REPLACEMENT VALUE OF SOME SORGHUM VARIETIES FOR MAIZE IN BROILER CHICKEN DIETS

BY

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DECLARATION

I hereby declare that the work reported in this dissertation has been performed by me in the Department of Animal Science under the supervision of Prof. G.S Bawa

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any University or institution.

Name of student	Signature/Date

CERTIFICATION

This Dissertation entitled "**Replacement Value Of Sorghum Varieties On The Performance Of Broiler Chicken"** by Sadiya Abubakar meets the regulations governing the award of the degree of Masters of Science (Animal Science) in Bayero University, kano, and is approved for its contribution to scientific knowledge and literary presentation.

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Abstract

An experiment was conducted to evaluate the effect of replacing maize with some sorghum varieties (*Farfara*, *ICSV 400*, *Kaura* and Red Sorghum) on performance of broiler chickens. A total of 675 day-old broiler chicks were allotted to nine dietary treatments in a completely randomized design (CRD) using a 4 x 2 factorial arrangement with 3 replicates, and a control diet. Data obtained from the study were subjected to Analysis of Variance and significant differences among treatment means were compared using the Duncan Multiple Range Test. The result of the proximate analysis showed significant ($p<0.05$) difference in all the parameters measured except either extract. The level of anti-nutritional factors differed significantly ($p<0.05$) between the sorghum varieties, the highest recorded in red sorghum. The mineral content differed significantly ($p<0.05$) between the sorghum varieties and maize. The main effect of sorghum varieties shows significant ($p<0.05$) effect on the final body weight, and mortality of broiler chicks at the starter phase, final body weight, feed conversion ratio, feed cost per gain and mortality of broiler chickens at finisher phase. Inclusion levels (50 and 100%) had no significant ($p>0.05$) effect on performance characteristics at both phases. Birds fed *farfara* had the highest final weight at the starter phase followed by *ICSV400*. Birds fed red sorghum at the finisher phase had significantly ($p<0.05$) higher final weight (2387.63g), feed efficiency (1.76) than those fed other dietary treatments and was cheaper (201.86₦/kg). There were significant interactions ($P<0.05$) between dietary treatments (maize and different sorghum varieties) and inclusion levels (50 and100%) for broiler performance at both phases. The carcass characteristics measured were significant ($p<0.05$) influenced by both dietary treatment and their interactions. There were significant ($p<0.05$) differences in all the organs weight except the intestinal length which did not differ significantly ($p>0.05$). Inclusion levels (50 and 100%) had significant ($p<0.05$) effect on liver, kidney and intestinal weight. Varietal and level interaction shows no significant ($p>0.05$) effect on hematological parameters but affect some serum biochemistry indices. It was concluded that *ICSV400* at 100% for starter phase and red sorghum at 50% inclusion level at the finisher phase as better for growth performance of broiler chickens.

CHAPTER ONE

1.0 INTRODUCTION

1.1. Background Information

Animal Protein consumption in the third world countries has not improved over the past decade. Nigeria among other third World countries have protein deficiency gap, especially that of high quality animal protein (Apantaku, 2006). The rising demand for animal products occasioned by increasing population has led to increasing cost of animal product, thus making it unaffordable for the masses. The average Nigerian consumes about 54 grams of protein per day, with 6.5 grams coming from animal sources, against the recommended 80 grams with 28 grams coming from Animal protein (FAO, 1995). Intensifying the production of highly reproductive animals with short generation intervals can ameliorate the problem of inadequate consumption of animal protein in Nigeria (Ani and Diegwu, 2005).

Poultry has been identified as the fastest means of bridging the protein deficiency gap pervading in most tropical countries like Nigeria (FAO, 1990) due to their short generation interval and rapid growth rate. High cost of feed is the major constraint in poultry industry. Feed represent approximately 75 to 80% of the total cost of production (Fasuyi, 2005). In terms of total cost, energy is the main factor influencing diet cost (Afolaye *et al.,* 2009). Conventionally, maize is the major energy source in poultry diet contributing up to 60% of complete poultry ration in Nigeria (Udebibie, *et al*., 2004). Other common cereals used in tropical countries include rice and sorghum and to a less extent, millet and wheat (Olumu, 2011). The demand for maize by man as food and other industrial uses coupled with its low local production due to the effect of recurrent drought in the semi-arid region has placed additional constraint on its continual uses in poultry diet (Olumu, 2011).Therefore, there is need to search for an alternative energy source such as sorghum.

Sorghum grain is the fifth most important cereal crop in the world after wheat, rice, corn and barley (Selle *et al.,* 2010). However, in West Africa sorghum is the second important cereal crop after maize and followed by millet. Nigeria was ranked the third largest producer of sorghum in the world with about 6 million tonnes of grains produced from 5.7 million hectares of land (ICRASAT, 2000).Sorghum is a drought tolerant cereal that is produced worldwide. It has the ability to tolerate drought, soil toxicities and temperature extremes effectively than other cereals. It can be grown in areas unsuitable for maize production (Olumu, 2011).

Sorghum had higher value of protein while its energy or fat is slightly lower than that of maize. The amino acid profile of sorghum compared well to maize although the average lysine content of sorghum was reported to be 0.26% versus that of maize 0.20% (Kriegshaurea *et al.,* 2006). Therefore sorghum grain can be compared quite favorable with the added advantages of tolerance to inclement weather, it could be economically incorporated into the diets of poultry to ease the demand pressure on maize (Scott, 2011).

However, sorghum grain is known to contain anti nutritional factors (ANTS) such as saponin, phytate, oxalates and tannin. The level of tannin in sorghum varies from 1.3 to 3.6% in tannin sorghum and from 1.0 to 0.6% in low tannin depending on the variety (Kriegshaurea *et al.,* 2006). The improved varieties are believed to have low level of tannin than the local varieties. However, starch granules and kernel characteristics of the sorghum grains play important role in sorghum nutritional values (Jabbari *et al.,* 2011).

The anti- nutritional factors such as saponin and tannin may induce changes in cellular integrity and membrane permeability of cells (Horfbrand *et al.,* 1997). In poultry tannin were known to reduce feed intake, feed efficiency, growth rate, egg production, causes damage to the musocal lining of the digestive tract and protein utilization (Hancock, 2004). However, supplementation of sorghum with choline or methionine at 0.15 to 3.0% can reduce tannin effect (Selle *et al.,* 2010). It is against this background that the study is design to compare the different sorghum varieties at varying inclusion levels on the performance of broiler chickens.

1.2. Problem Statement

All types of poultry require large amount of cereal grains in their diets to provide protein and energy (Scott, 2011). The primary cereal grains used in poultry ration around the world include corn, wheat, barley, rice and sorghum. Maize appears to be the major ingredient being used in feed formulation as a source of energy. It is also used by man as a source of food. Thus there is competition between human and animals for maize. This competition pushes the market price of maize to alarming rates (Sobamiva, 1988). Nevertheless, there is need for sufficient quality and quantity protein supply in the diets of Nigerians. In order to meet this, it is pertinent to embark on the production of animal species with quick turn-over rates. The poultry industry is in the best position to bridge the gap in animal protein supply and demand in Nigeria (FAO, 1990). Although the cost of maize is the major source of instability in the poultry industry today, another option is to use more available alternative energy sources. Sorghum being an indigenous cereal of Africa benefit from its ability to tolerate drought, soil toxicity and temperature extremes effectively than other cereals (Olumu, 2011). Also, sorghum generally is less expensive than corn in Africa, Australia and the US and when competitively priced, sorghum can be used at 55% in turkey rations replacing all of the corn (Selle *et al*, 2010).

Though several varieties of sorghum have been developed and introduced in Nigeria, it has been reported by Patricia *et al.* (2012) that there is diversity of chemical composition and anti-nutritional factors mainly tannin in the different varieties of sorghum, Its has also been reported by Patricia *et al.* (2012) that climatic, soil conditions, fertilizer types are listed among factors responsible for the variation in chemical composition of sorghum, resulting in a variability in digestion from 35 to 60% or more. Patricia *et al*. (2012) reported that sorghum grains contain an anti-nutritional factor which varies in different varieties of sorghum as energy source in poultry diet, that form complexes with protein and minerals which decrease digestibility and nutritional value. However, Medugu *et al*. (2010) reported that broiler chicks could tolerate dietary tannin concentration of 1.35% before their growth performance will be compromised. Sorghum varieties in Nigeria contain tannin in a range of 0.012 to 0.215% (Aduku, 1993).

In Nigeria sorghum has the potential to serve as alternative to maize in poultry diet. The rule of thumb that “the nutrient value of sorghum is 10% less than corn is no longer true as sorghum can be used to totally replace corn in poultry feed rations with only minor changes in the other dietary ingredients (Rooney and Serna-saldivar, 2000). Sorghum grain vary more in protein content and feeding value than maize due to cultural practices, soil fertility and varietal differences.

1.3. Justification

Poultry production play an important role in our economy both as source of animal protein to the teeming population and as source of employment for over 25 million people (Sonaiya, 2014). Among the problems of poultry production is inadequate supply and high cost of maize among other conventional feed ingredients (Salissou, 2014). This led to high cost of poultry feed which in turn has prompted the need to explore the use of alternative energy sources such as sorghum.

In terms of availability, Nigeria is the largest producer of sorghum in West Africa accounting for about 71% of the total regional sorghum output (FAO, 2013). Production post forecast Nigeria's corn production in 2012 to 2013 at 9.4 million tons, up from 9.2 million tons in 2011 to 2012. The bulk of Nigeria's maize crop is used for direct human consumption as maize is a staple of Nigerian diet. Maize is indispensible for food security as well as an industrial crop. Feed utilization of maize increase due to steady growth in poultry sector witnessed in recent years. Total corn usage for feed production in Nigeria is forecast at 1.85 million tons in 2012/2013 which is higher than 1.7 million tonnes in 2011/2012 (FAO, 2013). However, Sorghum production is low compared to maize but it's not widely used as maize (Marshall, 2011). Sorghum production in 2012/2013 is forecast at 6.9 million tons, from 6.8 million tons in 2011 to 2012 (FAO, 2013). Sorghum mostly is consumed by the poor and the under privileged people and the main industrial driving demand for sorghum production is from brewery industry (Marshall, 2011). Sorghum is not imported to Nigeria at the moment unlike maize.

In terms of cost, the cost of sorghum is about 80% that of maize at the grain marketing board (Marshall, 2011). Price of maize in 2013 remains high despite good corn production because of high demand. As at 2013 corn price in northern growing regions is 63,000 naira per ton, up from 55,000 naira in 2012 (FAO, 2013). Therefore well informed poultry farmers or feed manufacturers should be willing to pay up to 97% of maize price for non- sorghum grain, while for tannin sorghum they should be willing to pay up to 87% of maize value(Hancock, 2004). This represents the relative efficiencies of sorghum with respect to maize for tannin and non tannin sorghum (Hancock, 2004). Hancock (2004) reported that whenever, the relative price of non-tannin sorghum to maize is below 97% there is an economic advantage to using non-tannin sorghum and there be no loss in feeding efficiency.

Sorghum is close to maize in proximate composition, except for variation in protein, linoleic acid and mineral concentration (NRC, 1994). Faquinello *et al.* (2004) reported that sorghum could be considered in poultry nutrition as possible energy substitute for corn based on the similarity of their chemical composition.

In order to boost poultry production in the semi arid zones which are characterized by recurrent drought and poor soil condition, there is need to explore the use of well adapted cereal crops like sorghum. At present there is lack of adequate information on the chemical composition, anti-nutritional factors and the feeding value of different varieties of sorghum as source of energy in broiler diet. It is on this basis that the current study is designed to determine the chemical composition, anti-nutritional factors and the feeding value of sorghum varieties in broiler chickens.

1.4. Objectives of the Study

The main objective of this study is to evaluate the replacement value of some sorghum varieties on the performance of broiler chickens. The specific objectives are to

I. Determine the nutrient composition and anti-nutritional factor of *Kaura*, Red sorghum, *ICSV400* and *Farfara*.

II. Compare the replacement value of the different sorghum varieties for maize in broiler chicken diets.

III. Evaluate the effect of varying level(s) of four varieties of sorghum on carcass characteristics, and blood parameters of broiler chickens.

IV. Evaluate the cost benefit of replacing maize with different varieties of sorghum in broiler diets.

1.5. Research Hypothesis

1.5.1 . Null Hypothesis

1. The Four varieties of sorghum (*Kaura,* Red sorghum, *ICSVS400* and *Farfara*) have the same nutrient profile and level of anti-nutritional factors.
2. Varying level(s) of four varieties of sorghum have no effect on the performance of broilers Chickens.
3. Varying level(s) of the four varieties of sorghum have no effect on carcass characteristics, histopathology and blood parameters of broiler chickens.
4. The replacement of maize with the four varieties of sorghum has no effect on the cost of feed for broiler chickens.

1.5.2. Alternate Hypothesis

1. There is varietal difference in the proximate composition and anti-nutritional factors of the sorghum grain.
2. The different varieties of sorghum and levels of inclusion in diets have effect on the performance of broiler chickens.
3. The varying level(s) of the four varieties of sorghum have effect on carcass characteristics, histopathology and blood parameters of broiler chickens.
4. The replacement of maize with four sorghum varieties can reduce the cost of feed for broiler chickens.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Nutritional Requirement of Poultry

Poultry convert feed into food products quickly and efficiently. Their high rate of productivity results in relatively high nutrient needs. Poultry require the presence of at least 38 nutrients in their diets in appropriate concentrations and balance. Table 2.1 shows the nutrient requirement figures published in nutrient requirements of poultry (National Research Council, 1994).

2.1.1.Energy Requirement of Broiler

There are four main components that go together to make up a poultry diet. While protein, vitamins and mineral are referred to as nutrients, energy the fourth and most costly part of the diet is not a nutrients. Dietary nutrients that yield energy are protein, fat and carbohydrates. Protein is not commonly thought of as a source of energy but it does result in a significant contribution to the energy requirement of the bird and can, if fat and carbohydrate are in short supply, be used by the animal as its amino source of energy (Olomu, 1995). Diets with high levels of energy are referred to as having a higher nutrient density. This means that the same amounts of nutrients are available in a smaller volume with less weight. It follows that if the diet is dense the birds will have to eat less of it to obtain its nutrient requirements and thus feed: gain is reduced. Hence, improved feed efficiency or improved feed utilization (Mona and Osman, 2000).

Table 2 .1: Nutrients Requirement of Broilers

Age	0-3weeks	3-6weeks	6-8weeks

Kcal AMEn/kg diet	3,200	3,200	3,200
Crude protein	23.00	20.00	18.00
Arginine	1.25	1.10	1.00
Glycine + serine	1.25	1.14	0.97
Histidine	0.35	0.32	0.27
Isoleucine	0.80	0.73	0.62
Leucine	1.20	1.09	0.93
Lysine	1.10	1.00	0.85
Methionine + lysine	0.50	0.38	0.32
Phenylalanine	0.72	0.72	0.62
Phenylalanine+tyrosine	1.34	0.62	0,52
Proline	0.6	1.22	1.04
Threonine	0.80	0.74	0.86
Tryptophan	0.20	0.18	0.16
Valine	0.90	0.82	0.16

Requirement are listed as percentages of diets
The 0-3 to 3, 3- to 6-, and 6- to 8- weeks intervals for nutrients are based on chronology for which research data were available, however, these nutrient requirements are often implemented at younger age intervals on a weight of feed consumed basis.
These are typical dietary energy concentration. Different energy values may be appropriate depending on local ingredient prices and availability.
Broilers chickens do not have a requirement for crude protein per se. however; there should be sufficient crude protein to ensure an adequate nitrogen supply for synthesis of non-essential amino acids. Suggested requirements for crude protein are typical of those derived with corn soya bean meal diets, and levels can be reduced when synthetic amino acid are used.

SOURCE.white house station ,N.J.,U.S.A (2010)

Dietary energy level is the main factor influencing feed intake as birds under normal circumstances will eat to zsatisfy their energy needs. Therefore the dietary nutrients, protein, vitamins and minerals should vary in relation to the dietary energy content of the diet, if they are not to become deficient with low feed intakes or over consumed with low energy diet (Olomu, 1995).While there are a number of factors, such as level of protein, balance of essential amino acids and perhaps level of some of the other dietary nutrients that can influence the cost of diet, the level of dietary energy is usually the main factor influencing diet cost. Hence, the higher the level of energy the higher the diet cost and usually the lower is the feed consumption in relation to gain (Mona and Osman, 2000).

The energy content of a diet is usually given as so many calories per kilogram of diet. Thus diet are said to contain, 2800 or 3200 kcal (thousand small calories) per kilogram of diet. The energy content of feedstuff is measured by burning it in an oxygen saturated environment and increasing the amount of heat or total (gross energy) produced (Tewe and Egbunike, 1992). However, all the energy or heat produced from, for example burning a gram of corn is not available to the bird. According to Wilson and kelvin (2000) gross energy values of feedstuffs (kcal/g) are determined by the relative amounts of the 3 major classes of organic nutrients present; carbohydrates 4.1, proteins 5.7, fats (lipids) 9.4. Thus, feedstuffs high in fat are higher in energy concentration than are feedstuffs high in carbohydrates. The gross total energy of feed is not an accurate index of the amount of energy available to the animal because of the differences among feeds in the degree of utilization by birds (Olomu, 2011).

The utilization of energy is influence by a number of factors. One of the main factors increasing energy requirement of broiler is pen temperature. Broiler use dietary energy as a fuel to maintain body temperature. Hence in cold pen situation a significant amount of dietary energy can be used to maintain body temperature rather than be used for more productive purposes like weight gain. This suggested that lower energy levels are more beneficial to poultry birds in tropics than those in the temperate regions

(MCDonald *et al*., 1995). Based on this, Olomu (1976) recommended metabolisable energy range of 2.8-3.0 Mcal/ME/kg for optimum performance. The energy intake of broiler chicken fed a range of dietary energy 2.28Mcal/ME/kg to 3.61 Mcal/ME/kg showed no significant differences in the amount of ME consumed per unit weight (MC Donald *et al*., 1995). Mona and Osman (2000) reported that broiler birds fed a range of dietary energy 3135 kcal- 3320 kcal/kg showed no significant difference among dietary treatments in growth rate, performance index and chemical composition of broiler meat and carcass traits.

Relationship between Feed Intake and Dietary Metabolizable Energy

Dietary energy is known to have significant influence on feed intake. The relationship between energy requirement and intake is the cornerstone of practical diet formulation. By combining feedstuffs to produce diets with predetermine nutrient; energy ratios, the intakes of nutrient can be regulated (Sibbald, 1980). Dietary energy levels have been shown to affect broilers chickens feed intake. Tewe and Egbunike,1992 reported that as dietary energy levels decreased birds' statisfy their energy needs by increasing feed intake. Thus in formulating poultry diets, the nutrient requirements of broiler chickens have frequently been expressed per unit of dietary metabolizable energy (Olomu, 2011).This practice is based on the theory that birds will adjust their feed intake according to their metabolizable energy requirement.

Mona and Osman (2000) showed that broiler chickens fed up to 25 and 49 days of age were able to adjust their feed intake to a constant energy intake over a range of dietary metabolizable energy levels from 11.29 to 13.8 MJ ME/kg DM, which indicated that broiler chickens retain an innate ability to eat to a fixed energy requirement rather than to physical capacity as was suggested by Summers (2000). Burkhart *et al.* (1983) observed that modern broiler chickens selected for rapid growth not voluntary feed intake to achieve energy balance. This altered ability of broiler chickens to adjust feed intake due to differences in metabolizable energy density of the diet was postulated to result from continued selection for rapid growth rates, which may have altered hypothalamic mechanism that regulate feed intake in broiler chickens (Burkhart *et al.* 1983; Bokkers and koene, 2003). Other reports have also shown no effect of dietary metabolizable energy concentration on feed intake between two groups of broiler chickens fed ad-libitum diets containing two energy levels of 13.38 and 15MJ ME/DM.

Response of Birds to High Energy Feed

It terms of total cost, energy is the main factor influencing feed cost, the higher the level of energy, the higher the feed cost (Robinson *et al*., 2000b; Afolayan *et al.,* 2009a). Dietary energy level is the most important factor influencing feed intake and feed efficiency. Diets with high levels of energy are referred to as having a higher nutrient density. This implies that birds will need to eat less of it to obtain its nutrient requirements hence feed: gain ratio is reduced and feed efficiency is improved (NRC, 1989; Summers, 2000; Robinson *et al.,* 2000b; Afrouziyeh *et al.,* 2011). In other word, diets with higher concentration of energy are usually more efficiently used in terms of unit gain per feed consumed. According to Hartini *et al.* (2002) high density diet decrease the length of time spent in eating.

Response of Birds to Low Energy Feed

Afolayan *et al. (*2009b) reported that feeding lower energy diets during the hot season could help to lower cost production of poultry products in the tropical regions. Leeson and Summer (2001 and 2005) observed that growth was adversely affected when low energy diets were used and that birds eat more of such diets at constant growth rate. In contrast, broiler chickens have traditionally been fed relatively high-energy diets, because in addition to prompting efficient feed utilization it is also assumed that this type of diet maximizes growth rate (Lesson and summers, 1991). More recently, lower energy content diets have been used in an attempt to resolve such problems as arthritis (Afolayan *et al.,* 2009a), and has been realized that overall growth rate is little affected. The broiler chicken may, therefore adapt to diets of low energy content and simply eat more feed in an attempt to maintain energy intake, much the same as does the leg horn bird (Payne, 1987). Contrary to popular belief, the broiler chicken may not be eating to meet needs of physical satiety, although undoubtedly the birds voracious appetile does play some role in influencing both feed and energy intake.Control over energy intake is important not only because it affect growth rate, but also because it has a potentially negative effect on carcass characteristics (Afolayan *et al.,* 2009)

Protein and Amino Acid Requirements of Chickens

Protein have been described as complex organic compounds of high molecular weight composing of 22 different amino acids or derivatives that are linked by peptide bonds to form a primary chain structure. As a result of steric constraints this primary structure has been reported to form an x-helical structure stabilized by hydrogen bond as well as by-cross linking of individual amino-acid residues. The x-helix that describes the primary structure of the protein has been found to be subsequently folded and arranged into more complex secondary and tertiary structures which with the specific number and sequences of different amino acids ultimately determine the biological characteristics and function ability of protein (Leeson and Summers, 2001). Because body proteins are in dynamic state, with synthesis and degradation occurring continuously, an adequate intake of dietary amino acid is required, or there will be a reduction or cessation of growth or productivity and withdrawal of protein from less vital body tissues to maintain the functions of more vital tissues (NRC, 1994).

