickens. However, the chickens had similar duodenal and large intestinal lengths. Jamroz (2005) found that the GIT of broiler chickens were longer as compared to other slow growing chicken breeds. Mabelebele *et al.* (2013), also, observed that Ross 308 broiler chickens had longer GIT and small intestines as compared to Venda chickens. Yamauchi and Isshiki (1991) demonstrated that the small intestines of broiler chickens develop faster in order to facilitate higher digestion and absorption to support rapid growth rates.

Dietary crude fibre level did not affect the weights of jejunum, ileum, caeca, gizzard and crops of Ross 308 broiler chickens. However, the weights of duodenum and large intestines of the chickens were affected by dietary crude fibre level and they were optimized at dietary crude fibre levels of 4.9 and 5.2%, respectively. These results are consistent with the findings of Mossami (2011), who noted no significant differences in the weights of crop, gizzard and caeca of broiler chickens aged 22 to 35 days when the chickens were fed diets containing different crude fibre levels. Contrary to the current study, Hetland *et al.* (2005), Gonzalez-Alvarado *et al.* (2007) and Incharoen (2013) reported that an increased dietary crude fibre level resulted in increased gizzard weights of broiler chickens aged 22 to 42 days. Sacranie *et al.* (2012), also, observed the increased gizzard weights when broiler chickens were offered diets containing higher crude fibre levels. This is because the coarse fibre particles are retained in the gizzard until they are ground to a certain critical size, leading to an increased volume of gizzard contents and a muscular adaptation to meet the greater demand for grinding (Moore, 1999; Hetland *et al.,* 2005). Jimenez-Moreno *et al.* (2011) found that the inclusion of 5% dietary crude fibre level increased the gizzard weights of broiler chickens aged 22 to 36 days.

The current study indicates that dietary crude fibre level affected the weights of duodenum, caeca, large intestines, gizzard and crops of Venda chickens aged 56 to 91 days. However, the weights of jejunum and ileum were not influenced by dietary crude fibre level. Different dietary crude fibre levels of 5.0, 4.6, 5.7 and 4.9%, respectively, optimized the weights of duodenum, caeca, large intestines and gizzards of Venda chickens. Contrary to the current study, Ginindza (2014) observed the negative relationships between dietary crude fibre level and the small intestinal weights of male Venda chickens aged 50 to 91 days. This author, also, observed a positive relationship between dietary crude fibre level and large intestinal weights of the chickens.

Ross 308 broiler chickens had larger duodenum, jejunum, ileum, caeca, large intestines, gizzard and crops than Venda chickens. Jamroz (2005) reported that the reason for the broiler chickens to possess the heavier intestinal segments than indigenous chickens is to allow them to reach the mature weight faster.

Dietary crude fibre level did not affect the ileal villi height, crypt depth and villi height to crypt depth ratio of Ross 308 broiler chickens aged 56 to 91 days. The results are in agreement with the findings of Alshelmani *et al.* (2016), who reported that the inclusion of dietary crude fibre levels of 5 to 15% did not affect the villi height and crypt depth of broiler chickens aged 21 to 42 days. Similarly, Sarikhan *et al.* (2010), Jimenez-Moreno *et al.* (2013) and Incharoen (2013) reported that dietary crude fibre level had no effect on crypt depth of broiler chickens aged 21 to 42 days. In contrast to the current study, Iji *et al.* (2001) observed deeper crypts in broiler chickens aged 22 to 28 days when 5% dietary crude fibre level was included in the diet. Baurhoo *et al*. (2009) found that dietary crude fibre level of 2.5% significantly decreased the villi height of broiler chickens aged 22 to 42 days. Sarikhan *et al.* (2010) found that the inclusion of 0.50 or 0.75% dietary crude fibre level significantly increased the villi height and villi height to crypt depth ratio of broiler chickens aged 21 to 42 days. Jamroz *et al.* (2006), also, found that dietary crude fibre level resulted in higher villi heights in broiler chickens aged 22 to 42 days. The authors postulated that an increased villi height might be associated with the need to increase the surface area for absorption. Montagne *et al.* (2003) found that an increased dietary crude fibre level significantly decreased the villi height of broiler chickens aged 22 to 42 days. Incharoen (2013) observed that an increased dietary crude fibre level had decreased the ileal villi height of broiler chickens aged 22 to 42 days. Montagne *et al.* (2003) postulated that the reason for the decrease in villi height could be an excessive amount of dietary crude fibre abraded the small intestines in the mucosal surface, thereby reducing the villi height.