As mention early, there are 22 amino acids in body proteins and all are physiologically essential (NRC, 1994). Nutritionally ten of these are indispensable because chickens are unable to synthesize them or cannot synthesize them at a rate sufficient to meet their needs. These are Methionine, lysine, threonine, leusine, valine, isoleucine, argine, phenylalanine, histidine and tryptophan (Austic, 1995; NRC, 1994). The amino acid requirements of poultry represent the requirements for the indispensable amino acid plus sufficient nitrogen in an appropriate chemical form for synthesis of the dispensible amino acids. Chickens are sensitive to the dietary balance of these amino acids (Austie, 1995). For the diet to be used with maximum efficiency the chicken must receive the indispensable amino acids in the correct quantities and sufficient amino acids for metabolic demands must be available. Amino acid requirements may be classified as those for maintenance, carcass growth, egg production and feather growth on the basis of their respective amino acid profiles (Leeson and Summers, 2001).

In order for the bird to realize its genetic potential and achieved the best levels of performance through maximum rates of protein synthesis, amino acids must be provided in the necessary quantities, avoiding both excesses and deficiencies (Austie, 1995). Thus, stating dietary requirements for both protein and essential amino acids is an appropriate way to ensure that all amino acids needed physiologically are provided.

Protein and amino acid requirements vary considerably according to the physiological state of the birds that is, the rate of growth or egg production. Other factors contributing to various amino acid requirements of the chicken include age, body size, sex and breed. Amino acid requirements decrease with age and at the same time, the ideal balance of amino acids change gradually to reflect those of maintenance (Leeson and Summers, 2001). For instance, the percentage of amino acid required in the diet is higher for young growing animals and decline gradually to maturity, when only enough amino acid to maintained body tissue is required (Allison, 1955). The balance of amino acid needed for maintenance is not proportional to the balance of amino acids in bird tissues but rather reflects the relative rate of obligatory loss of each individual amino acid (Austic, 1995). For this reason, the balance needed for maintenance is considerably different from that needed for growth or egg production.

Dietary amino acid level slightly below maintenance can sustain life but muscle mass and functions are impaired (Leeson and Summers, 2001). Matching the amino acid profile of the diet with animal requirements is crucial for maximizing animal performance. For instance, turkey poults and broiler chickens have high amino acid requirements to meet the needs for rapid growth while the indigenous chickens such as the Vanda breed will require less amino acid to meet their needs because of their slow growth rate and small body size. Because the contributions of maintenance and growth to total amino acid requirement change with body size and the ideal amino acid profiles for maintenance and growth, the composition of the ideal amino acid pattern will change continuously during the growth period (Macaver, 1999).

2.1.2. Protein and Amino Acid Requirement of Broiler Chicken

Feed proteins are complex amino acid polymers which are broken down in the gut into amino acids. These amino acids are absorbed and assembled into body proteins which are used in the construction of body tissue e.g. muscles, nerves, skin and feathers. Dietary crude protein levels do not indicate the quality of the proteins in a feed, protein quality is based on the presence and balance of essential amino acids in the feed ingredients.

The availability to the bird of these essential amino acids is most important and broiler feeds should be formulated using digestible amino acids. The actual protein level used will vary according to the feed ingredients and will be driven by the first limiting essential amino acid not available in synthetic form (Arbor acre 2014).It is preferable to use high quality protein sources where these are available, especially for broilers under heat stress. Poor quality or imbalanced protein can create metabolic stress, as there is an energy cost associated with its excretion and may also result in wet litter (Arbor Acre, 2014).

The level of balanced protein in the feed will have a major influence upon margin achieved and profitability however, balance protein is only one of the nutritional package and energy also needs to be considered with regard to energy sources, it has become clear that growth of the biofuels industry has resulted in feed energy prices becoming more affected by oil prices than conventional commodities market with an increase in the use of cereals and feed fats for biofuels sector, combined with firm oil prices, energy is likely to become expensive. It is of a key important to appreciate that modern broilers are expensive to amino acid and energy density and that margin over feed cost must be considered when determining an appropriate feeding strategy (Macaver, 1999). The National Research Council, (NRC, 1994) and Smith (1995) recommended crude protein of 23% for broiler chicks at 0-3 weeks, 20% crude protein at 3-6 weeks and 18% crude protein at 6-9 weeks.

Response Trends of Chickens to Differing Feed Energy and Protein Levels

To be of any real value, attempts to optimize the feeding of chickens must be capable of predicting voluntary food intake (Austie, 1995). suggested that where feed intake is seen as an input, as is most often the case, it is not possible to optimize feeding programs successfully, since the composition of the food offered has a very important effect on voluntary food intake. As suggested by Emmans and Fishes (1986), appetite is dependent on the nutrient requirement of the animal and the contents of those nutrients in the feed. Therefore, response in feed intake is not independent of the composition of the feed and strain of the chicken as was previously believed Smith (1995). The theory of feed intake and growth in birds proposed by Emmans (1981,1989) was based on the premise that birds attempt to grow at their genetic potential, which would imply that they would attempt to eat as much of a given feed as would be necessary to grow at that rate.

Factors that will prevent the birds from achieving this goal would be the bulkiness of the feed and the inability to lose sufficient heat to the environment in order to enable the birds to remain in thermal balance. This theory has predicted feed intake and hence growth and carcass composition with considerable accuracy in birds (Ferguson and Gous; 1997). Additionally, Cobb 500 broiler chickens (Burnham *et al.,* 1992) and laying hens (Gou *et al.,* 2007) have been shown to increase feed intake as dietary protein content in the feed is reduced, attempting thereby, to obtain more of the limiting protein irrespective of the feed energy level until a dietary concentration is reached where performance is so constrained that feed intake falls.

It has been shown that chickens will increase their feed intake in response to marginal levels of first limiting feed nutrients independent of the diet energy level (Boorman, 1979) since appetite is assumed to be dependent on the nutrient requirements of the animal and the contents of those nutrient in the feed (Emmans and Fishes, 1986). As such feed intake of indigenous Venda chickens ate more feed in an attempt to meet their protein requirements which were limiting with decreasing dietary crude protein levels. This observation is similar to the result obtained with broiler chickens by Burnham *et al.* (1992) and with laying hens by Gou *et al.* (2007). These authors observed that chickens increased their feed intake as the limiting nutrient to satisfy their requirement for that nutrient. In fact, the nutritional factors involved in broiler chicken feed intake control mechanisms are not completely understood.

Ferguson *et al. (*1997) pointed out that in many experiments, where only responses to dietary energy level are involved, and such feed intake responses could be compounded with variable intake of other nutrients such as protein and hence differences in feed intake response patterns to limiting feed protein content observed for Ross 308 broiler chickens and Cobb 500 chickens. Austie (1999) suggested that when there is a dietary protein deficit the free amino acid patterns of both muscles and plasma become imbalanced and consequently triggers the appetite regulating system to reduce feed intake. This may be the scenario when Ross 308 broiler chickens receive feeds marginally deficient in protein unlike the cob 500 and indigenous Venda chickens. Apparently, genetic potential may influence the Ross 308 broiler chickens feeding behaviour as it affects their nutritional requirement (Gou *et al.,* 2007).

These observations on limitations in feed intake response patterns in Ross 308 broiler chickens, cob 500 and indigenous venda chickens contradicted the strongly held theory that all chickens eat to satisfy their energy requirements (Leeson and Summers, 2001) or that chickens will eat less of a feed higher in energy content than the one having a lower energy value (Olomu, 2011). However because of the important implications of these differences, both the energy and protein levels of the diet should be taken into account when formulating diets aimed at achieving optimal feed intake in growing birds.

2.1.3. Macro Minerals Requirement of Poultry

There are twenty nine elements known which are required by at least one animal species. According to usual division, seven elements are macro-minerals whose requirements or concentrations in organism are expressed by over 100ppm, and 22 elements are micro-minerals in traces whose requirements are below 100 ppm, and even can be expressed in ppb values (Lukic *et al.,* 2009). Of course this classification does not reflect important or less important role of these nutrients, but only necessary quantities in diets or their generally low (or in traces) concentration in tissues. The provision of correct levels of the major minerals in the appropriate balance is very important to grow broilers successfully. The macro minerals involved are calcium, phosphorus, magnesium, sodium, potassium and chloride.

Calcium

In the diet of broilers, Ca influences growth, feed efficiency, bone development, leg health, nerve function and the immune system. It is vital that calcium is supplied in adequate quantities and on a consistent basis to achieve optimum performance. These responses may require different calcium levels to allow optimum expression (Lukić *et al.,* 2009).

Functional and economically most important mineral in nutrition of layers is calcium, primary because of egg production, i.e. forming of the egg shell. Average egg shell contains approx. 2.3g (2.0-2.5g) Ca. This quantity is equivalent to approx. 10% of total calcium content in the skeleton of layer, considering that estimated amount of this macro element in skeleton of layers is approx. 20g (Whitehead and Fleming, 2000;

Lukić *et al.,* 2008, Lukić *et al.,* 2009). Roland (1986a), reported the main factors which can influence and impede determination of needs and requirements of layers for Ca, as stated by this author, are the following: constant genetic progress of layers, differences in needs of layers of same or different proveniences, mutual co-dependence between Ca and other nutrients, effect of particle size of Ca sources, ability of layers to partially adjust food consumption to their Ca needs, fear of producers or nutrition experts from harmful effects of over doses or inadequate consumption of Ca, as well as fact that many researchers expressed the layer needs in Ca in the form of its % in diet not taking into consideration variations in food consumption and those caused by level of energy, environment temperature, different provenience and/or age of poultry.

Practical implications of previous findings on mineral nutrition of layers with calcium are summarized by Roland and Bryant (2000), who pointed out that if maximum egg shell quality is to be achieved, it is necessary to provide to layers level of Ca necessary for laying period at least 7 days before the first egg. Keshavarz (2003) investigated in two trails individual and mutual effect of different levels of diet Ca (3.34; 4.3; 4.73 and 4.94%) and different sources of vitamin D (vitamin D3 and 25-OH D3), i.e. in other trial different levels of non-phytate phosphorus (0.11; 0.21 and 0.41%), presence of phytase (0 and 300 U/kg diet) and different sources of vitamin D (vitamin D3 and 25-OH-D3) in diet for layers on production traits and quality of egg shell. He concluded that the level of diet Ca of 3.34%, which was provided to layers, in trial due to realized consumption, by 3.63g Ca per layer daily, was adequate for production and quality of egg shell.

Phosphorus

Like calcium, is required in the correct form and quantity to optimize skeletal structure and growth. Inorganic phosphorus sources are described as being 100% available and plant sources are described as 33% available. Values of available phosphorus based on toe ash analysis have been found to show correlation with the classical system (Lukić *et al.,* 2009). Digestible phosphorous is used in some countries as a way of more accurately assessing the phosphorus contribution of materials. it is well known that lack of phosphorus in nutrition, because of its multiple and very important metabolic roles in organism, disturbs the intensity of the process of bio-synthesis and causes poorer growth and decrease of body mass in poultry in the phase of growth and development, and consequential incidence of irregular/incorrect ossification (Lukić *et al*., 2005).

Keshavarz (2003) used level of non-phytate phosphorus of 0.21% was adequate value, giving results in trial comparable to performance of layers fed 0.41% of non- phytate phosphorus, whereas application of enzyme phytase had no effect on production results but influenced some parameters of egg shell quality, and substitution of vitamin D3 with 25-OH D3 had no effect in any of the trails in given conditions.

Calcium: Available Phosphorus.

In most instances a Ca: Available P ratio of 2:1 is appropriate for broiler diets. However, there is information available which suggests that in Starter diets a higher Ca: AvP (e.g. 2.1:1) is beneficial to performance and especially helpful in promoting excellent leg strength. Huyghebaert and Maertens (2007) investigated the effect of different combinations of 2 forms of vitamin D (vitamin D3 and 25-OH D3) and 3 combinations of concentrations of Ca and P (normal Ca/normal P, low Ca/normal P and low Ca/low P) in diets for layers on production characteristics of tibia. Authors reported among other things, that in the first research phase in young layers (20-44 weeks of age), low Ca level in diets (3.1% Ca) induced significant decrease of egg mass and observed parameters of the egg shell quality, as well as increased incidence of damaged (cracked) eggs, and adding of active form of vitamin D (25-OH D3) to diet shoed tendency of compensation of the negative effect of low level of Ca on quality of egg shell.

Steenfeldt *et al*. (2007), who investigated different possibilities for feeding of layers with diets without added phosphates (diets with approx. 0.32% of total P) with increased share of wheat, addition of enzyme phytase or additional nutrition with coarsely ground sea shells. Authors stated that layers at the age of 19 to 35 weeks, fed main diets with 1.8% Ca and 0.32% total P with additional nutrition with coarsely ground sea shells (in average approx. 4.6g per layer daily), which they received separately from main diet two hours prior to dark period, realized equally good production parameters and quality of egg shell like layers from control group fed diets with 3.2% Ca and 0.57% P in diet, pointing out that applied strategy of nutrition with coarsely ground Ca source annulled negative effect of low content of total P in diet (Lukić, 2009).

2.1.4. Vitamin Requirements of Broilers

The vitamin requirement of poultry is usually affected by several factors such as age, body size, breed/strain, diet composition, diseases, endogenous or exogenous toxins, environment, feather coverage, feed form, feed intake, housing pattern, management conditions, minerals –vitamin bioavailability, other nutrient concentration, physiological condition, sex, stress, water intake(Sanda and Oyewole, 2015)

Vitamins and minerals play major roles in the metabolic functions of poultry. Because of the variations in the content, availability, and stability, premixes are formulated to assure adequacy, rather than just satisfying the NRC recommendations (Livingston and Klasing (2007).Vitamin D - Expressed in ICU, which are based on the activity of D3 because birds do not use D2. (Turkeys are especially sensitive!) D.Vitamin E - Requirements vary greatly depending on dietary lipids, Se, and antioxidant.Some vitamins that were thought to be adequate in feeds and feed ingredients in the past Folacin and biotin are now added to some turkey diets to prevent deficiency. Niacin May be required for laying and breeding hens. But, the requirement is so low that it will always be exceeded by natural feed ingredients. Choline: Growing chickens can use betaine interchangeably with choline for the methylate ion function, but it cannot replace choline to prevent perosis (Takahashi *et al.,* 1991).

Livingston and Klasing (2007) Fed 1,050 IU/kg of vitamin A to chicks hatched from eggs with 0.95 µg retinol/g egg yolk, those from eggs with1.29 µg retinol/g yolk were fed diets that contained 1,500 IU/kg of vitamin A, and those hatched from eggs with 1.66 µg retinol/g yolk were fed 1,950 IU/kg of vitamin A. At 7, 14, and 21 d of age the bursa of Fabricus was collected and relative mRNA expression for activation-induced cytidine deaminase (AID) and Bu-1 was measured. AID and Bu-1 expression was significantly depressed in chicks with inadequate vitamin A at 7 d of age ($P < 0.02$). Next bursacytes were isolated and stained with annexin V to determine the amount of apoptosis. When compared to bursacytes isolated from adequately fed chicks, bursacytes from chicks fed inadequate vitamin A had significantly higher amount of apoptosis at 7 and 11 d of age (P < 0.02. and the concluded that inadequate vitamin A during bursacyte development increases apoptosis, which leads to a decrease in AID expression.

Schaal and Cherian (2003) worked on the effect of ovo feeding of vitamin E on tissue lipid and vitamin E status of broiler chicks and concluded that over feeding of vitamin E may enhance brain tissue lipids and the antioxidant status of hatched chicks. Sanda and Oyewole (2015) reported better feed conversion ration and enhanced immunity in ND Vaccinated birds when exposed to Newcastle disease for birds fed vitamin A+C as supplement. Several researchers have reported beneficial effects of Vitamin C supplements given either in diets and / in drinking water. Supplements enhanced performance of broiler chickens with experimentally induced hypothyroidism (Takahashi *et al.,* 1991), reduced stress related response (Pardue and Thaxton, 1984) and improved disease resistance of the birds (Amakye-Anim *et al.,* 2000).

Null (2001) reported that Vitamin C takes part in the synthesis of leukocytes especially phagocytes and neutrophiles which play a part in the defense system of the chickens. Lessard *et al*. (1997) examined the effects of different VitA levels on the immune responsiveness of broiler chickens to Newcastle disease virus (NDV) postimmunization and demonstrated a significantly lower percentage of splenic CD4+ T lymphocytes in chickens fed a low Vitamin A diet (400 IU/kg) as compared to those on higher Vitamin A levels. The increased body weight in group C (vitamin supplemented group).

2.1.5 Water Requirement of Broiler

Water is an important nutrient in the body. Wilson and kelvin (2000) reported that water make up about 70% of the body mass of adult animals up to 90% of the newborn animal, and account for more than 99% of the molecules in the body. Water plays a key role in many phases of body metabolism and it is a critical factor in control of body temperature. It is required for many biochemical reactions in the body transportation of other nutrients and metabolites, maintenance of body temperature and dissipation of heat produce by certain biochemical reactions in the body. Many factors govern the amount of water needed to meet physiological needs such factors include level of physical action, physiological state like growth, reproduction, relative humidity, water content of the diet and ambient temperature. Water requirement is related to the animal heat production, energy consumption and body surface area (Wilson and kelvin, 2000).

Chickens cannot survive very long when deprived of water. A ten percent loss of body water through dehydration and excretion result in a serious physical disorder (Yasser *et al*. 2010). Dehydration is particularly noticeable in the shanks and some mortality may result as reported by Marble and Jeffrey *et al.,* (1964). Yasser *et al*. (2010) reported that water deprivation causes poor feed conversion ratio in birds as compared to the birds reared under ad libitum water availability at the age of 6 wks. Pires *et al.* (2007) reported that water deprivation in post hatching between 48 and 72 hours of age decreased spleenic weight but bursal weight was not affected in broilers. Offiong *et al.* (2003) reported decreased spleenic, liver and heart weight in 6-8 hours water deprivation daily in broiler chicks. Negative effect of post hatching water deprivation on liver weight in broiler was also reported by Maorka (2002). Monsi and Agbogidi (1991) reported that depressed growth rate is a typical symptom of water starvation. Apart from depression in appetite insufficient water intake is also known to affect vital metabolic processes such as digestion of food, absorption and utilization of nutrients and other intermediary general metabolism (Olumeyan *et al.,* 1997)

2.2 Sorghum grain

Sorghum a grain, forage or sugar, is among the most efficient crops in conversion of solar energy and user of water. Sorghum is known as a high energy drought tolerant crop. Because of its wide users and adaptation “sorghum is one of the really indispensible crops” required for survival of humankind (Doggett, 1988). Sorghum is adapted to a wide range of environmental conditions, particularly drought. Hence it is widely grown in different ecological zone of Nigeria (Purseglove, 1972). It has a number of morphologicals and physiological characteristics that contribute to its adaptation to dry conditions. These include: an extensive root system, waxy bloom in the leaves that reduces water loss, ability to stop growth in period of drought and resume when conditions are favourable as well as tolerance to water logging (FAO 1995). The crop equally grows on a wide range of soils; sand, loam, sandy loam, saline, and alkaline oils with a piH range of 4.0 -8.5 (FAO, 1995).

According to the report of USAID Market, (2009) sorghum grows well on deep, fertile and well-drained loamy soils. In Nigeria, these soils are common in the Northern Guinea Savannahs and in the Sudan Savannah of Nigeria (Ogbonna, 2011). Sorghum is grown mostly in the North West and North East of the country.

2.2.1.Common Names of sorghum grain

Sorghum is a global crop; it is known as kafferkoren, soedangrass, and suikergient in the Netherlands, mtatam, shallu or feterita in East Africa, kaoliang in China, durra in Egypt, chicken corn or guinea corn in the United Kingdom, milo in

Middle East Africa, jola, jowa, cholam, bisinga or durra in India, kaffir corn in South Africa, sorgo, milo or sudangrass in USA and guinea corn, feterita, sorghum, or sorghum in West Africa (Doggett, 1988).

2.2.2 Origin and distribution of sorghum

Sorghum is indigenous to Africa and accounts for 43% of all major food staples produced in sub- Saharan Africa (IFPRI, 1983). Mauncher (2002) considered sorghum as a traditional crop in much of Africa and Asia and an introduced and hybridized crop in the Western hemisphere. Doggett (1970) reported that sorghum was domesticated in Ethiopia some 5,000 or more years ago from wild sorghum, *S. arundinaceumsenslato* by descriptive selection. It is suggested that a people of Hamitic stock who migrated into Ethiopia through the Middle East or through Arabia may have domesticated the wild sorghum, which occurred as weed in their wheat fields (Purseglove, 1972).

Doggett (1970) documented that cultivated sorghum and its attendant weed, *S. arundinaceum*, were taken from Ethiopia to West Africa at an early date across Sudan to Upper Niger River, where sorghum was grown in Neolithic time. Sorghum was taken from Ethiopia to East Africa, which was occupied by bushmanoid hunters and food gatherers by Cushites who may have occupied favourable sites on high ground and practiced a terraced agriculture. Sorghum was taken from East Africa to India probably during the first millennium B.C. and probably reached China along the silk route from India in the early Christian era (Purseglove, 1972). It then spread to Mediterranean countries from materials brought from India and Africa. Sorghum was taken from West Africa as guinea corn to the new world by slave traders and introduced in the United States of America (USA) about the middle of the ninth century. Cultivated sorghum of the present arose from the wild progenitor belonging to the sub specie *Vertilliflorum* (FAO, 1995). The greatest variation in the genus sorghum was observed in the region of the northeast quadrant of Africa comprising Ethiopia, Sudan and East Africa (Doggett, 1988).

2.2.3 World Sorghum production

Sorghum is an important cereal crop which is grown globally for food and feed purposes. It is most widely grown in the semi-arid tropics where water availability is limited and frequently subjected to drought. About 100 countries grow sorghum, of which 66 cultivate it over more than 1000 ha or produce more than 1000 tons. India has the largest sorghum area with 10.06 million ha. The second largest sorghum cultivating country is Nigeria, followed by Sudan, USA and Niger. More than 90% of the world's sorghum area lies in the developing countries, mainly in Africa and Asia. In terms of annual production, USA tops the list with 13.38 million tons during 1999-2001, followed by India (8.23 million tons), Nigeria (7.65 million tons), Mexico (6.09 million tons) and Argentina (3.16 million t). However, none of these countries recorded the highest global yields.

The highest sorghum yields during 1999-2001 were recorded by Israel (12 664 kg ha-1), followed by Jordan (11 711 kg ha-1), Italy (6458 kg ha-1), Algeria (6400 kg ha-1) and France (6094 kg ha-1). Thus while Asian and African countries like India and Nigeria had the largest area devoted to sorghum cultivation, those in West Asia (like Israel and Jordan) and Europe (Italy and France) reaped the highest yields.

Nigeria is the largest sorghum producer in West Africa, accounting for about 71% of the total regional sorghum output (Ogbonna, 2011). Nigeria's sorghum production also accounted for 35% of the African production in 2007 (FAO, 1995). The country is the third largest world producer after the United States and India

(Gourichon, 2013). However, 90% of sorghum produced by United States and India is destined to animal feed, making Nigeria the world leading country for food grain sorghum production.

In Nigeria, sorghum is the third cereal in terms of production after maize and millet (Gourichon, 2013), with more than 4.5 million tons harvested in 2010 representing 25% of the total cereal production (Gourichon, 2013). In virtually all the North of the country, it is the primary food crop (USAID, 2011). We observe an overall alignment between sorghum production and area harvested in the 1990-2008 period, with production going upwards. Crop yields might have increased because of the growing acceptance of improved varieties by farmers (USDA, 2011).

However, since 2009, production and area harvested decreased in the same proportion with yields going back to 1990 levels. The decline rate between 2008 and 2009 was about 40% (USDA, 2011). This production decline is mainly due to the reduction of area harvested but the declining yields level also contributed. This probably occurred because of the increasing local prices as well as growing demand for corn and soybean. These encouraged farmers to extend the planted area for corn and soybean in the Northern regions, hence penalizing the sorghum and millet production. Indeed, the millet production also fell by 46% between 2008 and 2009 (FAOSTAT, 2012).

2.2.4 Varieties of Sorghum Grown In Nigeria

Sorghum belongs to the tribe Andropogonae of the grass family, Poaceae. Sugar cane (*Saccharum officinarum*) is a member of this tribe and a close relative of sorghum. In 1753, Linnaeus described in his species platinum, three species of cultivated sorghum: Holcus sorghum, Holcussaccaratus and Holcustricolour. In 1794, Moench distinguished the genus sorghum from the genus Holcus and in 1805, Person suggested the name Sorghum bicolor (L) Moench as the correct name for cultivated sorghum (FAO, 1995). Sorghum bicolour (L) Moench is known under a variety of names, great millet and guinea corn in West Africa, kaffir corn in South Africa, durra in Sudan, Mtama in East Africa, johaalacholam in India and kaoliang in China. Grain sorghum grown primarily for food can be divided into milo, kafir, hegari, feterita and hybrids (Purseglove, 1972).

Mauncher (2002) divided cultivated sorghum into five groups namely bicolor, guinea, caudatum, kafir and dura. Seven agronomic groups have also been described by Magness *et al*. (1971) viz kaffir sorghums originally from South Africa; milo sorghums originally from East Africa; feterita sorghums from Sudan; durra sorghum from the Mediterranean area, Near East and Middle East; sballu sorghum from India; koaliang sorghum grown mainly in China, Manchuria and Japan and the hegari sorghums also from Sudan.

The most abundant variety of sorghum in Nigeria is Sorghum guineense; other varieties include Sorghum durra, Sorghum caudatum and Sorghum margaritiferum (Irvine, 1953; Busson, 1965). Several cultivars have, however, been developed through sustained breeding. The most common cultivars in West Africa is the S35, ICSV 111, and ICSV 400 (ICRISAT, 2004).

Maunder (2002) reported that the single most important technology change in sorghum since the 1950's has been the development and use of hybrid seeds. Several improved varieties have been developed and released to farmers in Nigeria since the 1970's mainly by the Institute of Agricultural Research (IAR), Ahmadu Bello University, Zaria and the International Centre for Crop Research for Semi- Arid Tropics (ICRISAT), Kano Centre. Some of these cultivars have been developed from the local varieties, namely *Farafara,* Farida, *Kaura* and from the ICRISAT lines of the Sudan zone. [IAR, 1999; (NCGRB), 2004]. Among these are the *ICSV 111* and *ICSV 400* released by ICRISAT in 1996, SAMSORG series developed and released in the 1970's and 1980's; others are the NR series developed from the Sudan zone ICRISAT line (NCGRB, 2004), L-187, L-243 and L-333 and SK- 5912, which have pale yellow to yellow grains and L-1499, which have white coloured grains (Ega *et al.,* 1992).

The bulk of sorghum grown in Nigeria is grown in the Northern Guinea and Sudan/Sahel ecologies in the following states of Nigeria: Kaduna, Kano, Jigawa, Borno, Plateau, Bauchi, Adamawa, and Gombe. Development of commercial sorghum offers substantial benefits to Nigerian farmers and National food security. Sorghum displays a unique agricultural adaptability to a world in ever increasing need for more food (Aduku, 1993); it assumes greater importance in the economies of several African countries whose farmers are largely having limited resources and who are at subsistence level (ICRISAT, 2004).

2.2.5 Consumption Trend of Sorghum

The consumption trend of sorghum is very similar to global pattern of output since most of the grain is consumed in countries where it is grown, like many lesser known grains sorghum is basically used as animal feed in the developed countries of the world (Mason, 2010). About 300 million people from the developing countries essentially rely on sorghum as a source of energy (Godwin and Garry, 2000). The grain stands to contribute more to food supplies and food security than at present, especially, for developing countries and others in dire need around the globe. African Agricultural Technology Foundation (USAID, 2010) maintained that the cereal accounts for 37% of the total food grain produced in drier regions of West Africa, and that its importance as food security crop became more pronounced when the Nigerian government banned the importation of barley in 1986.

2.3 Nutrient composition of sorghum

The nutrient composition of sorghum has been well documented (Oyenuga, 1968; ARC, 1976; Bolton and Blair, 1977; Poultry Research Centre (PRC), 1981; NRC, 1984; Aduku, 1993; Tacon, 1995; and Aletor, 1999, Etuk, 2008). Whole grains of sorghum contain approximately 89 - 90% DM, 8.9 – 15% crude protein (CP), 2.8% ether extract (EE), 1.5 – 1.7% ash, 2.1 – 2.3% crude fibre (CF), and 71.7 – 72.3% nitrogen free extract (NFE) on as fed basis (Ensminger and Olentine, 1978). A summary of the nutrient composition of whole grain of sorghum and maize is presented in Tables 2.2. The CP content of sorghum is higher than that of maize but about equal to wheat. In terms of energy value, sorghum is rated as high as 90 – 100% of maize depending on the livestock specie (Subramanian and Metta, 2000). The amino acid profile of sorghum compares favorably to corn, and is complementary to the amino acid profile of soybean meal, which is often used as a protein source in poultry rations worldwide (Etuk and Ukaejiofo, 2007). Although the lysine and methionine levels are slightly lower for grain sorghum compared to corn, the current availability of these amino acids in synthetic form for supplementation into least cost rations lessens the importance of slight differences in amino acid content (Scott, 2011).

Table 2.2: Nutrient composition of maize and sorghum %

Components	Maize	Maize (decan 103)	Sorghum Nigerian local	Sorghum Indian local	Sorghum (brown coat)	Sorghum ICSV 11
Dry matter	90.10		93.31	92.50	88.94	----
Organic matter	90.53		93.06	----	-----	----
Crude protein	9.65	9.8	10.48	9.50	14.89	8.9
Either extract	3.98	5.2	2.97	2.50	3.30	3.7
Crude fibre	1.99	1.4	2.01	2.70	3.01	1.2
Ash	9.47	1.3	6.94	1.20	2.59	1.7
NFE(starch + energy)	73.46	73.10	61.24	76.60	65.16	73.50
Gross energy(Kcal/kg)		4140				4120

Olomu(1995); Maize
Subramanian and Metta (2000); Indian Sorghum (brown coat), Maize (decam 103)
Abubakar *et al.* (2006) Sorhgum ICSV 11

Etuk and Ukaejiofo(2007) Sorghum Ngerian Local

However, sorghum is lower than maize but higher than wheat in fat content (Magness *et al.,* 1971; Atteh, 2002). Ensminger and Olentine (1978) reported metabolisable energy (ME) value of 13.96, 14.04 and 13.70 MJ/kg, respectively for all grains, kaffir and milo types of sorghum. Abubakar *et al*. (2006) reported a slightly lower calculated value of 12.15 MJ/kg and 12.92 MJ/kg ME energy for unmalted and malted sorghum, respectively. Malting increases the protein, soluble sugars and lysine and reduces tannin content of sorghum (Kubiezek *et al.,* 1984).The proximate analysis of sorghum compared to corn indicates that the cereal grains are similar, with sorghum containing less oil and slightly more non-phytate phosphorus. The reduced oil results in slightly less energy value for Feeding (Scott, 2011).

Protein, oil, niacin and pyridoxine content of sorghum are highest in the germ fraction and lowest in the bran while the endosperm contains the highest level of starch. There is a marked variability in the mineral composition of the four primary varieties of sorghum in Nigeria. Sorghum *guineense* contains high level of phosphorus and manganese, *S. margaritiferum* contained higher levels of iron and zinc*, S. durra* contains higher levels of potassium while *S. caudatum* recorded moderate levels of all the minerals evaluated (Busson, 1965; Oyenuga, 1968).

Sorghum *per se* is known to be high in fibre and tannin (Tacon, 1995; Aletor, 1999). The young shoot and newly sprouted seeds also contain dhurrin (Olomu, 1995; D'Mello, 2000; Oduguwa and Farolu, 2004). Sorghum leaves are reported to have a haematinic property in ethno-veterinary treatment in combination with *Telfaria occidentalis* (Adedapo *et al.,* 2002). Biotin (0.26 vs 0.06 ppm), niacin (41 vs 24 ppm), pantothenic acid (12.4 vs 4.0 ppm) vitamins and some of the trace minerals including selenium (0.2 vs 0.03 ppm), manganese (15 vs 7 ppm), copper (10 vs 3 ppm) were higher in sorghum than maize (NRC, 1994). Selenium and biotin are nutritionally advantage for better health and disease resistance of birds.

2.3.1. Starch and Energy of sorghum

Starch is the largest component of sorghum (60-80%) and the major contributor to the energy value of the grain. It is unique among carbohydrate classes because it occurs naturally as discrete particles/granules (Watson, 1984). Granules are composed of an essentially linear polysaccharide called amylose (20-30% of starch), and a highly branched polysaccharide called amylopectin (70-80% of starch). Starch granules are surrounded by a protein matrix In many sorghums starch digestibility is low and starch content variable (Wagner, 1982). The protein matrix may limit enzyme access to the starch granules, thus reducing starch digestibility

Other factors important to the energy value of sorghum include channels or pores on starch granules that are sites for enzyme entry (Oduguwa and Fafiolu, 2004), granule size, starch-lipid complexes, kafirin content and kernel size (Cao *et al.,* 1998). Additional factors affecting sorghum starch digestibility are waxiness and hardness. Waxy starch is more digestible than starch of non-waxy (conventional) sorghum. Unfortunately, waxy sorghums have lower yields compared to non-waxy lines (Rooney and Serna-Saldivar, 2000) Vitreous endosperm contains more protein, kafirins and disulfide bonds than floury endosperm which has more soluble protein. Cao *et al.* (1998) reported feed: gain of 1.49 in broilers fed soft sorghum-based diets vs 1.68 for birds fed medium and hard sorghum-based diets. The differences in kafirin structure likely contribute to the differences in bird performance reported by Cao *et al.* (1998).

2.3.2. Protein and amino acids profile of sorghum

Grain proteins are broadly classified into four fractions according to their solubility characteristics (Guo *et al.,* 2007) albumin (water soluble), globulin (salt soluble), prolamine (alcohol soluble), glutelin (alkali soluble and acid extractable)

The protein content of sorghum is variable and approximately 80, 16 and 3% of the protein is in the endosperm, germ and pericarp, respectively. The main protein fraction in the kernel is prolamine, or more specifically kafirins, followed by glutelins. Corn typically has 1% more crude fat than sorghum, but typically sorghum has 1% more crude protein than corn. Otherwise, the gross physiochemical characteristics of corn and sorghum are similar and these cereals have similar amino acid profiles. Rooney and Serna-Saldivar (2000) suggest that reports of low performance in poultry and swine fed sorghum-based diets resulted from protein and starch characteristics and possibly use of sorghum with high tannin and phytate content.

Kafirins are rich in proline, aspartic and glutamic acids and are mainly found in protein bodies and their concentration is affected by nitrogen fertiliser use. Also, Hogan (1918) suggested that lysine and cystine were limiting amino acids in kafirin. Kafirin constitutes a substantial proportion of sorghum protein. Hamaker *et al.* (1995), for example, found the proportion of kafirin of total protein ranged from 68.1 to 72.9% in five sorghum samples with protein contents from 98 to 118 g/kg. Similarly, Salinas *et al.* (2006) reported that kafirin comprised an average of 48.2% total crude protein in twelve sorghum hybrids, with a range of 42.4 to 57.6%

There are three kafirins: α-kafirin, β-kafirin and γ-kafirin, which are defined on the basis of their molecular weight, solubility and structure. According to Chamba *et al.* (2005), α-kafirin (82.0%) is dominant relative to β-kafirin (7.5%) and γ-kafirin (10.5%) as a proportion of total kafirin. Earlier, Oria *et al.* (1995a) had reported a similar pattern with α-, β- and γ-kafirin comprising 67.3, 22.7 and 10.0% of total kafirin, respectively. Also, Hicks *et al.* (2001) found that the proportion of γ-kafirin of total kafirin ranged from 6.4 to 10.7% in 23 sorghum samples.

The amino acid composition of β-and γ-kafirins are unique because of their high content of cysteine and histidine that increase disulfide linkage formation among the different protein fractions. Kafirins also have high content in proline, glycine, glutamine, and asparagine, which place them among the list of proline-rich-proteins (PRP). The PRP have 1,000 times the affinity for tannins compared to the other proteins and are thought to be the first defense in humans and other mammals adapted to high tannin food (Butler and Rogler, 1992). Glutelins are high molecular weight proteins mainly located in the protein matrix. The lysine rich protein fractions (albumens and globulins) predominate in the germ.

2.4. Nutrient Digestibility of sorghum grain

2.4.1. Starch digestibility of sorghum grain

In the opinion of Rooney and Pflugtelder (1986) among cereals, sorghum has the lowest starch digestibility due to the resistance to digestive enzymes of the hard peripheral endosperm layer. Similarly, a study with growing pigs showed that digestibility was highest for cassava, followed by maize, sorghum and barley (Pascual-Reas, 1997; Rowe *et al*., 1999). Cousins *et al.* (1981) noted that variations exist among sorghum cultivars, especially those low in tannin which appears to have the same digestibility as maize.

There are also large differences between animal species in their capacity to digest cereal starch. Ostrowski - Meissner (1984) and Farhat *et al*. (1998) reported that most energy values in poultry are based on leghorn rooster evaluations while specie differences have been observed. On the other hand, Dale and Fuller (1980) and

Robbins and Firman (2006) reported that there is no difference between the ME values of cereals in chickens and turkeys including rooster. The digestibility of sorghum starch across the whole digestive tract of poultry is 99% compared with 87% for cattle (Rowe *et al.,* 1999). Within specie, age differences also affect digestibility of feedstuff. This fact has long been recognized when comparisons were made of AME values of some feedstuff fed to young and old birds with AME values tending to increase with age (Johnson, 1987). However, Mandal *et al.* (2006) observed no significant difference in the AME values of white (low tannin), brown (medium tannin) and red (high tannin) sorghum varieties fed to cockerel (chickens), guinea fowl and quail. Significant variations also exist between grains in the digestibility of starch in the rumen of cattle with reported values of 92%, 65% and 62% respectively, for oats, maize and sorghum.

Nutrient digestibility of sorghum is also influenced by the level of tannin concentration in the grain (Rostangno *et al.,* 1973; Guillaume and Belec, 1977; Sibbald, 1980). Mandal *et al.* (2006) reported a negative correlation between tannin concentration and AMEN. The AMEN value of high tannin red sorghum was significantly lower than those of medium tannin brown sorghum and low tannin white sorghum (11.3 MJ/kg vs. 12.5 MJ/kg vs. 12.8 MJ/kg) ME. Enhanced activities of lipase due to dietary tannins have been reported (Griffiths and Moseley, 1980). It is probable that tannins stimulate an increased pancreatic secretion of all digestive enzymes but have little affinity for lipase in the gut. Both enzyme inhibition and formation of complexes of dietary tannins with proteins and carbohydrate may cause reduction in digestibility (Horigome *et al.,* 1988)

Dowling *et al.* (2002) reported that the overall total digestible nutrients in sorghum are roughly 95% of those in dry rolled yellow dent maize; this is due to lower starch availability because sorghum starch content varies and is bound in a thicker protein matrix. The chemical nature of the starch, particularly amylose and amylopectin content, is yet another factor that affects its digestibility. The starch digestibility was reported to be higher in low amylase (waxy) sorghum than in normal sorghum, maize and pearl millet grains (Ega *et al.*, 1992). The actual dietary energy content of any feedstuff therefore will depend on its chemical composition since all organic components have an energy yielding value (Hardy, 1991). Ranjhan (2001) suggested that chemical composition gives only the potential value of feed though the quantity of carbohydrate, fat and protein does help in measuring the usefulness of feed. Black *et al.* (2005) also reported that sorghum AME values for both layer and broiler are consistently higher than the AME values for wheat.

2.4.2. Protein digestibility of sorghum grain

Mertz *et al.* (1984) reported that protein digestibility of five sorghum samples, as determined by an in vitro pepsin method, ranged from 59.0 to 79.0% with a mean of 60.9%. This value was considerably less than maize (85.3%) or wheat (85.5%). More recently, (Black *et al.,* 2005) compared amino acid digestibilities in low-tannin sorghum with maize in cockerels. The mean apparent total tract digestibility of fifteen amino acids was substantially higher in maize (0.85) than sorghum (0.73) with differences being most evident for cystine, histidine, lysine, and threonine.

Table 2.4: In vitro digestion of starch from sorghum and corn genotypes varying in ratio of amylase: amylopectin

Grain	Starch content g/kg	Amylose in starch ;	Starch enzyme digestion
Sorghum			
Conventional	660	460	
Non-waxy isoline	640	350	
Waxy isoline	630	240	
Corn			
Cultivar 1	638	0	550
Cultivar 2	663	300	350
Cultivar 3	586	570	210

Adopted from Black *et al*. (2005) salis-msc.mt

In a second study, Mertz *et al.* (1984) recorded similar results with a mean digestibility coefficient of 0.85 for maize and 0.73 for sorghum and most pronounced differences were observed in cystine, histidine, threonine, serine and arginine. While these were total tract assessments, the clear implication is that amino acid digestibility in sorghum is inferior to maize. This is consistent with the outcome of a study in which experimental diets were formulated to contain similar levels of essential amino acids, metabolisable energy, available phosphorus and calcium (Ravindran and Bliar, 1991). In this study, broilers offered maize-based diets had significantly greater weight gains than their counterparts offered sorghum-based diets to 14 days-of-age.

Factors impairing amino acid Availability

In some diets synthetic amino acids are being used as an economic method of adding those essential to improve the quality of proteins. The best quality protein for all poultry is white fish meal (Smith, 1995). For poultry, the evaluation of protein on the basis of digestible protein is not very practicable, owing to the combined excretion of faeces and urine (Butler and Rogler, 1992). Therefore, evaluation of systems tends to consider crude protein and in addition amino acid availability when defining the protein potential of the feedstuffs. Protein evaluation system of feedstuffs for various animals tends to consider as precisely as possible the amino acids absorbable in the intestine, in addition to digestible crude protein (Smith, 1992).

Some of the factors affect amino acid availability are inaccessibility of the total protein because of indigestible cell walls, bulley structures and too many cross-linkages in the molecule, presence of protease inhibitors. Inhibition of amino acid absorption by peptides or peptide-like compound, anti-nutritional factors in plant protein sources which reduce the digestibility, excessive heat treatment of the protein during processing of the feed and feedstuffs, low biological value of the protein sources (Smith, 1992).

2.5 Anti –nutritional factors in plants

The presence of anti-nutritional factors such as saponin, tannin, oxalate, trypsin inhibitors and cyanide has been reported to mask the nutritive value of feedstuffs. They also inhibit energy utilization in birds (Udedibe *et al.,* 2004). According to Adeyemo and Longe (2008), the presence of some anti-nutritional factors in the feedstuff can destroy lymphocyte there by predisposing the animal to infections. Reports by Abeke *et al.* (2003) also indicated that the presence of anti-nutritional factors in feedstuff especially at higher inclusion level negate growth and other physiological activities.

Abeke and Otu (2008) had reported several anti-nutrients that effect the optimum utilization of feeds by poultry and sub-divided them into three groups. The first group comprise of naturally occurring intrinsic factors such as anti-trypsin factors, tannin, glucosinates (alkaloid), prussic acids, gossypol and many others. The second was said to arise from contamination of feed ingredients with bacteria, toxins, heavy metal, pesticides and additives. While the third group was said to have originated from spoilage of feed ingredients such as aflatoxin moulds and oxidation of fats.

Abeke and Otu (2008) expressed concerns over the effect of anti-nutrients in poultry feeds and indicated that sometimes a well formulatedted diet with the right combination of ingredients may not produce a good performance in birds. High mortality was observed in birds fed diets containing raw lablab purpureus beans compared to those fed cooked lablab purpureus beans (Abeke *et al.,* 2003). Bawa *et al.(*2003) also reported reduce weight gain and high mortality in pigs fed raw lablab purpureus beans diets as opposed to better performance in the pig fed diets containing cooked lablab purpureus beans. Those authors therefore concluded that the presence of anti-nutrient in the raw lablab purpureus beans was responsible for the poor performance and high mortality recorded in the two classes of animals

2.5.1. Oxalate

Oxalate is an anti-nutrient which under normal conditions is confined to separate compartments. However, when it is processed and/or digested, it comes into contact with the nutrients in the gastrointestinal tract (Liebman and Al-wahsh, 2011). When released, oxalic acid binds with nutrients, rendering them inaccessible to the body. If food with excessive amounts of oxalic acid is consumed regularly, nutritional deficiencies are likely to occur, as well as severe irritation to the lining of the gut. In ruminants oxalic acid is of only minor significance as an anti-nutritive factor since ruminal micro-flora can readily metabolize soluble oxalates, and to a lesser extent even insoluble Ca oxalate. While the importance of the anti- nutritive activity of oxalic acid has been recognized for over fifty years it may be a subject of interest to nutritionists in the future (Reyers and Naude, 2012).

The complex formed by oxalate with calcium reduces the bioavailability of dietary calcium. This has serious implication in bone formation especially in the monogastric animals (Oke, 1996). A higher concentration of oxalate above 2.5% is capable of existing toxicological symptoms in human. Calcium oxalate in ruminant animals is degradable in the rumen and may not impair the performance of the animals significantly (Oke, 1996). Mcdonald *et al*. (1987) reported that higher concentration of oxalate diet of monogastric animals may cause extensive scouring, distress, dullness, loss of appetite, progressive inco-ordination and extreme cases may lead to death.The complex formed by oxalate with calcium reduces the bioavailability of dietary calcium which has implication in bone formation of the animals (Oke *et al*., 1995).