Dietary crude fibre level affected the villi height and villi height to crypt depth ratio of Venda chickens, and they were optimized at dietary crude fibre levels of 4.1 and 4.5%, respectively. The crude fibre level of 4.1% for optimal villi height to crypt depth ratio correlates with the 3.7% observed by Ginindza (2014) in Venda chickens aged 50 to 91 days. However, the author observed a higher CF level of 10.1% for optimal villi height as compared to the 4.5% noted in the current study.

In the present study, Venda and Ross 308 broiler chickens had similar villi height and crypt depth values. However, Ross 308 broiler chickens had a higher villi height to crypt depth ratio value than Venda chickens. A villi height to crypt depth ratio is a useful criterion for estimating the absorptive capacity of the small intestines (Hoerr, 2001; Montagne *et al.,* 2003). Higher ratios indicate the higher nutrient absorption capacity (Jimenez-Moreno *et al.,* 2011). No scientific literature was found comparing the effect of dietary crude fibre level on ileal villi height, crypt depth and villi height to crypt depth ratio of Venda and Ross 308 broiler chickens.

The digesta pH of digestive organs is related to the digesta content retained in the organ (Jimenez-Moreno *et al.,* 2013). The results of the present study indicate that dietary crude fibre level did not affect duodenum, jejunum, ileum, large intestine, gizzard, crop and caecal digesta pH of Ross 308 broiler chickens aged 56 to 91 days. This is similar to the observations of Liu *et al.* (2011) and Mateos *et al.* (2013), who observed no significant differences in duodenal, caecal and gizzard digesta pH values of broiler chickens aged 31 and 42 days, respectively. Incharoen *et al.* (2013), also, observed no difference in digesta pH of small intestines in broiler chickens aged 22 to

42 days, when the chickens were offered diets containing different dietary crude fibre levels. In contrast to the present study, González-Alvarado *et al.* (2007) reported that an increased dietary crude fibre level significantly decreased the gizzard pH in broiler chickens aged 22 to 42 days. Jimenez-Moreno *et al.* (2011) found that dietary crude fibre level of 2.5% significantly decreased the gizzard digesta pH of broiler chickens aged 22 to 36 days.

The present study indicates that dietary crude fibre level did not affect duodenum, jejunum, ileum, large intestine, gizzard, crop and caecal digesta pH of Venda chickens aged 56 to 91 days. Similar results were observed by Ginindza (2014) for gizzards and large intestinal digesta pH of Venda chickens aged 50 to 91 days. In contrast to the present study, the author found that dietary crude fibre level affected the pH values of the crop, small intestines and caeca of the chickens. Higher dietary CF level resulted in higher digesta pH values.

Venda and Ross 308 broiler chickens had similar crop digesta pH values. However, Venda chickens had higher duodenum, jejunum, ileum and large intestinal digesta pH values than those of Ross 308 broiler chickens. Ross 308 broiler chickens had higher gizzard and caecal digesta pH values than Venda chickens. No information was found comparing the effect of dietary crude fibre level on digesta pH of Venda and Ross 308 broiler chickens. However, the present results correlate with the observations of Mabelebele *et al.* (2013), who compared the gastrointestinal tracts and pH values of Venda and Ross 308 broiler chickens fed the same commercial diet. The authors found that Venda chickens had lower gizzard digesta pH as compared to Ross 308 broiler chickens. The possible reasons for the reduction in gizzard digesta pH of Venda chickens could be resulting from the increased secretion of hydrochloric acid in the gizzard, which normally occurs with higher accumulation and longer retention time of coarse feed particles in the gizzard (Hetland *et al.,* 2005). Guinotte *et al.* (1995) reported that low gizzard pH improves the pepsin activity and increases the solubility of mineral fraction of the feed, thereby, enhancing digestion and absorption of nutrients.