2.5.2. Saponins

Saponins are secondary compounds that are generally known as non-volatile, surface active compounds which are widely distributed in nature, occurring primarily in the plant kingdom. The name 'saponin' is derived from the Latin word sapo which means 'soap', because saponin molecules form soap-like foams when shaken with water. They are structurally diverse molecules that are chemically referred to as triterpene and steroid glycosides. They consist of nonpolar aglycones coupled with one or more monosaccharide moieties (Oleszek, 2002).

Saponins were treated as toxic because they seemed to be extremely toxic to fish and cold-blooded animals and many of them possessed strong hemolytic activity (Price *et al.,* 2001). Saponins, in high concentrations, impart a bitter taste and astringency in dietary plants. The bitter taste of saponin is the major factor that limits its use. In the past, saponins were recognized as antinutrient constituents, due to their adverse effects such as growth impairment and reduce their food intake due to the bitterness and throat-irritating activity of saponins (John *et al .,* 2004). In addition, saponins were found to reduce the bioavailability of nutrients and decrease enzyme activity and it affects protein digestibility by inhibit various digestive enzymes such as trypsin and chymotrypsin (Simee, 2011). In non-ruminant (chick and pigs) saponin retards growth rate, due to reduction in feed intake (cheek and shull, 1985). In ruminant animal saponin were implicated in causing bloat and inhibit microbial fermentation in the rumen. Joshi *et al.* (1989) observed that saponin from different plant species and seeds have varied biological effects probably due to structural differences in their saponin fraction. Symptom of saponin toxicity are; listlessness, anorexia, weight loss and gastroenteritis (Molyneux *et al.,* 1980).

2.5.3. Alkaloids

Alkaloids are considered to be anti-nutrients because of their action on the nervous system, disrupting or inappropriately augmenting electrochemical transmission. For instance, consumption of high tropane alkaloids will cause rapid heartbeat, paralysis and in fatal case, lead to death. Uptake of high dose of tryptamine alkaloids will lead to staggering gate and death. Indeed, the physiological effects of alkaloids on humans are very evident. Cholinesterase is greatly inhibited by glycoalkaloids, which also cause symptoms of neurological disorder. Other toxic action includes disruption of the cell membrane in the gastrointestinal tract (Friedman *et al.,* 2003).

Alkaloids occur mainly in various genera of seed plants, such as tobacco plant. Alkaloids can be found in almost all parts of this plants, including the leaves, roots, seeds, and bark (Childers, 1979). Each plant part usually contains several chemically related alkaloids in plant metabolism is not known. Out of hundreds of alkaloids found in nature, only about 30 are used commercially (Friedman *et al.,* 2003). The primary use of alkaloids, however, is in medicine, because they can act quickly on specific areas of the nervous system. Alkaloids are the active components of many anesthetics, sedatives, stimulants, relaxants, and tranquilizers.

Friedman *et al. (*2003) reported that bitter taste in potatoes after the potatoes have been cooked is usually a good indication that excessive amounts of alkaloids are present. EFSA (2012) gave a report that ergot alkaloids are produce by several members within the fungal orders of Hypocreales and Eurotiales and are classified as tryptophan-derived alkaloids. In the middle ages, the consumption of ergot alkaloids contaminated grains, flour or bread caused severe epidemics of the condition known as St. Anthony's fire and today, the cause of the disease is called "ergotism".

EFSA (2012) also reported that under normal conditions the risk of toxicosis in livestock is low. Furthermore, the risk of ergotism in livestock as a result of consuming contaminated cereal grains, or compounded feeds manufactured from them, is reduced where appropriate seed cleaning is carried out. Beier (1990) had earlier reported that exposure to ergot alkaloids to livestock was most likely to occur as a result of consuming rations containing cereal grains and cereal by-products, and in particular rye, sorghum and millet and by-products derived from them.

Poultry appear to be able to tolerate higher levels of ergot than other non-ruminant livestock. Studies published by EFSA (2012) indicated that 1.4mg ergot alkaloids/kg feed is safe for poultry. Bailey *et al*. (1999) reported that feeding rations with high levels of ergot sclerotia for an extended time can result in loss of appetite, increased thirst, diarrhea, vomiting and weakness in poultry. They also reported that convulsions, gangrene of the comb, wattles, or toes, paralysis and death may follow short-term feeding of ergot-contaminated rations. There are variations in both the quantity and type of the alkaloids present in ergot sclerotia. hence, it was difficult to establish safe levels, although safe dietary levels of ergot for chickens appear to be in the range of 0.3-0.8% by weight, depending on the actual alkaloid concentration (Bailey *et al.,* 1999).

Bailey *et al*. (1999) reported an experiment in which they compared the effect of ergot contaminated feed on performance and health of piglets and chickens. The treatment groups were offered feed with levels of 0.0, 0.5, 1.0, 2.0 and 4.0g of ergot/kg diet. Feed and water were available ad libitum throughout the experimental period. The ergot was analyzed to contain 2775mg of total alkaloids per kg. No mortality was observed in the groups fed .0, 0.5, 1.0 and 2.0g of ergot per kg feed. Feed intake and cumulative daily weight gains were not significantly affected by the dietary levels of ergot. The authors concluded that the optimum safety level could be identified at 1.4mg of ergot alkaloids/kg feed. In their study with C. purpurea, (alkaloids) they observed a reduced body weight gains in pigs when alkaloids diet were fed in the range of 0.60 and 4.66mg/kg diet and reported that no adverse effects typically associated with ergot poisoning were observed. Janssen *et al.* (2000) in a feeding trial using ergotamine reported that 0.33mg/kg per body weight perday calculated for the incidence of tail muscular atrophy in a 13-week old rat. They also observed decreased body weight gain and changes in the levels of some hormones. Peters-Volleberg *et al.* (1996) observed decreased body weight gain associated with depressed feed intake in rats, which was likely to be due to dopaminergic effects of ergot alkaloids. They also observed a decreased in serum thyroxine (T4) levels in male and female rats treated with ergometrinne. Janssen *et al.* (2000) reported a decrease in serum prolactin levels in the sub acute study on α-ergocryptine. The results for these hormonal levels were variable and could not be used for establishing a health-based guidance value.

EFSA (2005) reported that there were no evidences of accumulation of ergot alkaloids in meat and therefore concluded that there were no carry over effect of alkaloids on animal product. Bailey *et al*. (1999) reported a study in which growing and fattening pigs (30-115kg body weight) were fed diets containing up to 4.66mg ergot alkaloids/kg diet, but they were unable to detect any alkaloids inn meat and back fat.

2.5.4. Trypsin inhibitor and chymotrypsin inhibitor

Trypsin inhibitor and chymotrypsin inhibitor are protease inhibitors occurring in raw legume seeds. Trypsin inhibitors that inhibit the activity of the enzymes trypsin and chymotrypsin in the gut, thus preventing protein digestion, are found in many plant species mainly in different grain legumes. Trypsin inhibitors are a unique class of proteins found in raw soybeans that inhibit protease enzymes in the digestive tract by forming indigestible complexes with dietary protein. These complexes are indigestible even in the presence of high amounts of digestive enzymes. Protease inhibitors reduce trypsin activity and to a lesser extent chymotrypsin; therefore impairing protein digestion by monogastric animals and some young ruminant animals (Liener, 2005).

Since the pancreas is responsible for the production of most digestive enzymes any substance that affects the pancreatic function will evidently influence nutrient digestibility and availability (Mushtaq, 2000). Bawa *et al.* (2003) reported that the replacement of soya bean meal with raw and dehulled kidney bean meal caused a significantly poorer growth rate of chicks as a result of structural alterations in the pancreas, kidney and liver. The most significant effect was the enlargement of the pancreas caused by hyperplasia and hypertrophy of the organs. There is evidence that the ingestion of trypsin inhibitors from legume result in hypertrophy and hyperplasia of the pancreas. Liener and Kakade (1980) also reported that the presence of trypsin inhibitors in legume is in part responsible for the depressions in the nutritional value of proteins inhibition of growth, and stimulation of pancreatic hypertrophy and hyperplasia. Liener and Hasdai (1986) observed a depressed average daily gain in bird fed raw and dehulled kidney bean diet which they attributed it to high intake of trypsin inhibitors in there diet.

Lyman and Lepkovsky (1957) reported that growth depression caused by trypsin inhibitors might be the consequences of an endogenous loss of essential amino acid being secreted by hyperactive pancreas. This could be as a result of a combination of endogenous losses of essential amino acid especially threonine which are important components of trypsin and decreas proteolysis of dietary protein. Zarkadas and Wiseman (2005) reported a reduction in the efficiency of feed utilization when diets containing trypsin inhibitor was fed to monogastric animals They are called protease inhibitors because of the action they exert on protein digestion and utilization in monogastric animals.

Mcdonald *et al.* (2000) stated trypsin inhibitors prevent the action of trypsin during digestion of feed by irreversibly binding to it and thus making the enzyme unavailable for its role in the breaking down of protein (Linear and Kakade, 1980). Their reduction effect on proteins digestibility and energy availability lead to the overall economic effects of growth depression. The protease inhibitors are partly responsible for the retardation of growth. Growth retardation has been attributed firstly to the anti-nutritional factors capacity to block the action of trypsin in protein digestion. Catoni *et al.* (2008) also affirmed that trypsin and chemotrypsin inhibitors are perhaps the most widely distributed of all anti-nutritional factors. Trypsin, chymotrypsin and elastase are low molecular weight proteins capable of binding to and inhibiting the normal catalyst functions of the digestive enzymes; Thereby interfering with the enzymes digestion of protein into their basic amino acid components. The effect of trypsin inhibitors in digestion causes enlargement of pancreas in rat and chicks (Fashina-Bombata and Tewe, 1995). These authors stated that the inhibition induces hypertrophy of pancreas, resulting to an increased production of trypsin and chymotrypsin with consequent loss of growth retardation. This reduces the digestibility of protein and thereby reduces the nutritive value of feedstuffs while at the same time increases the requirement for sulphur based amino acid.

Depressed feed intake, weight gain and pancreatic hypertrophy had been reported in pigs and chicks fed high trypsin inhibitors diets (Fashina-Bombata and Tewe, 1995). Lyman and Lepkovsky (1957) reported that feeding of crude trypsin inhibitor or raw soya bean meal enlarged the pancreas and greatly stimulated its activity. They observed a reduction of trypsin the gut shortly after the intake, this low trypsin activity was followed by an increase secretion of the enzyme such that after 6 hours the secretion of trypsin was three times greater than normal. They concluded that growth depression cause by trypsin inhibitor was due to an endogenous loss of protein produced by hyperactive pancreas.

2.5.5. Flavonoids

Flavonoids are a large group and non-nutrient compounds naturally produced from plants as part of their defence mechanisms against stresses of different origins, (Catoni *et a.l,* 2008). They are mostly water-soluble polyphinols (Eastwood, 1999). Fruits and beverages such as tea and red wine constitute the main sources of polyphenols Monarch *et al. (* 2004). Certain polyphenoils such as quercetin are found in all plants and derivatives.While others are specific to particular foods (e.g. flavanones in citrus fruit, isoflavanes in dryandphloridzin in apples). (Monarch *et al.,* 2004)

2.6. Factors Affecting the Nutritional Quality of Sorghum Grain

Several tractors have been shown to affect the feeding value of sorghum. Among these are endosperm type and texture, starch and protein digestibility, presence of tannin, test weigh, the growing environment and prossesing method (Anglani, 1998).

2.6.1. Sorghum grain texture and physical properties

The biochemical basis and implications of grain strength and endosperm texture of sorghum have been reviewed by Anglani (1998) and Chandrashekar and Mazhar (1999). Sorghum endosperm texture is governed by the proportion of corneous (vitreous or hard) endosperm in relation to the floury (soft) fraction. A single kernel characterization system (SKCS) can be used to determine sorghum grain hardness and other physical characteristics (Watterson *et al*., 1993). Wu *et al.* (2008) completed a survey of 43 sorghum in relation to ethanol yields. Using the SKCS system the mean grain hardness index was 78.1, with a range of 49.6 to 97.5, and the grain hardness index was positively correlated ($r=0.459$; $P<0.005$) with the protein content (mean: 123gkg−1). Watterson *et al*. (1993) found that, overall, kafirin comprised 0.55 of protein in sorghum endosperm; however, the proportion was 0.67 in the vitreous or 'hard' endosperm as opposed to 0.35 in the opaque or 'soft' sorghum endosperm.

Hybrids with a waxy endosperm have been shown to be more visible and improve rate of gain and be more seed efficient than than normal sorghum. Very few waxy hybrids (one or two recessive waxy genes) have shown mixed result in cattle feeding trials. Among hybrids with normal endosperm (25 percent any loses cover 75 percent any l0 pectin). Studies have shown hybrids with intermediate texture outer petro soft-hoary or hard corneous endosperm hybrids when compared on the basis of dry matters and energy digestibility, or on the basis of swine performance (Hancock *et al.,* 1992).

Subsequently, Cao *et al*. (1998b) found that soft sorghum was associated with enhanced total tract retention of crude protein and gross energy. Cabrera (1994) determined the effects of hard and soft sorghums with an average particle size of 1000m in a 21-day broiler growth assay. Broilers offered diets based on soft sorghum exhibited superior weight gain (15.1%), feed intake (10.6%) and feed efficiency (10.3%) in comparison to their hard sorghum counterparts. Differences in voluntary feed intake of broilers are one causal factor of inconsistent growth performance. As reported by Oduhu and Baker (2005) that tannin can depress feed intake in broilers when present in sorghum, although Nyachoti *et al.* (1997) considered the effects of tannin lack consistency in this regard. Buffo *et al*. (1998) assessed the water absorption properties of sorghum by three different methods and reported several significant correlations with physical properties of the grain. It may be that the water holding capacity of sorghum is similarly indicative of feed intake and the possible relationship between sorghum water holding capacity and broiler growth performance merits consideration given the hydrophobicity of kafirin. However, Chandrashekar and Mazhar (1999) found very little variation in the water retention of fifteen sorghum samples and this could be a limiting factor for water holding capacity assessments.

2.6.2. Starch and Protein Digestibility of sorghum grain

The starch in the endosperm of the sorghum kernel is surrounded by a dense, hard peripheral endosperm layer than that resists both physical and enzymatic digestion. In addition, the starch granules of the sorghum endosperm are embedded in a dense protein matix. Together, these factors contribute to the lower protein and starch digestibility of sorghum. Processing methods such as grinding or steam flaking that expose the starch granules and protein matix of digestion help overcome this problem. The negative effects of tannin can be over comed through supplementing the diet with additional protein. High tannin sorghum grain can be detoxified by passing gaseous ammonia through the grain or by treating with aqueous alkaline solutions (Butler, 1978).

2.6.3. Test Weight of sorghum grain

Swine fed low test weight sorghum in trials at Kano State University showed intoner daily gain and feed efficiency then those fed higher more sensitive to low- test weight grain. Test weight did not, however, affect the feeding value of low- test weight grain granted to ruminant (sheep and cattle) (Hancock *et al.* 1992).

2.6.4. Growing Environment

There is available information variable on the effect of specific growing conditions on the quality of nutrients in sorghum grain. It is known, however, that the growing environment can change the relative proportion of the kernels parts. Stressful environments may result in shrunken endosperm and kernels with a higher proportion of embryo. Grain from stressed areas will often be higher in protein than grain grown in optimum environments. Luce *et al*. (1988) sampled sorghum grown in a number of different parts of Oklahoma where crude protein varies from 10.9 percent to 16.5 percent. The interaction of hybrid genotype and growth conditions to which it is exposed, may have a major impact on the nutritional value of the grain. Sorghum, perhaps due to the wide range of environments in which it is grown, is more variable for feeding value than corn (Hancock *et al.,* 1992).

2.6.5. Sorghum phenolic compounds (Tannins)

Sorghum is unique among major cereals because some cultivars produce polymeric phenols known as tannins. All sorghums contain phenols and most contain flavonoids and only few cultivars with a pigmented testa, B1_B2_ genes, produce condensed tannins (proanthocyanidins). Most cultivated sorghum do not contain condensed tannins even though non-tannin, phenolic compounds are occasionally reported as tannins. Tannins have antioxidant properties considered as neutraceuticals (Waniska, 2000). The tannins bind with protein and other nutrients and cause growth depression in birds.

The tannin can be estimated by simple bleaching test (Leeson and Summers, 2001) or by chemical analysis using certain standards like catechin (Waniska, 2000). Tannin analysis much depends on the correct use of extraction protocols and tannin standards. Sorghum cultivars reported by Tulasi *et al.* (2004) contained very less tannins particularly condensed tannins.

2.6.6 Sorghum grain moulds and grain weathering

Sorghum grain with open type panicle (ear-head) inhabits several fungi. Grain moulds including grain weathering is problematic in hot, humid environments. This reduces grain yield and quality which affect physical properties, processing, nutritional and market value (Hancock *et al.* 1992). Unfavorable weather conditions at the time of grain harvest may lead to grain discoloration or black color. Harvesting sorghum ear-heads at physiological maturity followed by drying prevented grain moulds and improved the grain quality during prolonged storage (CFC-FAO-ICRISAT, 2005).

2.6.7 Mycotoxins of sorghum

Common mycotoxins in sorghum are fumonisins, aflatoxins, T2 and ochratoxins. These toxigenic fungal strains grow when moisture content exceeds 12 percent. Fumonisins and aflatoxins were very low in certain sorghum cultivars. Sorghum does not differ from maize or any other cereal as far as mycotoxin hazards are concerned but are relatively less susceptible to mycotoxins due to hard seed coat and phenolic compounds. Acotinic acid in sorghum is believed to be mycotoxin preventive agent (Luce *et al*., 1988).

2.6.8 Infestation

Insect damage during storage not only results in the loss of food grain but also affects its nutritional quality. Kapu *et al.,* (1989) reported that crude protein values of all the food stuffs including sorghum decreased significantly with insect damages.

Hancock *et al.* (1992) observed varietal differences in susceptibility to insect attack in 10 months storage under ambient temperature and humidity.

Moderate insect infestation did not alter the protein quality of the grain but high infestation (30 percent) decreased it significantly. Insect infested grain showed significant losses in total fats minerals matter, thiamine and riboflavin food. Bravo (1998) have observed reduction in protein and starch digestively on grain infestation. In sorghum, wheat and maize this effect was found to be dependent on the distribution of protein and starch in the kernel component.

2. 7. Phenolic Compounds in Sorghum Grain

2.7.1. Phenolic

Phenolic Sorghum is unique among cereals in that some cultivars can produce large amounts of condensed tannins. All sorghums contain phenols and most contain flavonoids; however only cultivars with a pigmented testa, B1_B2 genes, produce condensed tannins or proanthocyanidins. Most cultivated sorghums do not contain condensed tannins even though non-tannin, phenolic compounds are sometimes reported as tannins (Hagerman *et al.,* 1997)

Phenolic compounds (phenolics) in cereal grains encompass a diverse group of secondary plant metabolites. They can be conveniently divided into three broad groups, phenolic acids, flavanols, and polymeric flavanols including condensed tannins. While Cheeke and Shull (1985) classified phenolic compounds as simple phenol, phenolic acids, hydrolysable tannins, condensed tannins, lignin, and lignans Agronomically, the presence of phenolics is associated with diminished pre- harvest losses due to bird predation and post-harvest losses due to storage pests (Beta,). All of the phenolics consist of one or more aromatic (benzene) and one hydroxyl group which enable formation of cross linkages with proteins such as Kafirins, cellulose, and phytate. Among cereals, a unique characteristic of sorghum is having some cultivars that produce large amounts of condensed tannins. Total phenols in sorghums range from 2 to 103 g/kg, while they are negligible in corn and wheat and 14 g/kg in barley (Bravo, 1998).

Tannin

The essential property of tannins is their ability to combine with protein and other polymers such as cellulose, hemicellulose and pectin to form stable complexes (Ribereau-Gayon, 1972; Mangan, 1988). Tannins are distinguished from lignin by thier relative solubility and ability to combine with protein to form leather-like precipitates which are resistant to attack by proteases or microbes (Van Soest, 1994). Tannins also help to inhibit attack on lignified tissues by fungi and bacteria and provide defence against over-grazing by vertebrate- herbivores (Swain, 1979; Barry and Blaney, 1987). Although the classification of tannins presents many problems it is usual to divide them into two groups: hydrolyzable and condensed tannins (Ribereau-Gayon, 1972; Mangan, 1988).

The hydrolyzable tannins are based on a core of polyhydric alcohol, usually glucose, whose OH groups are esterified either partly or wholly with one or more trihydroxybenzenecarboxylic acids such as: gallic acid or m-digallic acid (gallotannins) or hexahydroxydiphenic acid (ellagitannins). These tannins have a polyester type of structure which is easily hydrolyzed by acid, base or tannases derived from fungi such as Aspergillus and Penicillium species (Pierpoint, 1983; Mangan, 1988). They are also hydrolyzed in the intestine of non ruminants, although tannases have not been detected in animal tissues or intestinal bacteria. The hydrolysis products can be absorbed by animals and the sugars are metabolized, whereas the phenols are hydroxylated, methylated, or conjugated before being excreted (Pierpoint, 1983). Partial hydrolysis often occurs spontaneously during extraction and purification (Ribereau-Gayon, 1972). Hydrolyzable tannins bind strongly to proteins at pH 3-4, but to a continuously decreasing extent above pH 5 (Barry and Blaney, 1987).

Condensed Tannins

The condensed tannins are the most widespread and typical of the plant tannins and are derivatives of flavanols and consist of oligomers of the flavan-3-ols (catechins) and flavan-3, 4-diols (leucoanthocyanidins) nuclei. Both catechins and leucoanthocyanidins are easily converted by dehydrogenating enzymes or even by very dilute mineral acids at room temperature into flavonoid tannins (McLeod, 1974). They are often called catechin tannins. The monomers of condensed tannins do not have the properties of tannins. Unlike the hydrolyzable tannins, the condensed tannins do not have a central carbohydrate, but occur as a polymer (Van Soest, 1994). Tannins can be determined by colorimetric techniques (Broadhurst and Jones, 1978) and HPLC (Mueller-Harvey *et al.,* 1987). Unfortunately "it is impossible to estimate tannin content of 1% or less with any accuracy by any method" (McLeod, 1974).