5.1.3 Carcass parts and meat quality

Dietary crude fibre level did not affect carcass, breast, thigh and drumstick meat weights of Ross 308 broiler chickens aged 56 to 91 days. Sarikhan *et al.* (2010), also, observed the similar results in broiler chickens aged 21 to 42 days. Incharoen *et al.* (2013), also, observed no differences in the weights of thigh and drumsticks of broiler chickens aged 22 to 42 days when dietary crude fibre level was increased in the diet. In contrast to the present study, Sarikhan *et al.* (2010) found that increasing CF by 0.50 or 0.75% resulted in increased carcass weight and breast meat yield of broiler chickens aged 22 to 42 days. Shahin and Abdelazim (2006) and Mourao *et al.* (2008) found that an increase in dietary crude fibre level decreased the carcass weights of broiler chickens aged 34 and 56 days, respectively.

Dietary CF level had no effect on the weights of carcass, breast and drumstick meat of Venda chickens aged 56 to 91 days. However, the thigh weights of Venda chickens were increased with the increasing levels of dietary crude fibre until optimized at a dietary crude fibre level of 4.6%. This level is higher than the 3.6% observed by Ginindza (2014) in Venda chickens aged 50 to 91 days. Contrary to the current study, Ginindza (2014) found that dietary crude fibre level affected the weights of carcass, breast and drumstick weights of male Venda chickens; higher dietary CF levels resulted in lower weights.

Ross 308 broiler chickens had heavier carcass, breast, thigh and drumstick meat than Venda chickens. Young *et al*. (2001), Havenstein *et al.* (2003) and Sebola *et al*. (2015) reported that carcass yield is affected by genetic and feed factors. Moreover, low body weight is associated with low carcass yield (Moujahed and Haddad, 2013). No literature was found comparing the effect of dietary crude fibre level on the weights of carcass, breast, thigh and drumstick meat of Venda with those of Ross 308 broiler chickens.

This study indicates that the increase in dietary crude fibre level significantly increased the lightness (L*) of breast meat colour of Ross 308 broiler chickens aged 56 to 91 days and it was optimized at a dietary crude fibre level of 6.0%. However, the redness (a*) and yellowness (b*) of breast meat were not affected by dietary crude fibre level in the diet. Meat colour depends on the melanin pigment production ability of the dermis and epidermis and also on absorption and storage of carotenoid pigments in the epidermis (Fletcher, 1999). Other factors that influence skin colour are genetics and feeding (Xiong *et al.,* 1999). Contrary to the current findings, Mourão *et al.* (2008) observed that the inclusion of 5% dietary crude fibre level significantly increased the yellowness of breast skin of broiler chickens aged 22 to 34 days. Pe´rez-Vendrell *et al.* (2001) indicated that the yellowness in breast skin is a good indicator of the xanthophyll content of the ingested feed.

In the present study, dietary crude fibre level did not affect the (L*), (a*) and (b*) values of breast meat of Venda chickens aged 56 to 91 days. Sañudo *et al.* (2007) indicated that the production system used when rearing the animals plays a major role in terms of meat colour. The authors postulated that animals raised in a closed confinement and fed concentrate feeds tend to have lighter meat colour than those raised in a free-range system, which normally produce darker meat. No related information was found for Venda chickens.

Broiler and Venda chickens' meat had similar lightness and yellowness colours. However, Ross 308 broiler chickens had a higher breast meat redness colour than Venda chickens. Fanatico *et al.* (2007) reported that the meat of slow-growing chickens have less red colouration than the fast-growing ones. This is mostly influenced by the animal related factors, mainly the genotype (Fletcher, 1999).

The results of the present study indicate that an increase in dietary crude fibre level significantly increased the breast meat shear force of Ross 308 broiler chickens aged 56 to 91 days until it was optimized at a CF level of 4.6%. However, the breast meat tenderness, juiciness, flavour and acceptability of the chickens were not influenced by different dietary crude fibre levels. Contrary to the present study, Iyayi *et al.* (2005) observed that higher different dietary CF levels improved meat tenderness and flavour of broiler chickens aged 22 to 42 days.

Dietary crude fibre level affected the meat shear force and juiciness of Venda chickens aged 56 to 91 days. The optimal meat shear force and juiciness of Venda chickens were achieved at dietary crude fibre levels of 5.0 and 5.5%, respectively. However, the meat tenderness, flavour and acceptability were not influenced by different dietary crude fibre levels in the diet. This is similar to the findings of Ginindza (2014), who reported that different dietary crude fibre levels had no effect on meat tenderness and flavour of Venda chickens aged 50 to 91 days.

Venda and Ross 308 broiler chickens had similar scores of breast meat juiciness. However, Ross 308 broiler chickens had higher breast meat tenderness scores than those of Venda chickens. Venda chickens had higher breast meat shear force, flavour and acceptability scores than those of Ross 308 broiler chickens. Castellini *et al.* (2008) reported that the slower growing chickens tend to have firmer texture, outstanding meat flavour and taste than faster growing chicken breeds. The increased shear force values of Venda chickens in the current study indicate that Venda chicken' meat was tougher than broiler meat (Jaturasitha, 2000).

In the present study, dietary crude fibre level had no effect on the pH of breast, thigh and drumstick meat of Ross 308 broiler chickens aged 56 to 91 days. No literature was found on the effect of dietary crude fibre level on meat pH of broiler chickens.

Dietary crude fibre level had no effect on pH of breast and drumstick meat of Venda chickens aged 56 to 91 days. However, increasing CF level increased pH values of thigh meat of the chickens. Husak *et al.* (2008) reported that higher meat pH is more effective for retaining desirable colour and moisture absorption properties. Fanatico *et al.* (2007) indicated that the ultimate pH of the meat is determined by the level of glycogen reserves present in the muscles post-slaughter. The author, also, reported that the decline in post-mortem muscle pH is determined by the glycolytic enzyme activity in the muscles. No information was found on the effect of dietary crude fibre level on pH values of carcass parts of Venda chickens.

Venda and Ross 308 broiler chickens had similar breast, thigh and drumstick pH values. Jaturasitha (2000) reported that meat pH level of slow growing breeds tends to be lower than that of broiler chickens. This is believed to be the result of more aggressive behaviour of these chickens which leads to great intensity of stress, which in turn draws more glycogen into use. As a result, this greatly affects the post-mortem glycolysis process, leading to a high lactic acid accumulation and hence low pH value of meat (Jaturasitha, 2000). No related information comparing the effect of dietary crude fibre levels on breast, thigh and drumstick pH of Venda and Ross 308 broiler chickens was found.

5.2 Conclusion

An increase in dietary crude fibre level resulted in decreased NDF and ADF digestibilities and N-retention of Ross 308 broiler chickens aged 56 to 91 days. Dietary crude fibre level had no effect on the villi height, crypt depths, villi height to crypt depth ratio and duodenum, jejunum, ileum, large intestines, gizzard, crop and caecal digesta pH values of Ross 308 broiler chickens. The lengths of jejunum and GIT of Ross 308 broiler chickens were optimized at dietary crude fibre levels of 5.5 and 6.8%, respectively. The weights of duodenum and large intestines of Ross 308 broiler chickens were optimized at dietary crude fibre levels of 4.9 and 5.2%, respectively. The L* value of breast meat of Ross 308 broiler chickens was optimized at a dietary crude fibre level of 5.6%. The shear force value of Ross 308 broiler chickens was optimized at a dietary crude fibre level of 4.6%.