The total polyphenol content of sorghum, which consists of tannins or proanthocyanidins, flavonoids and phenolic acids ranges from 1.7 to 102.6 g/kg DM. In comparison, the polyphenol concentrations in maize and wheat are negligible and barley contains 13.5 g/kg polyphenols (Bravo, 1998). Dicko *et al.* (2002) surveyed fifty sorghum varieties in which tannin was positively correlated ($r = 0.88$; $P < 0.001$) to total phenolic compounds. The majority of the samples, 41, were classified as low tannin varieties (< 2.5 g/kg tannin) while 4 samples were within the 2.6 to 7.5 g/kg range and 5 samples exceeded 7.5 g/kg tannin. It has been the development of low tannin or tannin free varieties that have facilitated the widespread use sorghum in the animal feed industries.

Anti-nutritional property of tannin

McClymont and Duncan (1952) reported that sorghum contained a 'toxic factor' because sorghum inclusions in poultry diets substantially depressed growth rates and tended to increase mortalities. McLeod, (1974) subsequently identified this toxic factor in sorghum as tannin. An array of deleterious influences has been attributed to tannin including; Depressed feed intakes, formation of less digestible tannin-dietary protein complexes, inhibition digestive enzymes, increased endogenous protein secretion, negative impacts on the gastro intestinal tract function and toxicity of absorbed tannin or its metabolites (Price and Butler, 1980).

Tannin has the capacity to interact with and bind proteins (McLeod, 1974), such that tannins have the capacity to precipitate twelve times their weight of protein, indicating that tannin had the potential to complex a substantial proportion of dietary protein. Mitaru *et al.* (1985) found a negative impact of tannin concentrations on the true ileal digestibility (TID) of sorghum AA in broilers. The average TID coefficients of 15 amino acids in sorghums with divergent tannin concentrations were 0.509 (28.3gkg$-$1 tannin), 0.660 (19.1gkg$-$1tannin) and 0.908(0.8gkg$-$1tannin). Nyachoti *et al. (*1997) reviewed the impact of low (0.47gkg$-$1) versus high (10.79gkg$-$1) tannin sorghums from 18 broiler feeding studies. by approximately 19.6%, feed intake by 10.1% and feed efficiency by 14.1%. However, it is noteworthy that parameters of broiler performance were not closely correlated with sorghum tannin concentrations in this series of comparisons. However, Nyachoti *et al*. (1996) concluded earlier that tannins in some sorghum cultivars may have little effect on their feeding values for poultry and that effects attributed to tannin in other studies it may reflect the presence of other anti-nutritive factors.

Protein–Tannin Interactions

The capacity of condensed tannin to interact with protein differentiates tannin from other polyphenolic compounds. According to Hagerman and Butler (1978), the formation of tannin-protein complexes is maximal under pH conditions that closely approach the isoelectric point of protein. Isoelectric points of relevant proteins are usually in the order of pH5.5 a level likely to been countered in the crop of broiler chickens.Tannin has an affinity for proteins with large molecular weights, open structures and, in particular, high proline contents (Mitaru *et al.,* 1985). It is probable that hydrogen bonding and non-polar, hydrophobic interactions are responsible for tannin-protein complex formation and there are considerable differences in the propensity of proteins to be bound by tannin (Butler *et al.,* 1984). Blytt *et al*. (1988) stressed the importance of hydrophobic bonding in the formation of stable complexes and hydrophobic amino acids include cysteine, isoleucine, leucine, methionine, tryptophan and valine.

Inhibition of Digestive Enzymes

Tannins may also bind endogenous enzymes in the gastrointestinal tract, thereby inhibiting their activity and impeding digestion. Tamir and Alumot (1969) reported that condensed tannin derived from carob, a leguminous shrub, inhibited α-amylase, trypsin and lipase activities. Nyamambi *et al.* (2000) investigated the impact of sorghum tannin on trypsin and amylase activity in poultry. In chickens from 21–42 days post-hatch a high-tannin sorghum depressed weight gain (43%), feed intake (24%) and feed efficiency (22%) in comparison to maize-based diets. Amylase activity in the duodenum and ileum and trypsin activity in the ileum was lower in broilers offered sorghum than maize. The authors concluded that tannin-enzyme interactions, in addition to tannin binding dietary proteins, contributed to the poor performance of birds offered diets based on high-tannin sorghum.

It has been reported by Griffiths and Moseley (1980) that increased tannin intakes significantly reduced trypsin and α-amylase activities in intestinal contents of rats in vivo. In contrast Blytt *et al*. (1988) proposed that tannin does not bind with digestive enzymes because of the inadequate amount of tannin available in the gut to interact with endogenous enzymes. Moreover, Griffiths and Moseley (1980) maintained that tannin does not directly inhibit trypsin activity and proposed that tannin-induced reductions in proteolysis are a consequence of substrate deprivation rather than enzyme inhibition. In pigs, Nyamambi *et al.* (2000) investigated the impact of tannin from faba beans on the activities of trypsin and chymotrypsin in the lumen of the small intestine. While the higher tannin level depressed crude protein digestibility by 15.7%, this was not associated with marked differences in the activity of these proteolytic enzymes in the gut lumen.

Iji *et al.* (2004) supplemented maize-soy broiler diets with graded levels of tannin derived from mimosa extract so that tannin concentrations in five diets ranged from 0 to 25 g/kg. The highest tannin levels reduced feed intake (21%) and weight gain (20%) in a 21-day feeding study. Also, tannin generally depressed ileal amino acid digestibility but this was most evident at the 25 g/kg inclusion level, where tannin generated a 6.0% decline in average ileal digestibility of eight essential amino acids (0.80 versus 0.86). In this study, 25 g/kg tannin was associated with a decline in ileal energy digestibility (10.7%) and in ileal protein digestibility (8.9%). However, increasing dietary tannin levels did not influence the activities of amylase, lipase or chymotrypsin in pancreatic homogenates, or the activities of maltase, sucrase and alkaline phosphatase in jejunal homogenates. These findings suggest that the observed deleterious impacts of mimosa tannin in birds were not related to inhibition of endogenous enzymes.

Longstaff and McNab (1991) reported that in poultry, high levels of tannin derived from field beans reduced lipase and α-amylase activities in the jejunum and ileum of young broilers but did not influence enzyme activities in pancreatic homogenates. Ahmed *et al.* (1991) manipulated tannin levels in broiler diets containing barley and soyabean meal with salseed meal so that experimental diets contained 0, 13.5, 25.0 and 50.0 g/kg total tannins. The highest tannin level depressed crude protein digestibility by 49% and weight gain by 73% in broilers from 14 to 42 days- of-age. Tannin (50.0 g/kg) increased relative pancreatic weights, more than doubled trypsin and α- amylase activities in the pancreas and reduced trypsin activity in the gut lumen by approximately 77%.

Systemic effects of tannin

In chickens, Sell *et al.* (2010) found that high-tannin sorghum activated UPD-glucuronyltransferase, which is involved in the detoxifi- cation of polyphenolic compounds in the liver. Following studies in chickens with 14C-radiolabeled condensed tannin and related phenolic compounds from sorghum, Dilworth *et al.* (2005) concluded that low molecular weight poly-phenolic fractions derived from tannin, but not tannin per se, were absorbed from the digestive tract. Butler and Rogler (1992) concluded that tannins inhibit protein digestion to a marginal extent and that this negative influence is more pronounced in respect of endogenous rather than dietary protein. However, they argued that the impact of tannins on post-digestive metabolism or a systemic effect was more deleterious than the influence of tannins on protein digestion in the gut.

Possible tannin degrading enzymes

Pillai *et al*. (1995) supplemented tannin-enriched, maize-soy broiler diet with an unspecified fungal protease; growth performance and feed efficiency were enhanced. The authors conceded that little is known about the capacity of proteases to dissociate protein-tannin complexes. However, if the protease reduced the molecular weights of proteins then it follows that a lower proportion of protein would be complexed by tannin.

Polyphenol oxidase, extracted from pear, banana and avocado, has been shown to reduce concentrations of phenolic compounds in dephytinised, high-tannin sorghum flour (Matuschek and Svanberg, 2005). Similarly, the addition of mushroom polyphenol oxidase, in conjunction with wheat phytase, to sorghum gruels has been investigated (Towo *et al.,* 2006). It may be possible to develop a feed enzyme with polyphenol oxidase activity to degrade tannin in broilers offered sorghum-based diets. However, the feasibility of developing such a feed enzyme would be governed by the tannin contents in contemporary sorghum crops

Phytate

Phytate is not unique to sorghum as it is found in all feed ingredients of plant origin. Phytate, the mixed salt of phytic acid (myo-inositol hexaphosphate; IP6), is only a partially available source of phosphorus (P) in broilers and phytate possesses anti-nutritive properties (Bryden *et al.*,2007). Established by Heubner and Stadler (1914).Overall, the weighted mean concentration of total P was 3.42 g/kg, and phytate-P was 2.66 g/kg, or 77.6% as a proportion of total P in sorghum.

The proportion of phytate P varies from 60-80% of the total P in seeds of cereals, grain legumes and oil-bearing plants. Results of six surveys conducted between 1968 and 2003 showed that total P content in sorghum ranged from 3 to 4 g/kg and phytate-P content ranged from 2.1 to 2.4 g/kg (Nelson *et al.,* 1968; Selle *et al.,* 2010). Digestibility of plant phosphorus in monogastric ranges from 23 to 69% with a value of 42% for sorghum (Wu *et al.,* 2004). In addition to its ability to bind with P, phytate's anti-nutritional properties include its ability to complex with protein and minerals (Bryden *et al.,* 2007). In contrast to tannins, sorghum phytate content has not been reduced through breeding research.

Anti-nutritive properties of phytate

The anti-nutritive properties of phytate have been reviewed in poultry and pigs (Selle *et al.,* 2010). The P component of phytate (282 g/kg) is only partially available to monogastrics because their intrinsic capacity to hydrolyse phytate and release phytate-bound P is inadequate in standard diets; in this respect, Tamim *et al.* (2004) reported that increasing dietary calcium concentrations have a significant negative impact. In addition, the polyanionic phytate molecule has a tremendous capacity to bind positively-charged nutrients, including proteins at pH levels less than their isoelectric points. The capacity of phytate to form binary protein-phytate complexes under acidic pH conditions in the gut, which are refractory to pepsin digestion, and the consequences of this interaction, may be fundamental to the 'protein effect' of phytate and phytase (Selle *et al.,* 2010). De novo complex formation is initiated by electrostatic attractions between phytate and the basic amino acid residues of arginine, histidine and lysine. There is a corresponding 'energy effect', which is more evident in broilers than pigs, but the underlying mechanisms require even more clarification.

2.7.3 Analogous anti-nutritive properties of phytate and tannin

Tannin and phytate have been shown to depress digestibility of amino acids in broilers and both factors have the capacity to complex proteins in the gut. However, binding of proteins is via different mechanisms and at different pH values and may be at different sites along the gastrointestinal tract. (Rostagno *et al.,* 1973; Mitaru *et al*., 1985)

There are indications in broilers that tannin depresses Na absorption (Hassan *et al.,* 2003) and Mitjavila *et al.* (1977) reported that tannic acid increased Na excretion in rats. It appears that both phytate and tannin decrease Na absorption and increase Na excretion. The capacity of phytate to drag Na into the gut lumen and phytase to counteract this depletion has led to the suggestion that phytate and phytase impact on intestinal uptakes of amino acids and other nutrients because Na-dependent transport systems and the activity of Na+-K+-ATPase or the 'sodium pump' may be compromised by this Na depletion (Selle *et al.,* 2010). In support of this, phytate has been shown to reduce Na+-K+-ATPase activity by approximately 80% in the jejunum and ileum of rats, which was associated with numerical reductions in blood glucose levels (Dilworth *et al.,* 2005). Also, Kreydiyyeh *et al.* (1994) found that tannin-containing tea extracts reduced intestinal mucosal Na+-K+-ATPase activity and uptakes of glucose and sodium in rats.

Hassan *et al.,* (2003) found that phytate and tannic acid reduced in vitro wheat starch digestibility by 60% and 13%, respectively. The authors considered that phytate and polyphenols may negatively influence starch digestibility by interacting with amylase, with protein that is closely associated with starch or with starch directly. In contrast, Bjork and Nyman (1987) concluded that tannic acid had a substantially greater negative impact than phytate on in vitro starch digestion but the same authors found that tannic acid or phytate did not influence starch digestibility in rats.

2.8 Kafirin in sorghum grain

Salinas *et al.* (2006) reported that kafirin comprised an average 48.2% of total crude protein in twelve sorghum hybrids, with a range of 42.4 to 57.6% Kafirin Hicks *et al.* (2001) found that γ-kafirin concentrations were negatively correlated ($r = -0.21$; $P < 0.05$) with the protein content of sorghum. Shull *et al*. (1992) determined the amino acid profile of kafirins where there is considerable variation between the three kafirin components including the sulphur-containing amino acid, cystine. Cystine comprises 6.9 mole % in γ-kafirin but 4.9 mole % in β-kafirin and only 1.1 mole % in α-kafirin. γ-kafirin is relatively rich in proline, which contributes to the preferential binding of γ-kafirin by sorghum tannin relative to α- and β-kafirin (Taylor *et al.,* 2007). Shull *et al.* (1992) reported that kafirin contains a paucity of lysine (0.4 to 0.5 mole %). Therefore, if the negative relationship between kafirin and crude protein of sorghum found by Salinas *et al.* (2006) is generally valid, then low protein sorghums contain relatively greater amounts of kafirin and, by implication, relatively lesser amounts of lysine. Alternatively, Li *et al.* (2006) reported that concentrations of lysine did not increase significantly with increasing crude protein levels in sorghum. Moreover, it may be deduced from the data of Douglas *et al.* (1990a) that there was a negative relationship ($r = -0.540$; $P < 0.04$) between the crude protein content and the lysine proportion of crude protein in sixteen sorghum samples. The linear regression equation predicts that lysine would represent 2.7% of crude protein in 78.8 g/kg protein sorghum (the minimum value) but 2.0% in 120.6 g/kg protein sorghum (the maximum value).

2.9 Effects of Kafirins, Tannins, and Phytate in Sorghum-Based Diets

Oria *et al*. (2000) demonstrated that protein body shape and exposure and β- and λ-kafirin location are key factors in sorghum protein digestibility. β-and λ-kafirins bind to each other as well as to α-kafirins, tannins, and phytate to form stable complexes (Taylor *et al.,* 2007). Perez-Maldonado and Rodriguez (2007) reported that amino acid ileal digestibly for non-tannin sorghum in poultry varied from 73 to 82% with poor digestibility of cysteine (53%), histidine (69%), threonine (63%), and tryptophan (71%). Elkin *et al.* (1996) evaluated amino acid digestibility and TME of 20 sorghum cultivar with an average protein content of 10.7%. The sorghums had a range in tannins from 2 to 38 g/kg. The α-kafirins were assayed using a SDS-PAGE procedure. As shown in table 2.5, α-kafirin (r = - 0.79) was negatively correlated with the mean essential amino acids digestibility, even more closely than tannin content (r = -0.60). In addition, there was a strong negative correlation between α-kafirins and TMEn (-0.81) whereas the negative correlation between tannin and TMEn was not significant. The correlation between kafirins and total protein also was not significant. Finally, correlations between "combined tannin and kafirin" and digestibility of individual amino acid and TMEn were consistently negative and significant.

Hicks *et al.* (2001) suggested that amino acid digestibility is high in tannin-free or very low-tannin sorghums compared to tannin sorghums. The authors went on to suggest that an increase of 0.1% in tannin can induce a decrease of 10% in digestibility of most amino acids with twice that much reduction for sulfur amino acids and lysine. Additionally, an increase of 0.35% dietary phytate reduced amino acid digestibility by 3.6% (Ravindran and Bliar, 1991). In a 42-d growth assay, Hassan *et al.* (2003) evaluated the effect of tannins (2.8 vs 13.8 g/kg) on growth performance and mineral absorption in broiler chicks. Response criteria were weight gain, feed intake, feed:gain, and total tract absorption of eight minerals. Depression in weight gain, feed intake, and feed: gain were 4, 1, and 2% respectively. For mineral absorption, Na, Mg, and Zn were the most affected with 10, 5, and 5% reductions, respectively.

Table 2.5: Correlation among protein content, tannin content, kafirin, TAAD, and TMEn for 12 sorghum samples

	protein	Tannin [b]	α-kafirin[c]	TAAD[d]	TMEn[e]
Protein	1.00				
Tannin	0.18	1.00			
	(0.51)				
Kafirin	0.22	0.44	1.00		
	(0.49)	(0.57)			
TAAD	-0.20	-0.60	-0.79	1.00	
	(0.54)	(0.04)	(0.02)		
TMEn	-0.152	-0.44	-0.81	0.79	1.00
	(0.636)	(0.128)	(0.002)	(0.002)	

Adapted from Elkin *et al*. (1996)
Tannin = g/kg catechin equivalent
Kafirin = α-kafirins peak area as determined with SDS-PAGE
TAAD = true amino acid digestibility, mean of nine essential amino acids as determined in cecectomized cockerels
TMEn = Nitrogen-corrected metabolizable energy

2.10 Feeding value of sorghum in broilers diets

Sorghum is a summer cereal that grows very effectively in low rainfall areas and it is usually favorably priced compared to other cereal grains. It is therefore likely to remain an important grain for chicken meat industry. With the development of low tannin varieties, sorghum has become an important alternative cereal in poultry production. Considering the nutritive value, cost and availability, sorghum grain is the next alternative to maize in poultry feed (Mauncher, 2002). Kriegshauser *et al.* (2006) compared the proximate analysis of several varieties of sorghum to corn and found that sorghum had higher values of protein as expected, while the energy or fat content of sorghum was slightly lower than that of corn. The amino acid profile of the sorghums compared well to corn, although the average lysine content of sorghum tested to be 26% versus corn at 30%. Luis (1980) noted that sorghum was similar to millet in true metabolisable energy (TME) but lower than maize. Dry matter digestion and gross energy of sorghum was, however, higher than millet. When sorghum was compared to millet and maize on an equal weight or a protein equivalent basis in broiler diets with adequate protein (22.5%), there was no significant differences in body weight gain or feed efficiency.

Spiridon *et al.* (1979) observed no depressive effect of sorghum on growth and feed efficiency even at 100% replacement of maize with sorghum in meat chickens; however, carcasses of birds fed most sorghum diets were lighter than the control. A study by Subramanian and Metta (2000) also indicated that sorghum grain is as ideal as maize for poultry. Some workers reported no significant effects on weight gain of chicks when high-tannin sorghum was fed (Musharaf and Latshaw, 1991). So also several investigators had studied the utilization of sorghum in broiler diets and found that weight gains of chicks fed diets containing corn or sorghum did not differ significantly (Bornstein and Bartov, 1967, Bornstein and Lipstein, 1971, Douglas *et al.,* 1991, Reddy, 1993).

Table 2.6 Showed no adverse effect on egg production with 15% and total replacement of maize with white and yellow local sorghum varieties. Table 2.7 showed no significant (p>0.05) in weight gain and feed efficiency ratio of broilers fed both local (white and yellow) and improved (ICRISAT developed ICSV 112) varieties at 45% replacement level for maize (Subramanian and Metta, 2000). This report agrees with earlier observation on the use of sorghum for layers and broilers (Thakur *et al.,* 1984; Asha Rajam *et al.,* 1986). However, Thakur *et al.* (1984) and Rama Rao *et al.* (1995) suggested that sorghum can replace maize from 74% to 50% only.

The growth of poultry has frequently been shown to be reduced by the presence of dietary tannin, probably because tannins reduce utilization of energy, protein and specific amino acids (Trevino *et al.,* 1992 and Elkin *et al.,* 1996). This consequently results in poor growth rates. This is in accordance to the finding of Smithhard (2002) who reported poor performance of poultry fed high tannin sorghum - based diet even when supplemented with soybean. Studies by Rama Rao *et al.* (1995) revealed that feeding reconstituted red sorghum-based diet with a tannin content of 16 g/kg to broiler chicken did not exert any appreciable influence on nutrient utilization, blood biochemicals, enzymes and gross pathological changes even at 100% replacement of maize. However, raw red sorghum-based diet with 23 g/kg tannin fed to broiler chickens caused higher immuno-responsiveness in comparison to their reconstituted counterpart. It is possible that the development of low tannin sorghum could raise its value to comparable level with maize in poultry diet.

Table 2.6: Feed consumed and egg production in layer fed feed containing maize and sorghum grains

Feed	Feed consumed(g/bird/day)	Egg production (%)
45% maize	117	95
15% white sorghum + 30% maiz	118	94
45% white sorghum	116	94
15%yellow sorghum + 30% mai:	118	96
45% yellow sorghum	117	94

Adopted from: Subramanian and Metta, 2000

Table 2.7: Broiler weight gain and final bird weight with maize and sorghum feed

Feed	Weight gain(g/bird/day)	Bird weight kg/bird	Feed efficiency ratio
6 0% maize	42.4	1.12	3.30
1 5%ws+ 15% maize	42.3	1.18	3.22
45WS+ 15% maize	41.2	1.15	3.35
15% YS + 45% maize	39.5	1.11	3.87
45% YS + 15% maize	44.4	1.24	3.18

Feed contained 40% concentrate 60% cereal component WS= white sorghum YW =yellow sorghum. Adopted from: Subramanian and Metta, 2000

No clear relationship was found between the amount of tannin contained in the diet and the magnitude of reduction in feed intake (FI) (Nyachoti *et al.,* 1997) they also reported a non-significant but higher FI for chicks fed tannin-containing sorghum relative to birds fed a maize control diet, while others found significantly higher FI for birds eating high-tannin sorghum (Nyachoti and Atkinson 1995). However, significant reduction in feed intake by chicks fed diets containing tannins was reported by Ibrahim *et al.* (1988), and this effect was attributed to the astringent taste of tannins (Trevino *et al.,* 1992). On the other hand, Attia (1998) found that low-tannin sorghum variety had insignificant effect on FI. Improta and Kellems (2001) compared raw, polished and washed quinoa with wheat, sorghum and maize on low protein diet (13.28%) and observed that at 21 and 28 days of age broiler chicks fed sorghum had the highest survival rate (100% and 96.72% vs. 96.37 and 96.3%), respectively, for sorghum and maize. Weight gains at day 7, 14 and 21 days of age were also highest for sorghum diet (88 g, 139.9 g and 221.0 g vs. 63.1 g, 76.05 and 91.0 g) respectively, for sorghum and maize based diet). Feed intake followed the same trend (33.48 kg vs. 26.36 kg) for sorghum and maize, respectively.

2.11.0. Effect of processing on the nutritional quality of sorghum

Sorghum is the most amenable cereals grain to different processing technologies including ; primary, secondary and tertiary method (Douglas *et al.* 1990b). The digestibility of feed grains, including sorghum is influence by physical and chemical effects of heat, steam or moisture, pressure, and grinding. Oliver and Jonker (1997) reported that broilers performed equally when fed whole sorghum or pelleted feed. However, Douglas *et al.* (1990b) concluded that sorghum must be adequately ground to ensure maximum utilization by broilers. Some researchers have indicated that it may be possible to process sorghum in such a way to improve the availability of nutrients to a greater extent than other grains. The number of recent investigations that examine the effect of milling grain sorghum and making feed have been limited. Because more corn is used than sorghum in pelleted feeds, manufacturers have a large amount of experience with corn processing relative to sorghum processing in the poultry industry.

Over the last decade, increasing attention has been paid to the interactions of grain particle size and pelleting temperature of diets on broiler performance However, research into particle size and pelleting temperatures of sorghum-based diets and broiler performance is limited (Amerah *et al.,* 2007). Douglas *et al.* (1990b) compared the performance of broilers offered diets based on low- and high- tannin sorghums that had been either hammer-milled or roller-milled. Diets based on ground sorghum (837 µm geometric mean diameter) were associated with improvements of 7.7% in weight gain and 3.3% in feed efficiency in a 21-day feeding study in comparison to rolled sorghum (1786 µm). In a second experiment, pelleted diets based on low-tannin sorghum enhanced weight gain and feed efficiency by 13.4% and 7.1% respectively, in comparison to mash diets to 21-days, although responses to pelleting were more modest to 42-days of age.

Feed particle size may affect nutrient availability. However, broilers, layers and turkey choose feed based on size of the completed feed, not ground particle sizes. These birds do not masticate and reduce particle size orally, but instead rely on the gizzard to grind grain particles down to final size before the particles reach the small intestine Church *et al.* (1984) demonstrated that grinding sorghum to 500 to 700 m improve gain. Efficiency of gain also was improved more with fine grinding of sorghum than corn.

Elkin *et al*. (1991) reported substantial improvements in weight gain (41.7%) and feed efficiency (14.7%) with pelleted versus mash sorghum-soyabean meal diets containing either high- or low-tannin sorghum. The temperature of the pellets exiting the mill was low at 55-60°C and the performance responses with high- or low-tannin sorghum were of similar magnitude. Nir *et al*. (1995) offered sorghum-based diets to male and female broilers in which the sorghum was either roller-milled (~1413 μm) or hammer-milled (~628 μm) and the diets were fed either 'raw' as mash or following steam-pelleting at 85°C. In contrast to the findings discussed above, Nir *et al.* (1995) reported that male broilers performed better on the more coarse sorghum to 42-days of age with significant improvements in weight gain (7.5%), feed intake (3.9%) and feed efficiency (3.5%). Alternatively, steam-pelleting generated modest responses of 3.1% in weight gain and 2.0% in feed efficiency with a 1.2% trend towards higher feed intakes. The responses observed to treatments in female broilers were uniformly less pronounced than in males. Moreover, significant treatment interactions were recorded which were attributed to steam-pelleting diets being more advantageous when sorghum was hammer-milled as opposed to roller-milled.

2.12.0. Hematological Indices of Chickens

The purpose of investigating blood composition is to have a way of distinguishing normal states from that of stress, The stress factors could be nutritional, environmental or physical, serum plasma chemical values are useful in the assessment of the nutritional and health of animals. Dietary components have measurable effects on blood components and blood constituents are widely used in nutritional evaluation and survey of animals (Church *et al.,* 1984). Blood variable most insistently affected by dietary influences include red blood cell counts, packed cell volume, plasma protein and glucose. (Aletor and Egbercngbe, 1992). Serum level detection tells the existence of live cell damage (Aniket, 2005). For example if liver fails to deaminate amino acids, nitrogenous wastes may accumulate in the body causing harm. Babatunde and Pond (1987) have established that packed cell volume and hemoglobin were directly related to the nutritional balance of the diet fed to the animal and attributed decrease in total protein to inhibition of protein utilization.

Hematological parameters usually studied include erythrocytes (RBC), packed cell volume (PCV, haematocrit), hemoglobin (Hb), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC), leucocytes total count (WBC), thrombocytes (platelets), etc (Jaini, 1986). These parameters measure the condition of health of the animal under study. Serum biochemical metabolites include electrolytes, blood proteins, plasma lipids and blood glucose.

Red blood cell count (Erythrocytes)

The normal physiological functions of erythrocytes are gas exchange, participation in the buffer system of the blood, and a role in the clothing mechanisms. The number of red blood cells (RBC) varies from species to species because of physiological variation of certain pathological conditions (Mitruka and Rawnsle, 1997). The increase in the number of RBCs is called polycythemia. Temporary polycythemia (erythrocytosis) may be caused by dehydration (from fever, loss of fluid, etc) or by anoxemia (high altitudes, pulmonary and cardiac disease Met-haemoglobinemia). Progressive polycythemia (polycythemia Vera, erythremia) is an Idiopathic disease of the erythropoietic tissue characterized by hyperplasia of the bone marrow and enlargement of the liver and spleen. The decrease in RBC count is called anemia. Deldar (1998) stated that the red colour of erythrocytes was due to the presence of haemoglobin.

Up to 95% of the erythrocytes is haemoglobin and anaemia is indicated when either haemoglobin, packed cell volume and or red blood cell are below normal level for age, sex and breed of the species concerned while physiologically adult women have a lower red cell count than men (Coles. 1986). Deldar (1998) found that 50% of the mean erythrocytes' parameters in the blood of the Nigeria indigenous chicken studied fell below the normal values for healthy chickens, and that the values of packed cell volume and red blood cells were of particular interest as they indicated that the birds were probably anaemic. Poor nutrition resulting from their inability to ingest enough of highly nutritious feeds while scavenging for their daily nutrients needed maybe the major cause of this anaemic condition, the author asserted. Mitchell and Macleod (1983) had linked the higher total protein problem to the female than the male than physiological status of rise in number of circulating plasma lipid and phosphor - protein during laying period.

Packed cell volume (PCV)

Haematocrit or packed Cell volume (PCV) measures the proportion of red blood cell to plasma in the peripheral blood but not in the entire circulation (William, 1997). The body haematocrit gives the ratio of total erythrocyte mass to total blood volume. Upon centrifugation blood is separated into three distinct parts. The mass of erythrocyte at the bottom, which is referred to as packed red cell volume or PCV, and a white or gray layer of leukocytes and thrombocytes (platelets) immediately above the red cell mass, which is most referred to as the Buffy coat, representing about 10,000 WBC/rnm3 of blood (William, 1997). Mitruka and Rawnsley, (1977) reported normal range values of 2.58-4.10 x10/mm6,7.40-1310g/dl, 24.90-45.20ml% and 9.20-31.00x10/mm3, respectively for red blood cells, haemoglobin, packed cell volume and white blood cells counts for chickens,

Hemoglobin (Hb)

Hemoglobin is an iron-containing conjugated protein (haeme+globin) which has physiological function of transporting oxygen and carbon dioxide. Each molecule of hemoglobin consists of 1molecule of globins' linked to 4 haeme molecules, and each is able to reversibly bind 4 molecules of oxygen to form oxy-hemoglobin.

William (1997) indicated that the affinity of hemoglobin for oxygen is affected by pH, temperature and the concentration in the red cells of 2, 3-diphospho-glyccrate (2, 3-DPG). 23-DPG and H^+ compete with oxygen for binding of deoxygenated haemoglobin and decreases the affinity of haemoglobin for oxygen by shifting the positions of the four peptide chains.

In man about 55% of every red blood cell is hemoglobin (Mitruka and Rawnsley 1997). According to these authors the following methods which include colorimetric methods, gasometric methods, oxygen capacity method, carbon monoxide saturation, spectrophotometric methods, oxyhaemoglobin methods, cyanomethaemoglobin method and acid and alkaline haematin production methods can be used for the determination of haemoglobin. They all vary in accuracy, ease of performance and reproducibility. Lindsey (1977) observed that hemoglobin concentrations decrease in animals on low protein intake, parasite infection or liver damage.

White blood cells (Leucocytes)

The white blood cells or leucocytes are cells of the immune system defending the body against both infectious disease and foreign materials. Different types of leucocytes exist, but are all produced and derived from multipurpose cells in the bone marrow known as a haematopoitic stem cell. Leucocytes are found throughout the body including the blood and life system (Maton *et al.,* 2008)

The number of leukocytes in the blood is often an indicator of disease. In a condition such as leukemia, the number of leucocytes is higher than normal and in leucopenia, this number is much lower. The body use white blood cells to fight infection. There are several types of white blood cells. The most numerous is the neutrophil which defend against bacterial and fungal infections. Eosonophil cells deal with parasitic infections. If this is high, is an indication of parasitic infection. This type of cells is also responsible for reacting to any substance that causes an allergic response.

The lymphocyte cell is the cell most responsible for providing the body with immunity against disease. They create antibodies that bind themselves to the pathogens or invaders in the system (Brooks, 2008).

Basophils are cells responsible for allergy and antigen responses. These are the cells that release the histamines and cause inflammation during an allergic reaction.

Monocytes are the white cells that act as the vacuum cleaner in the system, after an infection. It is these cells that clean up the damage left behind, by ingesting dead cells, tissue debris and old red blood cells (Alberts, 2005).

2.12.2. Blood Serum Biochemistry

When blood clots in a test tube, a solid red mass is formed, however, on standing longer, the clot will contract, expressing out a supernatant yellow fluid, which is called serum. Essentially, serum is plasma minus fibrinogen and most clotting factors. The fact that serum contains antibodies that the animal may have formed makes it useful in the prevention and treatment of disease (Anon, 1980)

Protein Constituents

The plasma proteins are of two major types: albumin and globulin. The primary globulins are classed in types based on their migration or separation by electrophoresis (Anon,1980).The types are alpha-1, alpha-2, beta-1, beta-2, and gamma (α_1, α_2 , β_2 y). The alpha and beta globulins are synthesized by plasma cells and lymphocytes when antigens stimulate these cells. Most of the known antibodies are included in the gamma-globulin fractions. Fibrinogen is a β_1 globulin that is synthesized in the liver. It is essential part of the blood clotting mechanism (Harrk, 2002)

Albumin, the most abundant protein in the plasma, is the major protein produced by the liver. Albumin is important in binding and transporting many substances in the blood, and is responsible for about 80% of the total potential osmotic pressure (oncotic pressure) of the plasma. This is because albumin and the other large molecular weight proteins do not pass readily through the vessel or capillary walls, and so they aid in keeping fluid in the vascular system (Allison,1995)

Total Serum Proteins

The total protein, as its name implies, represent the sum total of numerous different proteins, many of which vary independently of each other. The total protein concentration must be measured when performing an electrophoresis in order to calculate the concentration of each of the protein fraction from its percentage. Aside from this situation, the determination of total protein supplies limited information except in condition relating to changes in plasma or fluid volume, such as shock, dehydration, possible over-hydration and haemorrhage (Hermierd, 1992). The need for fluid is revealed by an elevated serum protein that shows haemoconcentration. It is also useful to measure the total serum protein because the non diffusible calcium fraction is bound to protein and varies directly as the serum protein. Analyses for proteins are usually performed on serum because this is the fluid medium generally used in the chemistry laboratory (Harrk, 2002)

Significance of Scrum Protein

The serum protein has many functions that may be summarized as Follows according to Kaplan and Szabo (1983); they affect the distribution of extracellular fluid between the vascular bed and intestinal fluid by means of the oncotic pressure they generate. This is a general property of proteins, but the most important protein in this respect is albumen because of its relative small size and high concentration, about 60% of the total plasma proteins. They serve as carriers for various cations and some compounds that are relatively insoluble in water, such as bilirubin, fatty acids, steroid hormones and lipids. They function as antibodies to provide a defense system for the body against foreign proteins, viruses, bacteria. This role is reserved for the gamma globulins. They form parts of the endocrine system. They protect against damage to the vascular system by forming a complex, blood clotting system. They provide tissues with a source of nutrients for building materials, or calories. Some proteins function as enzymes (Peter *et al.,* 1982)

Serum Albumin

It synthesized exclusively in the liver, functions as a regulator of blood osmotic pressure, as a carrier for many cations and water insoluble substances (calcium, bilirubin, fatty acids),and as a pool of amine acids for caloric or synthetic purpose. It has a half life of in plasma of about 17days, which means that its plasma concentration would fall about 3% per day if synthesis were completely halted. Haepatocellular damage usually results in a decrease in the sum albumin concentrations, but the change is relatively slow (Peter *et al.,* 1982)

The concentration of serum albumen is decreased in the following situation: Extensive protein loss, whether (a) through the kidneys as in the nephritic syndrome, (b) through the skin, following-extensive burns or severe skin lesions as in exfoliative dermatitis, or (d) through the gastrointestinal tract, as in protein-losing enteropathies (protein- losing internal diseases). Decrease synthesis; whether caused by (a) damaged hepatic cells, (b) deficient protein intake, as in malnutrition and or starvation, or (c) impaired digestive or absorption of protein products. Shift to ascetic fluid, which may happen in chronic liver diseases with cirrhosis (Hermierd, 1992).

Serum Globulin

(a) α_1 – Globulin

the α_1 – Globulin is a mixture of many proteins, some of which have been indentified and characterized. The α_1 – globulin band increases as a response to inflammation arising from a variety of causes: infection, trauma, and neoplasm. They are synthesed in the liver (Kaplan and Szabo, 1983).

(b) α_2 –Globulin

Some of the well known proteins in this fraction include the haptoglobins, and ceruloplasmin, a copper binding protein that has oxidase activity. The micro proteins in the α_2 – globulin fraction also are increased in inflammatory conditions (Kaplan and Szabo, 1983).

(c) β_1 – Globulin

The β – globulin fraction contain the β-lipoproteins, the iron-transporting protein (transferring), folorinogen, and other lesser known proteins. Any condition that increases the β-lipoproteins makes this band more prominent because the lipoproteins predominate in this fraction (Jurgens and Peo, 1970)

This fraction also contains the immunoglobulins or circulating antibodies, that are so essential for defence against foreign proteins of all sort. Reticuloendothelial system, Plasma cells and lymphocytes β – globulin (Kaplan and Szabo, 1983). The plasma concentrations of gamma globulins as a group usually rise in chronic infection with an increase in immunoglobulin (Ig, G, IgA and JgM). There are some diseases, however, in which there may be an increase in only one class of the immunoglobulins. These are called monoclonal diseases. A single class of immunoglobulins is synthesized in excess by a proliferation of lympyotic cells (Kaplan and Szabo, 1983).

2.12.3. Serum Lipids

Serum cholesterol

The lipids are fats and fatty acids derivatives together with some other substances of similar solubility properties that are concerned with fat metabolism. Reference is sometimes made to blood lipids, but usually the substances determined are contained in serum (or plasma). There are some lipids in the erythrocytes (chiefly in the cell membrane) but these are not concerned with fat metabolism (Bauer *et al.,* 1975).The main constituents of serum lipids are cholesterol and cholesterol esters, phospholipids and triglycerides. There are also small amounts of free (un-esterified) fatty acids, mono- and di- glycerides, and other sterols together with the fat soluble vitamins.

Cholesterol is a fat like substance in the blood which, also if elevated has been associated with heart diseases. High cholesterol in the blood is a major risk factor for heart and blood vessel disease (Hark, 2002). Cholesterol in itself is not bad; in fact, the body needs a certain amount of this substance to function properly. However, when the level gets too high, vascular disease can result. As the level of blood cholesterol increases, so does the possibility of plugging the arteries due to cholesterol plaque build-up. Such a disease process is called hardening of the arteries' or atherosclerosis. When the arteries feeding the heart become plugged, a heart attack may occur (Hermied,1992).

There are three major kinds of cholesterol, High Density Lipoprotein (HDL), Low Density Lipoprotein (LDL), and Very Low Density Lipoprotein (VLDL). LDL cholesterol is considered "bad cholesterol' because cholesterol deposits formed in the arteries with LDL levels are high. HDL cholesterol is good cholesterol as it protects against heart disease by helping remove excess cholesterol deposited in the arteries.

High levels seem to be associated with low incidence of coronary heart disease (Krasnodebska, 2000)

It has been reported that serum cholesterol level was lower at birth, rises rapidly until 10 days of age and transiently lower at weaning (Mitruka and Rawnsley, 1997). An increase in serum cholesterol was reported by the authors to occur with age in pigs. However, reports on effect of sex and age are conflicting. Jurgens and Peo (1970) reported low values for females than males. In adult pigs, extreme protein depletion was reported to be necessary for a slight elevation in serum cholesterol. Dietary fat been reported to affect serum cholesterol (Jurgens *et al.,* 1970).

Serum Urea Nitrogen and Creatinine

Serum nitrogen is a byproduct of protein metabolism. This waste product is produced in liver. Then filtered from the blood and excreted in the urine by the kidneys. The serum nitrogen test measures the amount of nitrogen contained in the urea. High serum nitrogen levels can indicate kidney dysfunction, but because blood urea nitrogen is also by protein intake and liver function, the test is usually done in conjunction with blood creatinine, a better indicator of kidney function (Krasnodebska, 2000).

Creatinine is a metabolic by product of muscle energy metabolism that like urea is filtered from the blood by the kidney and excreted in the urine. Production of creatinine depends on individual muscle mass, which usually fluctuates very little. With normal kidney function, the amount of creatinine in the blood remains relatively constant and normal. For this on and because creatinine is affected by very little by liver function, therefore an elevated serum creatinine level is a more sensitive indication of renal failure. Lead and cadium had reported to impair renal function and consequently leading to elevated serum urea and creatinine levels (Sturkie, 1970). High values may mean that the kidneys are not working well as they should. The serum urea nitrogen is also affected by high protein diets and /or strenuous exercise, which raises its levels, and by pregnancy, which lower it. An abnormally elevated blood creatinine, a more specific and sensitive indicator of kidney disease than the serum urea nitrogen (Wyssm, 2002).

2.12.4 Serum Enzymes

Aspartate aminotransferase (AST) formerly known as glutamate oxaloacetate transaminase (GOT), Alanine aminotransferase (ALT) formerly known as glutamate pyruvate transaminase (GPT), and gamma-glutamyl transferase (GGT) and Alkaline phosphatase are enzymes which help all the chemical activities within cells to take place. Injury to cells releases these enzymes into the blood (Sturkie, 1970)

Alanine aminotransferase (ALT)

Alanine aminotransferase, also called ALT, is present in many tissues. The enzyme catalyses the transfer of the amino group of alanine to α- ketoglutarate, resulting in the formation of pyruvate and glutamate.

Aianin + α- ketoglutarate => pyruvate and glutamate

This enzyme may be assayed by coupling via the product, pyruvate, to an LDH-catalysed indicator reaction. Alanine aminotransferase is found in high concentration in liver cells, and the enzyme is released into the plasma by liver cell death, which is a normal event. However, when liver cell death increases, ALT levels rise above the normal range. The spillover of the enzyme into the blood is routinely measured as a marker of abnormal liver damage (Hark, 2002). Hence markedly raised plasma activity indicates a severe liver disease, usually viral hepatitis or toxic necrosis (Champe and

Harvey, 1994). An elevated ALT in the presence of normal levels of plasma alkaline phosphatase helps distinguish liver disease from liver- cell damage from disease caused by problems in biliary ducts. The enzyme aspartale aminotransferase (AST) has a similar role, but this enzyme tends to be found in other tissues, such as heart, so is not as specific to the liver as ALT. Prolonged circulatory collapse may also be responsible for an increased ALT levels resulting in myocardial infarction and muscle disorders. However, these disorders can only be distinguished clinically from the liver disease (Champe and Harvey, 1994)

Aspartate aminotransferase (AST)

Aspartate aminotransferase, formerly known as glutamate oxaloacetate transminase (GOT), an enzyme widely distributed throughout the body catalysed the reaction.

Aspartate + α- oxoglutarate => oxaloacetale + glutamate

It may be assayed by coupling, via product, oxaloacetate, to an indicator reaction catalysed by malate dehydrogenase, which involves NAI^+/NADH as coenzyme. AST is an exception to the rule aminotranseferase turned amino group to form glutamate (Champe and Harvey, 1994).

During amino acid catabolism, AST transfer amino group from glutamate to oxaloacetate, forming aspartate which itself is used as a source of nitrogen in the urea cycle.Markedly raised plasma activities (10-100 limes normal) of AST usually Indicate severe damage to the cells of heart (as in myocardial infarction) or liver (as in viral hepatitis or toxic necrosis). Moderate increases of activity are found in many diseases (Trevor, 2001).

Mechanism of action of aminotransferase

Aminotransferase are a family of enzymes, which catalysis the transfer of amino groups from one carbon skeleton to another. All amino acids, with the exception of lysine and threonine, participate in transmination at some point in their catabolism. All aminotransferase enzyme require pyridoxial phosphate (a derivative of Vitamin B6), which is covalently linked to three amino groups of a specific lysine residue at the active site of the enzyme. They act by transferring the amino group of an amino acid to the pyridoxal part of the coenzyme to generate pyridoxamine phosphate. The pyridoxamine form of the coenzyme then reacts with an α- keto acid to form an amino acid and regenerate the original aldehyde form of the coenzyme. These two most important aminotransferase reactions are catalysed by alanine aminotransferase and aspartate aminotransferase (Sturkie, 1970).

2.13.0. Carcass Characteristics

Hunton (1972) observed that nutrition; age, sex, environment and stage of development and feed efficiency determine the carcass qualify and gut characteristics, The quality of carcass goes a long way in the determination of profit obtainable from the broiler enterprise. The proportion of dressed carcass weight to live weight is usually taken as a measurement of meat production.

In the evaluation of meat production in poultry, the relationship between eviscerated and other body weight is of great importance. The dressed percentage is a ratio of dressed weight to live weight. High energy diets have been shown to promote more rapid growth and better utilization of feed than low energy diets (Hunton, 1972), Rations which incorporate lower energy-protein level could lead to cheaper unit gain costs, reduced live weight and adversely affect the carcass quality. It was reported by

Minear and Marison (1980) that 90% of the differences in body weight between the male and female broiler could be accounted for approximately by feed intake. It was observed that male broilers had heavier carcass than the female. However the consumers are so much interested in the amount of edible meat obtained, while the processors are interested in plucked and eviscerated weight, but the breeders are more concerned with production of birds that will satisfy both the consumers and processors. The profit obtained from broilers depends on the carcass quality and feed conversion or feed efficiency ratio.