Dietary crude fibre level did not affect ADF digestibility and N-retention of Venda chickens aged 56 to 91 days. However, a positive relationship was observed between dietary CF level and NDF digestibility. Dietary crude fibre level did not affect duodenum, jejunum, ileum, large intestines, gizzard, crop and caeca digesta pH values of Venda chickens. The lengths of jejunum, ileum and GIT of Venda chickens were optimized at different dietary crude fibre levels of 5.8, 3.5 and 5.7%, respectively. The weights of duodenum, large intestines, gizzards and caeca of Venda chickens were optimized at different dietary crude fibre levels of 5.0, 5.7, 4.9 and 4.6%, respectively. Dietary crude fibre level did not affect the crypt depths of Venda chickens. However, the villi height and villi height to crypt depth ratio were optimized at different CF levels of 4.1 and 4.5%, respectively. The thigh meat weight of Venda chickens was optimized at a dietary crude fibre level of 4.7%. The breast meat shear force and juiciness of Venda chickens were optimized at dietary crude fibre levels of 5.0 and 5.5%, respectively.

Dietary crude fibre level had different effects on the performance variables, digestive physiology, meat quality traits and carcass characteristics of Venda and Ross 308 broiler chickens aged 56 to 91 days. Ross 308 broiler chickens had higher feed intake, growth rate, live weight, N-retention, better FCR values, longer and heavier digestive organs, higher gizzard and caecal digesta pH values, heavier carcass parts, tender and redder meat than Venda chickens. This was expected since Ross 308 broiler chickens are genetically heavier than Venda chickens. It is possible that longer jejunum, ileum, caeca, GIT and higher villi height to crypt depth ratio enabled Ross 308 broiler chickens to absorb more nutrients for their faster growth rates. Higher villi height to crypt depth ratio is associated with higher absorptive capacity. Venda chickens had higher NDF and ADF digestibility values, higher duodenum, jejunum, ileum and large intestinal digesta pH values, higher breast meat shear force values, better meat flavour and higher meat acceptability scores than Ross 308 broiler chickens. These might have implications on crude fibre digestibility by these chickens.

5.3 Recommendations

Increasing dietary crude fibre level up to 7%, significantly decreased NDF digestibility, ADF digestibility and N-retention of Ross 308 broiler chickens. However, similar inclusion levels exhibited positive relationships between dietary crude fibre level and NDF and ADF digestibility values of Venda chickens. It is, therefore, recommended that dietary crude fibre level in broiler chickens' diets should be kept below 7% in order to enhance crude fibre digestibility. Conversely, this level of 7% crude fibre could be recommended for diets of Venda chickens, due to their ability to digest course fibre fractions. However, more studies are required to explore dietary crude fibre levels for optimal digestibility in Venda and Ross 308 broiler chickens. There is, also, a need to explore more of the biological reasons responsible for the variations in crude fibre digestibility between Venda and Ross 308 broiler chickens.

CHAPTER 6

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CHAPTER 7

APPENDIX

APENDIX A: VACCINATION PROGRAM

The vaccination programmes of the study were as follows:

Day 1 Chicks were vaccinated against New castle disease from the hatchery unit using Clone 30. Thereafter, they were administered Vita stress immediately on arrival in order to alleviate stress that might have resulted during transportation and handling. This was done via drinking water.

Day 2 Vita stress was added again in the drinking water to proceed with the alleviation of possible stress.

Day 3 Chicks were prevented for Escheria coli bacteria and other disease-causing microorganisms using Tylo Tad. This was administered via drinking water.

Day 7 Chicks were vaccinated against infectious Bronchitis using “IBH 120”.

Day 12 Chicks were vaccinated against Gumbora disease using D78 via drinking water.

Day 18 Chickens were vaccinated again for the prevention of Gumbora disease using D78 via drinking water.

Day 21 Tylo tad was added in the drinking water for the prevention of bacterial infections.

Day 23 Chickens were vaccinated again for the prevention of New Castle disease using Clone 30.