There is a linear relationship between the live weight and eviscerated weight (Hunton, 1972). Excessive accumulation of fat, particularly in the abdominal region has become a great problem in broiler production because excessive fat deposition results in inefficient feed utilization and the energetic cost of gaining a unit fat to unit protein is about seven to one (Campbell *et al.,* 1988). According to the authors the public is now concerned with consumption of poultry meat with low fat. Decuypere *et al.* (1992) reported that even slight increase in dietary protein levels under hot and humid tropical conditions are beneficial for growth rate and feed efficiency in broilers and that the abdominal fat content is reduced depending on the age of the chickens. Feed efficiency is generally negatively correlated with fat deposition (Leenstra, 1986). Abdominal fat content increased significantly ($p<0.01$) with age (Decuypere *at al.,* 1992). Moderately decreasing the protein content of the diet, increased abdominal fat content (Lin *el al,,* 1980; Buyse *et al.,*1992***;*** Decuypere *et al.,* 1992). The augmented fat deposition of chicken fed a lower dietary protein potential in controlling abdominal fat attempt to meet their protein requirement.

Hayse and Morrison (1973) reported 70-75% as dress percentage (% live weight), while Akpodiete *et al.* (1997) reported a dress percentage (% live weight) of

77-83%. Feathers were observed to account for 6-8% of the body weight of birds and tend to decrease with increasing body weight (Znamiecka and Frydry-Chewica, 1976). The authors also observed that dressed percentage of Rhode-Island Red birds at two months of age were 69.5%. Hayse and Morrison (1973) obtained the following percentage yield for the body parts 22.4-25.1, 5.5-15.9, 14.6-15.0 and 4.9- 8.25 for breasts, thighs, drumsticks and neck, respectively. Bamgbose and Niba (1998) reported dressing percentage of 60.30-74.65% and abdominal fat of 2.73-4.09% on broilers fed soybean meal and cottonseed meal as main sources of plant protein.

Variation in size of the gut was reported to be associated with amount of fibre being consumed by the birds in the process of meeting their energy requirement. It is related to the quantity of water taken, increase in fibre intake could lead to increase in the gut size and an increase in the volume of water taken increases gut size (Savory and Grentle, 1973). Summers and Lesson (1986) noted that gizzard size increased with fibre intake, also high fibre content in the diet led to lower deposition of abdominal fat and poorer carcass quality and vice versa.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Study Area

This experiment was conducted at the poultry unit Department of Animal Science, Teaching and Research Farm, Bayero University, Kano. Kano falls within the Sudan Savannah Zone bordering the Guinea Savannah Vegetation in the south. The area has a wet season from May to September and dry season from October to April. The area has an annual rainfall of 787mm to 960mm and temperature between $21^{O}C$ to $30^{O}C$ (Olofin, 1987).

3.2. Source of Experimental Birds

A total of 675 day-old broiler chicks (Arbor acre plus strain) of mixed sexes were purchased from Obasanjo Farms, Otta, Ogun State, Nigeria for the study.

3.3. Sources of Sorghum Varieties

The different sorghum varieties (Farfara, Kaura, ICSV400 and Red sorghum) used for the study was obtained from The International Crops Reseach Institute for the Semi-Arid Tropics (ICRISAT) and local markets in Kano State.

3.4. Proximate Composition of the sorghum varieties, maize and the experimental diets

The proximate composition of the different sorghum varieties and experimental diets was carried out according to the method of A.O.A.C (1990) in the Animal Science Biochemical Laboratory, Faculty of Agriculture, Ahmadu Bello University, Zaria. The proximate component determined were dry matter (%DM), crude protein (%CP), Crude Fiber (%CF), Ether extract (% EE), Nitrogen free extract (NFE)

3.5. Determination of Anti-Nutritional Factors in sorghum Varieties

The anti-nutritional factors in the sorghum varieties and experimental diets were analyzed using the method described by AOAC (1990) at the Animal Science Biochemical Laboratory, of Faculty of Agriculture, Ahmadu Bello University, Zaria.

The tannin acid content of the different sorghum varieties was determined using a slightly modified method described by AOAC (2005).The Saponin content of the different sorghum varieties was determined using the method described by AOAC (1984).The method described by Munro and Bassir (1969) was used to determine the total oxalic acid present in the different sorghum varieties. The phytate content of the sorghum varieties was analyzed using the method of Sutardi and buckle (1985).The alkaloids was determined using the gravimetric method of Hurbone (1980).

3.6. Determination of the Mineral content of the different Varieties of Sorghum

Mineral analysis of the Sorghum Varieties was carried out at Biochemistry Laboratory Department of Animal science, Ahmadu Bello University, Zaria. The sorghum varieties were subjected to digestion with Hcl and nitric acid using the method of Johnson and Ulrice (1959). This was followed by reading of the Mineral element. Cu, Mg, Zn, Ca, and Fe were determined using atomic absorption spectrophotometry (John, 1980). P and Na were determined by flame photometry using Jenway Digital Flame Photometers.

Biological Studies

3.7. Experiment I: The Replacement Value of Some Sorghum Varieties on the Performance of Broiler Starter (0-4wks)

3.7.1 Experimental Design

At the starter phase (0-4 weeks) a total of 675 day- old broiler chicks (Arbor acre plus strain) of both sexes were divided into nine groups with 75 birds per group in a completely randomized design in a 4 × 2 factorial arrangement with a control. Each treatment was subdivided into three replicates with 25 birds per replicate. Each group was allotted to one experimental diet.

3.7.2. The treatments (diets) evaluated were

Nine broiler starter diets were formulated as follows

D1. 100% maize (control)

D2. *Farfara* at 50% level of inclusion.

D3. *Farfara* at 100% level of inclusion.

D4. *Kaura* at 50% level of inclusion

D5. *Kaura* at 100% level of inclusion.

D6. *ICSV400* at 50%level of inclusion.

D7. *ICSV40*0 at 100%level of inclusion.

D8. Red sorghum at 50% level of inclusion.

D9. Red sorghum at 100% level of inclusion.

Table 3. 1.Gross composition of the experimental starter diets (0-4wks) with sorghum replacing maize

Ingredient	Diets 1	2	3	4	5	6	7	8	9
Maize	45.82	22.91	-	22.91	-	22.91	-	22.91	-
Farfara	-	22.91	45.82	-	-	-	-	-	-
Kaura	-	-	-	22.91	45.82	-	-	-	-
ICSV400	-	-	-	-	-	22.91	45.82	-	-
Red sorghum	-	-	-	-	-	-	-	22.91	45.82
Soybean	32.28	32.28	32.28	32.28	32.28	32.28	32.28	32.28	32.28
Groundnut cake	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Wheat offal	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Bone meal	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Limestone	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Lysin	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Unit cost (₦)	130.76	127.13	123.23	126.69	123.47	132.92	123.46	127.13	123.24

1 Kg of premix contains vitamins A (5,000,000 I.u), vitamins D3 (1,000,000 i.u), vitamins E (16,000mg), vitamins K3 (800mg), vitamins B1 (1,200mg), (22,000mg), Calcium pentothenate (4,600mg), Vitamins B6 (2,000 mg), vitamin B12 (10mg), Folic acid (400mg), Biotin (32mg), Choline chloride (200 Iron (40,000mg), Cobalt (120mg), Zinc (32,000mg), Copper (3,400mg), Iodine (600mg), Selenium (48mg), Anti-oxidant (48,000mg).

Table 3.2: Proximate composition of the broiler starter diets (0-4wks) with sorghum replacing maize

	Diets								
Parameters (%)	1	2	3	4	5	6	7	8	9
Dry matter	91.06	91.94	91.68	92.28	91.63	91.53	90.79	91.98	90.75
ME kcal/kg	2825.20	2802.70	2800.33	2820.12	2835.01	2815.00	2801.42	2799.51	2792.00
Crude protein	23.52	23.59	23.71	23.68	23.71	23.84	23.91	24.00	24.09
Either Extract	5.54	5.85	5.88	5.90	5.95	5.72	5.80	5.75	5.79
Ash	7.20	7.32	7.38	7.27	7.34	7.55	7.84	7.45	7.44
NFE	58.86	58.45	58.64	58.25	57.80	58.34	58.06	58.14	57.54

ME: Metabolisable energy
NFE: Nitrogen Free Exract

3.7.3. Management of Experimental birds and data collection

The experimental birds were raised on deep litter system. The chicks were brooded under 100 watts electric bulb as source of heat. Feed and water were provided adlibitum. Routine vaccination against Newcastle and Gumbor diseases was administered as at when due. The initial weights of the birds were taken before the commencement of the experiment and the birds were subsequently weighed every week to determine weight gain. Feed offered and left-over were weighed on daily basis feed intake and weight gain were determined from the primary data collected on feed intake and weekly weight of the birds. Feed conversion ratio and feed cost per unit gain in weight was also determined. The percentage mortality was calculated from the mortality record. The starter phase lasted for four weeks.

3.8. Experiment II: The Replacement Value of Some Sorghum Varieties on the Performance of Broiler Finisher (5-8wks)

3.8.1. Experimental Design

At the finisher phase (5-8 weeks) the birds from the starter Phase were used after 7 days adjustment period. The birds were fed a common diet. The birds were subsequently allotted to nine finisher diets in a Completely Randomized Design (CRD) comprising of four sorghum varieties at two different inclusion levels of 50% and 100%, respectively. Each treatment group had 72 birds which were sub-divided into three replicate of 24 birds each in a 4 ×2 factorial arrangement with a fixed control.

3.8.2. The treatments (diets) evaluated were

Nine broiler finisher diets was formulated as follows

D1. 100% maize (control)

D2. Farfara at 50% level of inclusion

D3. Farfara at 100% level of inclusion

D4. Kaura at 50% level of inclusion

D5. Kaura at 100% level of inclusion

D6. ICSV400 at 50% level of inclusion

D7. ICSV400 at 100% level of inclusion

D8. Red sorghum at 50% level of inclusion

D9. Red sorghum at 100% level of inclusion

Table 3 .3 Gross compositions of the finisher diets (5-9wks) with sorghum varieties replacing maize

	Diet								
Ingredients (%)	D1	D2	D3	D4	D5	D6	D7	D8	D9
Maize	54.89	27.45	-	27.54	-	27.54	-	27.54	-
Farfara	-	27.45	54.89	-	-	-	-	-	-
Kaura	-	-	-	27.54	54.89	-	-	-	-
ICSV400	-	-	-	-	-	27.54	54.89	-	-

Red sorghum	-	-	-	-	-	-	-	27.54	54.89
Soybean	15.71	15.71	15.71	15.71	15.71	15.71	15.71	15.71	15.71
Groundnut cake	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Wheat offal	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Bone meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Limestone	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Lysin	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total	100	100	100	100	100	100	100	100	100
Unit cost									

1 Kg of premix contains vitamins A (5,000,000 I.u), vitamins D3 (1,000,000 i.u), vitamins E (16,000mg), vitamins K3 (800mg), vitamins B1 (1,200mg), vitamins B2 (22,000mg), Niacin (22,000mg), Calcium pentothenate (4,600mg), Vitamins B6 (2,000 mg), vitamin B12 (10mg), Folic acid (400mg), Biotin (32mg), Choline chloride (200,000mg), Manganese (948,000mg), Iron (40,000mg), Cobalt (120mg), Zinc (32,000mg), Copper (3,400mg), Iodine (600mg), Selenium (48mg), Anti-oxidant (48,000mg).

Table 3.4: Proximate composition of the experimental finisher diets (5-8wks)

	Diets								
Parameters %	1	2	3	4	5	6	7	8	9
DM	93.55	92.83	92.73	92.13	94.64	93.29	93.79	92.28	92.13
ME(kcal/kg)	2856.9	2849.0	2853.	2859.45	2863.04	2844.99	2859.46	2850.80	2850.95
CP	20.61	21.17	21.38	20.62	20.89	21.03	21.15	21.10	21.22
CF	5.65	6.14	5.50	5.88	6.35	6.50	5.98	5.83	6.08
EE	5.88	5.66	6.13	5.88	6.35	5.97	5.66	5.79	5.88
Ash	8.00	8.00	8.12	8.26	7.92	8.00	7.96	8.13	8.24
NFE	59.62	59.24	58.81	59.36	58.99	58.86	59.15	58.93	59.12

DM = Dry matter,

CP = Crude Protein

EE= Either extract

CF= Crude fibre

ME= Metabolisable energy

NFE= Nitrogen Free Extract

3.8.3. Management of Experimental birds and data collection

A total of 648 birds from the starter phase were fed a common diet for 7days adjustment period. The birds were then randomized and allotted to the nine experimental diets. All routine management and recommended health practices were strictly adhered to. The necessary vaccinations were carried out at when due. Feed and water were provided ad-libitum .The amount of feed given and left over was recorded on daily basis. The experimental birds were weighed initially and weekly up to the end of the experiment. Feed intake, weight gain, feed conversion ratio and feed cost per gain were calculated. Mortality was calculated in percentage.

3.8.4. Blood sampling and analysis

At the end of the eight weeks feeding trial 2mls of blood samples were collected from two birds per replicate making a total of 72 birds. The blood sample was collected from the wing vein of the birds into Ethylene Diamine Tetra-acetic Acid (EDTA) bottles to prevent blood coagulation for haematological evaluation. Another 3mls of blood samples was collected into other sampling bottles without EDTA for serum chemistry. The entire blood samples were analysed at the Clinical Pathology Laboratory at the Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria.

The haematological parameters determined were Red Blood Cell Count (RBC), Haemoglobin (Hb), White Blood Cell Count(WBC), Packed Cell Volume (PCV), while Mean Corpuscular Haemoglobin Concentration (MCHC), Mean Corpuscular Haemoglobin (MCH), and Mean Corpuscular Volume (MCV) was calculated using the formulae;

$$MCHC = \frac{\text{Haemoglobin (g/100ml)} \times 10}{PVC\%}$$

$$MCH = \frac{\text{Haemoglobin (g/100ml)} \times 10}{\text{RBC (count million per cu.mm)}}$$

$$MCV = \frac{PVC \times 100}{\text{RBC (count million per cu.mm)}}$$

The blood chemistry parameters determined include Total protein, Albumin, Glucose, Globulin, Cholesterol, Blood urea, Creatinine, Alanine amino transferase, Aspartate amino transferase, Alkaline phosphorus, Calcium and Phosphorus

3.8.5. Nutrient Digestibility

At the end of the finisher phase (5-8 weeks) digestibility studies was carried out. A total of 54 birds comprising of two birds per replicate were randomly selected and used for the digestibility study. The birds were housed in individual cages and were fed common diet for forty eight hours to adjust to the cage before the commencement of faecal collection .The different experimental diets were fed to each bird daily for one week. Faecal samples were collected daily. The total faecal output for each bird was bulked together, oven dried and weighed. The dried samples were assayed for proximate composition of dry matter, crude protein, nitrogen free extract, ether extract, crude fiber, and ash using the method described by (AOAC, 1990). Amount of nutrient intake was calculated as amount of dry feed intake × nutrient in diets. Amount of nutrient output was calculated as amout of dry feacal output × nutrient in faecal. The percentage digestibility was calculated using the equation.

$$\%\text{Digestibility of nutrient} = \frac{\text{Amount of nutrient intake} - \text{Amount of nutrient output in faeces}}{\text{Amount of nutrient intake}}$$

-

3.8.6. Carcass Evaluation

At the end of the finisher phase (5-8 weeks), three birds of the same sex per replicate were selected based on the average pen weight. The birds were fasted for 12 hours before slaughtering so as to allow for the emptying of the gastro intestinal track. The final live weights of the birds was taken before slaughtered. The birds were slaughter, weighed, immersed in hot water, defeathered, and eviscerated. Carcass weight and meat cut parts (back, drumstick, thigh, ribs cage, neck and wings) were weighed. Similarly, the gut weights (proventriculus, gizzard, small intestine and large intestine weights) and weights of visceral organs were weighed and expressed as percentage of live weights.

3.8.7. Cost Analysis

A cost appraisal of the study was carried out to show the efficiency of the ration in terms of cost per live weight gain. This was calculated using the formulae.

Cost of feed = price per kg of feed

Total cost of feed = feed intake × cost per kg

$$\text{Cost per kg body weight} = \frac{\text{Total cost of feed intake}}{\text{Final body weight in kg}}$$

3.8.8. Statistical Analysis

Data obtained were subjected to one way analysis of variance in a 4 ×2 factorial arrangement with a fixed control using SAS version 9. Significant ($p < 0.05$) differences among treatments means was separated using Duncan Multiple Range Test.

Experimental Model

$\gamma_{ijk} = \mu + V_i + L_j + (VL)_{ij} + E_{ijk}$

γ_{ijk}= observed value of the dependent variable

μ = population mean

V_i = Effect of ith varieties (Red Sorghum, Kaura, ICSV 400 and Farafara)

L_j = Effect of jth level(s) of inclusion (50% and 100%)

$(VL)_{ij}$ = Interaction of sorghum varieties and inclusion level(s)

E_{ijk} = Experimental Error

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

4.1. RESULTS

4.1.1. Proximate Composition

The result of the proximate composition of the sorghum varieties and maize is presented in Table 4.1.1. The results showed a significant ($p<0.05$) in all the parameters measured except either extract. A significant difference ($p<0.05$) was observed for crude protein among the treatments with red sorghum variety having the highest value (11.53%) maize was significantly ($p<0.05$) higher in crude fibre (4.74%) which was significantly ($p<0.05$) similar to *Farfara* variety while *ICSV400* recorded the least value. Ash was significantly higher in red sorghum which was similar to *Farfara* and *ICSV400*. The highest value for nitrogen free extract was observed in maize while red sorghum had the lowest value (78.52%) Metabolizable energy was statistically similar to maize (3466.29Kcal/kg) while *Farfara* had the lowest value (3280.62kcal/kg).

4.1.2. Anti-nutritional Factors in different sorghum varieties and maize

The anti-nutrition factors of maize and different varieties of sorghum are presented in TJable 4.2. A significant difference ($p<0.05$) was observed in all the parameters measured. Tannin was significantly ($p<0.05$) higher in *Farfara* followed by red sorghum while *ICSV400* recorded the least value. Red sorghum was significantly ($p< 0.05$) higher in Saponin followed by *Farara* while maize, *ICSV400* and *kaura* are statistically similar. Oxalate was significantly ($p<0.05$) higher in red sorghum while I*CSV400* had the least value which was similar to *Farfara*. Flavonoid was significantly ($p<0.05$) higher in red sorghum and the lowest value was recorded in *Farfara* which was similar to *kaura*. The highest value for trypsin inhibitor was found in *Kaura* while *Farfara* recorded the least value. Red sorghum was significantly

($P<0.05$) higher in phytate which was similar to maize and the least value was recorded in *Farfara.*

4.1.3. Mineral composition of the sorghum varieties and maize

The mineral composition of the sorghum varieties and maize used in this study is presented in Table 4.3. A significant difference ($p<0.05$) was observed in all the minerals tested except Copper. Red sorghum recorded the highest value for phosphorus while maize, *Farfara* and *ICSV400* are similar. *ICSV400* had the highest value for Sodium while the least value was recorded in *Kaura.* Calcium was significantly ($P<0.05$) higher in *Kau*ra while Red sorghum, *ICSV400*, Maize and *Farfara* were statistically similar. Red sorghum was significantly ($p<0.05$) higher in Magnesium compared to the other sorghum varieties and maize. The highest value for Iron was recorded in red sorghum and the least value was found in *Farfara* while *Kaura*, maize and *ICSV400* were statistically similar. *Kaura* had the highest value for Zinc.

Table 4.1: Proximate Composition of different varieties of sorghum and maize

		Sorghum varieties				
Nutrients (%)	Maize	*Farafara*	*Kaura*	*ICSV400*	Red sorghum	SEM
Dry matter	93.88^{d}	94.17^{c}	93.39^{e}	94.35^{a}	94.18^{b}	0.02
Crude protein	9.24^{b}	10.52^{ab}	10.07^{b}	11.49^{a}	11.53^{a}	0.23
Crude fibre	4.74^{a}	4.39^{ab}	4.08^{b}	3.63^{c}	4.09^{b}	0.08
Either extract	2.12	2.31	2.43	2.27	2.15	0.06
Ash	2.74^{c}	3.50^{a}	3.14^{b}	3.28^{ab}	3.53^{a}	0.09
NFE	81.20^{a}	79.22^{bc}	80.28^{ab}	79.32^{bc}	78.52^{c}	0.25
ME(Kcal/kg)	3466.29^{ab}	3280.62^{c}	3474.71^{a}	3348.80^{bc}	3281.22^{c}	93.71

NFE = Nitrogen Free Extract SEM = Standard Error Mean

NFE: Nitrogen Free Extract =100-(%CP+%CF+%EE+%Ash) *ME: Metabolizable Energy ME (Kcal/kg) = 37 x % CP + 81.8 x % EE + 35.5 x %NFE (Pauzenga, 1985).

Table 4.2: Anti-nutritional of some sorghum varieties and maize

		Sorghum Varieties				
Parameters (g/100mg)	Maize	*Farfara*	*Kaura*	*ICSV400*	Red sorghu	SEM
Tannin	ND	0.13^{d}	0.11^{b}	0.09^{a}	0.12^{c}	0.01
Saponin	0.08^{a}	0.10^{a}	0.09^{b}	0.08^{a}	0.15^{c}	0.02
Oxalate	0.41^{c}	0.19^{a}	0.22^{b}	0.20^{a}	0.45^{d}	0.02
Flavonoid	0.32^{c}	0.29^{a}	0.29^{a}	0.30^{b}	0.45^{d}	0.01
Trypsin inhib	0.14^{b}	0.20^{e}	0.19^{d}	0.13^{a}	0.16^{c}	0.01
Phytate	0.19^{c}	0.09^{a}	0.17^{b}	0.18^{b}	0.19^{c}	0.02

^{abc}: Means on the same row with different superscripts differ significantly ($p<0.05$)

NS: Not significant ($p>0.05$) SEM: Standard error of means ND: Not detected

Table 4.3: Mineral composition of sorghum varieties and maize

		Sorghum Varieties					
Parameters(mg/l)	Maize	*Farfara*	*Kaura*	*ICSV400*	Red sorgh	SEM	LOS
Macro minerals							
Phosphorus	5788.67^{b}	5980.00^{b}	4951.33^{c}	5836.40^{b}	5987.00^{a}	42.09	*
Sodium	732.24^{c}	883.52^{b}	500.51^{d}	861.92^{a}	869.95^{b}	7.11	*
Calcium	291.13^{b}	336.54^{b}	502.14^{a}	267.09^{b}	384.62^{ab}	24.75	*
Magnesium	286.66^{d}	298.76^{c}	299.80^{c}	308.65^{b}	321.52^{a}	0.40	*
Micro minerals							
Iron	742.64^{b}	673.79^{c}	740.27^{b}	768.76^{b}	1143.88^{a}	5.01	*
Zinc	ND	0.22^{c}	20.21^{a}	ND	14.87^{b}	129.65	*
Copper	22.24	23.67	22.24	20.11	21.53	13.70	NS

^{abc}: Means on the same row with different superscripts differ significantly ($p<0.05$)
NS: Not significant ($p>0.05$)   SEM: Standard error of means   LOS: Level of significance   *= $p<0.05$
ND: Not Detected

Biological Studies

4.1.4. Experiment I: The replacement value of some sorghum varieties on the performance of broiler chickens (0-4wks)

The result on the main effect of sorghum varieties and inclusion levels on the performance of broiler chickens is presented in Table 4.4 Sorghum variety significantly ($p<0.05$) influenced the final body weight and mortality. Birds fed *farfara* had the highest final body weight (534.50g) which was statistically similar to birds on *ICSV40*0 while those fed red sorghum had the lowest final body weight (495.77g) which was similar to birds on maize and *kaura* (496.93 and 497.98g respectively). Mortality was significantly different ($p<0.05$) between the sorghum varieties and maize with the highest value found in maize while *farfara*, *Kaura, ICSV400* and red sorghum where statistically similar. However, the inclusion levels showed no significant ($p>0.05$) effect in all the performance characteristics measured.

4.4.2. Interaction effect of sorghum varieties and inclusion levels on performance of broiler chicken (0-4wks)

The result of interaction effects of sorghum varieties and inclusion levels on performance of broiler chicken is shown in Table 4.5. Feed cost per gain and mortality were significantly ($p<0.05$) influenced by the sorghum variety and inclusion levels. Bird fed the control diet had the highest cost of feed per kg gain which was statistically similar to birds fed 50% *ICSV400*. The bird fed 100% *ICSV400* recorded the least cost feed per kg gain. Mortality was significantly ($p<0.05$) higher in bird fed the control diet which was statistically similar to bird fed 50% *farfara* and 100% red sorghum. The lowest value was recorded in birds fed *kaura* which was statistically similar to the other diets

Table 4.4: Main effect of sorghum varieties and inclusion levels on broiler chicken (0-4wks)

	Sorghum varieties						Inclusion levels		
Parameters	Maize	*Farfara*	*Kaura*	*ICSV400*	Red sorghum	SEM	50%	100%	SEM
IWT (g/bird)	41.69	41.25	41.11	39.88	39.58	9.88	40.48	40.44	10.25
FWT (g/bird)	496.62^{b}	534.50^{a}	497.98^{b}	524.75^{a}	495.77^{b}	6.58	509.55	516.94	90.87
TWG (g/bird)	454.93	493.25	456.87	484.87	456.18	30.24	469.07	475.56	110.21
AWT (g/bird)	16.25	17.61	16.32	17.32	16.29	6.21	16.75	16.98	7.10
TFI (g/bird)	1012.37	900.42	888.83	880.62	862.47	97.11	895.68	870.49	83.12
AFI (g/bird/day)	35.83	32.16	31.75	31.45	30.80	17.37	31.99	31.09	4.20
FCR	1.97	1.78	1.90	1.82	1.84	0.13	3.67	4.00	2.31
FC/G (₦)	257.60	222.73	237.06	228.75	230.38	17.37	238.05	221.41	22.19
Mortality (%)	6.67^{b}	4.68^{a}	4.38^{a}	3.27^{a}	2.07^{a}	1.93	3.66	4.33	1.89

^{abc}: Means on the same row with different superscripts differ significantly ($p<0.05$)
NS: Not significant ($p>0.05$) SEM: Standard error of
IWT =Initial weight
FWT= final weight
WG= weight gain
AWT=average weight gain
TFI=total feed intake
AFI= average feed intake
FCR= Feed conversion ratio
FC/G= Feed cost per gain
SEM = standard error of means

Table 4.5: Interaction effect of sorghum varieties and level of inclusion on the performance of broiler chicken (0-4wks)

abc: Means on the same row with different superscripts differ significantly ($p<0.05$)

	Maize	*Farfara*		*Kaura*		*ICSV400*		Red sorghum		Sem
Parmeters	100%	50%	100%	50%	100%	50%	100%	50%	100%	
Initial weight (g/bird)	41.69	40.90	41.62	41.35	40.87	40.53	39.23	39.13	40.03	1.47
Final weight(g/bird)	496.62	559.79	509.20	487.15	508.80	495.90	553.61	495.37	496.17	41.10
Weight gain (g/bird)	454.93	518.89	467.58	445.80	467.93	475.37	514.38	456.24	456.14c	37.08
Average weight gain (g/bird/day)	16.25	18.53	16.69	15.92	16.71	16.26	18.37	16.29	16.29	6.88
Total feed intake (g/bird)	1012.37	926.74	874.10	882.97	894.70	900.65	860.59	872.37	852.57	91.36
Average feed intake (g/bird/day)	35.83	33.10	31.22	31.54	31.96	31.17	30.74	31.16	30.44	3.27
Feed conversion ratio	1.97	1.73	1.83	1.92	1.87	1.90	1.66	1.86	1.82	1.05
Feed/gain kg/₦	257.60^{e}	219.94^{b}	225.52^{b}	243.24^{d}	230.88^{c}	252.55^{e}	204.95^{a}	236.46^{c}	224.29^{b}	5.95
Mortality %	6.67^{b}	6.67^{b}	2.67^{a}	2.67^{a}	5.33^{b}	2.67^{a}	2.67^{a}	2.67^{a}	5.33^{b}	1.39

NS: Not significant ($p>0.05$) SEM: Standard error of means

4.5. Experiment II: the replacement value of some sorghum varieties on the performance of broiler finisher (5-8wks)

4.5.1. Main effect of sorghum varieties and inclusion levels on the performance of broiler chicken (5-8wks)

Table 4.6 Shown the result of the main effect of sorghum varieties and inclusion level on broiler performance. There were significant ($p<0.05$) differences in final body weight, feed conversion ratio, feed cost per gain and mortality for varietal effect. Inclusion levels (50 and 100%) had no significant ($p>0.05$) effect on the performance characteristics. Birds fed red sorghum had significantly ($p <0.05$) higher value for final weight (2387.63g). Red sorghum (1340.00g) had the best weight gain. Birds fed red sorghum had si gnificantly ($p<0.05$) higher feed efficiency (1.76) than those fed other dietary treatments and was cheaper (201.86 ₦/kg) the birds fed maize based diet had the highest value for mortality which was statistically similar to bird fed *ICSV400* and the least value was obtained in *kaura*.

4.5.2. Interaction effect of sorghum varieties and inclusion level on the performance of broiler chicken (5-8wks)

There were significant interactions ($P<0.05$) between dietary treatments (maize and different sorghum varieties) and inclusion levels (50 and 100%). Dietary treatments and inclusion levels had significant ($p<0.05$) effect on final weight, total weight gain and feed cost per gain while other parameters did not differs ($p>0.05$) significantly. The inclusion of 50 and 100% red sorghum and 50% *farfara* had significantly ($p<0.05$) higher values (2405.27, 2370.00 and 2357.50g) for final weight gain. Birds fed 50% Red sorghum (1354.17g) and 50% *f*arfara inclusion level gained better weight on the total as compared to other dietary treatments. Birds fed diets containing the different sorghum varieties at both 50 and 100% inclusion levels were cheaper (297.77g) when compared to birds fed maize based diet.

Table 4.6: Main effect of sorghum varieties and inclusion levels on the performance of broiler chicken (5-8wks)

Parameters	Maize	*Farfara*	*Kaura*	*ICSV400*	Red sorghum	SEM	50%	100%	SEM
IWT (g/bird)	1076.63	1074.28	1074.20	1073.17	1047.05	47.72	1061.06	1073.29	67.69
FWT (g/bird)	2271.53^{b}	2269.62^{b}	2280.32^{b}	2262.07^{b}	2387.63^{a}	41.47	2332.13	2267.70	115.55
WG (g/bird)	1194.90	1195.34	1206.12	1189.53	1340.58	85.75	1294.13	1194.53	121.63
AWT (g/bird)	56.90	56.92	57.43	56.64	63.84	4.08	61.65	56.88	5.80
TFI (g/bird)	3407.64	3230.10	3074.30	2964.40	3152.20	100.9	3074.61	3136.88	143.18
AFI (g/bird/da	121.70	115.36	109.80	105.62	112.65	17.37	109.68	112.03	5.12
FCR	2.28^{c}	1.91^{b}	1.86^{b}	1.86^{b}	1.76^{a}	0.13	1.78	1.91	0.18
FC/G (₦)	297.77^{c}	239.07^{b}	233.09^{b}	224.81b	201.86^{a}	17.37	216.94	232.47	24.80
Mortality (%)	5.33^{b}	3.33^{a}	3.33^{a}	6.00^{b}	3.33^{a}	1.83	3.66	4.33	2.59

^{abc}: Means on the same row with different superscripts differ significantly ($p<0.05$)
NS: Not significant ($p>0.05$) SEM: Standard error of means
IWT =Initial weight
FWT= final weight
WG= weight gain
AWT=average weight gain
TFI=total feed intake
AFI= average feed intake
FCR= Feed conversion ratio
FC/G= Feed cost per gain

Table 4.7: Interaction effect of sorghum varieties and level of inclusion on the performance of broiler chickens (5-8wks)

	Maize	*Farfara*		*Kaura*		*ICSV400*		Red sorghu		SEM
Parameters	100%	50%	100%	50%	100%	50%	100%	50%	100%	
IWT (g/bi	1076.6	1074.07	1074.5	1074.03	1072.3	1075.03	1073.37	1071.10	1073.00	40.86
FWT (g/bi	2271.53	2357.50	2181.77	2298.27	2225.87	2267.47	2293.17	2405.27^{a}	2370.00	57.42
WG (g/bi	1194.90	1283.43	1107.2	1224.24	1153.57^{c}	1192.44	1219.80	1334.17^{a}	1297.00	100.05
AWT (g/bir /day)	56.90	61.12	52.73	58.30	54.93	56.78	58.09	65.91	61.77	20.98
TFI (g/bird)	3407.6	3093.0	3367.2	2867.97	3060.7	3131.54	3017.08	3205.89	3102.48	121.34
AFI (g/bird/	121.70	110.47	120.26	101.93	109.31	111.84	107.75	114.49	110.80	56.76
FCR	2.28	1.77	2.04	1.68	2.03	1.88	1.84	1.78	1.74	1.27
FC/G kg/₦	297.77^{b}	225.87^{a}	252.27^{a}	213.16^{a}	236.46^{a}	239.43^{a}	226.76^{a}	189.30^{a}	214.41^{a}	43.35
Mortality (%)	5.33	2.67	4.00	5.33	6.67	4.00	2.67	2.67	4.00	3.21

^{abc}: Means on the same row with different superscripts differ significantly ($p<0.05$)
NS: Not significant ($p>0.05$)   SEM: Standard error of means
IWT =Initial weight
FWT= final weight
WG= weight gain
AWT=average weight gain
TFI=total feed intake
AFI= average feed intake
FCR= Feed conversion ratio
FC/G= Feed cost per gain

4.5.3. Main effect of sorghum varieties and inclusion level on Hematological parameters of broiler chicken

Table 4.8 shows the main effect of sorghum varieties and inclusion levels on haematological parameters of broiler chickens. There was no significant difference (P>0.05) in all the haematological parameters measured for varietal effect. However, birds fed red sorghum recorded the highest numerical value for Hb and PVC (8.28 g/d and 25.00%, respectively) while those fed maize recorded the lowest value (7.43 g/d and 22.33%, respectively) *ICSV400* recorded the highest numerical value for red blood cell (3.89x10^9/c). Birds fed maize based diet had the highest value for WBC (9.57x10^9/l) while the lowest value (5.58x10^9/l) was obtained for birds fed red sorghum diets. The inclusion level had no effect on the haematological parameter. However, Hb and PVC increases numerically with an increase in the level of inclusion

4.5.3. Interaction effect of sorghum varieties and inclusion level on hematological parameter of broiler chicken

The interaction effect of the sorghum varieties and inclusion levels on haematological parameters of broiler chicken is shown in Table 4.9. There were significant (p<0.05) interaction between the sorghum varieties and inclusion levels on haemoglobin, pack cell volume and neutrophil while other parameters did not differ significantly (p>0.05). Higher value for Hb (9.53 g/dl) was recorded in birds fed 100% *kaura* while the lowest value was obtained for bird fed 100% *farfara* which was statistically similar to 50% *kaura* and 50% *ICSV400*. PVC was significantly (p<0.05) higher for birds fed 100% *ICSV400* which was statistically similar to birds fed 100% *kaura*. Birds fed 50% red sorghum had the highest value for neutrophil (7.69%) which was similar to 50% *ICSV400* and 100% *farfara* (7.33 and 7.33%, respectively).

Table 4.8: Main effect of sorghum varieties and inclusion levels on the hematological parameters of broiler chicken
HB: Hemoglobin

	Sorghum Varieties						Inclusion levels		
Parameters	Maize	*Farfara*	*Kaura*	*ICSV400*	*Red sorghum*	SEM	50%	100%	SEM
HB (g/dl)	7.43	7.90	8.25	8.18	8.28	1.84	7.65	8.66	1.19
PCV (%)	22.33	23.83	25.00	24.67	25.00	2,54	23.17	26.08	3.61
RBC ($\times 10^9$/l)	3.70	3.65	3.40	3.89	3.51	1.76	3.64	3.67	1.78
WBC ($\times 10^9$/l)	9.57	9.02	9.18	6.8	5.58	2.36	6.17	5.67	2.96
MCV (%)	58.89	63.29	62.14	62.08	62.78	3.22	62.82	62.32	4.56
MCH (pg)	19.60	20.97	20.64	20.59	20.79	1.08	20.81	20.68	1.54
MCHC (%)	33.29	33.12	33.21	33.14	33.13	1.07	33.13	33.17	0.10
Neutrophil (%)	6.00	5.33	4.83	6.83	6.67	2.09	6.17	5.67	2.96
Lymphocyte %)	91.33	92.83	95.00	92.33	91.83	2.75	92.67	93.33	3.90

PCV : Pack cell volume
RBC : red blood cell count
WBC : white blood cell count

MCV : Mean corpuscular volume
MCH : mean corpuscular hemoglobin
MCHC : mean corpuscular hemoglobin concentration
NEU: Neutrophil
LYM : Lymphocyte

Table 4.9: Interaction effect of sorghum varieties and level of inclusion on hematological parameters of broiler chicken

	Maize	*Farfara*		*Kaura*		*ICSV400*		Red Sorg		SEM
Parameters	100%	50%	100%	50%	100%	50%	100%	50%	100%	
HB(g/dl)	7.43^{ab}	8.83^{a}	6.97^{b}	6.97^{b}	9.53^{a}	6.97^{b}	9.40^{a}	7.83^{ab}	8.73^{ab}	0.59
PCV (%)	22.33^{b}	26.67^{ab}	21.00^{b}	21.33^{b}	28.67^{a}	21.00^{b}	28.88^{a}	23.67^{b}	26.33^{ab}	1.80
RBC($\times 10^9$/l)	3.70	4.10	3.40	3.73	4.06	3.37	4.53	3.73	4.23	1.56
WBC(($\times 10^9$/l)	9.57	8.63	9.40	7.87	10.50	7.70	5.60	7.13	4.03	1.66
MCV (%)	58.89	64.99	61.59	61.77	62.59	61.24	62.92	63.26	62.26	2.27
MCH (pg)	19.60	21.54	20.40	20.49	20.79	20.31	20.88	20.94	20.65	1.76
MCHC (%)	33.29	33.12	33.12	33.16	33.25	33.13	33.15	33.10	33.16	0.05
Neutrophil (%)	6.00^{ab}	3.33^{b}	7.33^{a}	6.33^{b}	3.33b	7.33^{a}	6.33^{b}	7.67^{a}	5.67^{ab}	1.48
Lymphocyte (%)	91.33	96.00	89.67	93.66	96.33	91.67	93.00	89.33	94.33	1.94

^{abc}: Means on the same row with different superscripts differ significantly (p<0.05)
NS: Not significant (p>0.05) SEM: Standard error of means
HB: Hemoglobin
PCV: Pack cell volume
RBC: red blood cell count
WBC: white blood cell count
MCV: Mean corpuscular volume,
MCH: mean corpuscular hemoglobin
MCHC: mean corpuscular hemoglobin concentration
NEU: Neutrophil,
LYM : Lymphocyte.

4.5.5. Main effect of sorghum varieties and inclusion levels on serum biochemistry of broiler chickens

Table 4.10: shown the main effect of sorghum varieties and inclusion levels on serum biochemistry of broiler chickens fed the experiments diets. There were significant (p<0.05) differences in albumin, globulin, albumin: globulin, creatinine,

aspartate, bilirubin and cholesterol for varietal effect. Birds fed maize *Kaura*, *ICSV400* and red sorghum had similar albumin which were significantly ($p<0.05$) higher than what was recorded for maize. Birds on *ICSV400* recorded the highest value for globulin (31.17g/l) while *kaura* had the lowest value (24.67g/l). Bird fed *ICSV400* recorded the highest value for creatinine when compared to other diets. AST recorded the highest value in birds fed *Farfara* (54.00IU/L) while birds fed red sorghum, *ICSV400*, *kaura* and maize where statistically similar. The highest value for bilirubin and cholesterol where recorded in birds fed maize (13.00 and 5.63 mmol/l, respectively). Inclusion levels did not show any significant ($p>0.05$) effect on the parameters measured.

4.5.6. Interaction effect of sorghum varieties and inclusion on serum biochemistry of broiler chicken

The interaction effect of sorghum varieties and inclusion levels was presented in Table 4.11 The different varieties of sorghum and inclusion level shows significant difference ($p<0.05$) on total protein, albumin, globulin, albumin:globulin, creatnine, aspartate, Alanine amino transferase, Alkaline Phosphate, total bilirubin and glucose. Birds fed 100% red sorghum, 50% *kaura*, maize and 50% *ICSV400* had similar value for total protein (5.67, 5.87, 5.47 and 5.29 g/dl, respectively). Albumin and globulin were significantly ($p<0.05$) higher for birds fed 100% *kaura*. Birds fed *kaura* had the highest value (89.33mmol/l) for creatinine while birds fed 100% *farfara* recorded the least value (69.00mmol/l). Bird fed 100% *ICSV400* recorded the highest value for AST and alkaline phosphate (93.33 and 152.00IU/L, respectively). Total bilirubin was significantly ($p<0.05$) higher on birds fed 50% red sorghum. Birds fed maize based diet recorded the highest value for glucose (3.63mmol/l).

4.5.7. Main effect of sorghum varieties and inclusion level on carcass characteristics of broiler chickens

The main effect of sorghum varieties and inclusion levels on carcass characteristics of broiler chickens fed the experimental diets is shown in Table 4.12. There were significant ($p<0.05$) differences in the live weight, thigh, neck, abdominal fat, wing and back of broiler chickens for varietal effects. Inclusion levels (50 and 100%) effect had no significant ($p>0.05$) effect on performance traits. Birds fed red sorghum had significantly ($p<0.05$) the heaviest values for live weight (2681.00g), neck (5.93g) and back percentage (8.23g) as compared to other dietary treatments. Red sorghum had the best numerical value (5.93) for neck while birds fed *ICSV400* as the sole dietary treatment had highest values for abdominal fat (3.26) and wings (9.05).

Table 4.10: Main effect of sorghum varieties and inclusion level on the serum biochemistry of broiler chickens

	Sorghum Variaties						Inclusion level		
Parameters	Maize	*Farfara*	*Kaura*	*ICSV400*	Red Sorg	SEM	50%	100%	SEM
Total protein(g/dl)	5.47	3.83	4.65	4.70	4.83	1.05	5.23	3.76	1.49
Albumin(g/l)	26.00^{a}	24.17^{b}	26.50^{a}	28.50^{a}	27.83^{a}	1.65	25.42	28.08	2.33
Globulin (g/l)	24.33^{b}	29.50^{ab}	24.67^{b}	31.17^{a}	22.83^{b}	2.68	26.67	27.42	3.80
AL:GLO	1.14^{a}	0.83b	1.17^{ab}	1.02^{ab}	1.28^{a}	0.14	0.10^{b}	1.15^{a}	0.19
Creatinine(µmol/l)	68.67^{b}	75.00^{ab}	80.17^{a}	81.67^{a}	75.50^{ab}	9.41	83.42	72.75	13.34
AST(IU/l)	32.33^{b}	54.00^{a}	34.00^{b}	38.00^{b}	44.67^{ab}	4.98	45.42	39.92	7.06
Alkaline phosphate(IU/l)	125.67	122.67	134.50	97.33	128.50	21.11	114.67	126.83	29.94
Bilirubin(µmol/l)	13.00^{a}	11.500^{a}	9.33^{b}	12.33^{a}	12.83^{a}	1.47	12.17	10.83	2.09
ALT(IU/l)	77.33	70.67	84.17	71.50	70.67	10.61	71.42	77.08	15.04
Glucose (mmol/l)	3.63	3.18	2.80	2.82	2.75	0.28	2.77	3.01	0.40
Cholesterol(mmol/l)	5.63^{a}	5.17^{a}	4.37^{a}	4.47^{b}	4.95^{ab}	0.42	4.79	4.68	0.60
Calcium(mmol/l)	2.17	2.18	2.23	2.02	2.10	0.10	2.10	2.17	0.14
Phosphorus(mmol/l)	0.86	1.43	1.27	1.30	1.25	0.18	1.42	1.20	0.25

^{abc}: Means on the same row with different superscripts differ significantly ($p<0.05$)
NS: Not significant ($p>0.05$) SEM: Standard error of means
AST: Aspartate amino transferase ALT: Alanine amino transferase

Table.4.11: Interaction effect of sorghum varieties and levels of inclusion on serum biochemistry of broiler chicken

	Maize	*Farfara*		*ICSV400*		*Kaura*		Red sorghum		SEM
Parameters	100%	50%	100%	50%	100%	50%	100%	50%	100%	SEM
Total protein (g/dl)	5.67^{a}	4.13^{b}	3.53^{c}	5.27^{a}	4.03^{b}	5.53^{a}	5.87^{a}	5.47^{a}	4.00^{b}	0.74
Albumin (g/l)	26.0^{b}	24.00^{c}	24.33^{c}	23.67^{c}	29.33^{ab}	24.67^{c}	32.33^{a}	29.33^{ab}	26.33^{b}	1.16
Globulin (g/l)	24.33^{c}	26.67^{bc}	29.33^{b}	25.33^{bc}	24.00^{c}	28.00^{b}	34.33^{a}	23.67^{c}	22.00^{c}	1.89
Albumin:Globulin	1.14^{a}	0.82^{b}	0.83^{b}	0.97^{b}	1.36^{a}	0.88^{b}	1.15^{a}	1.29^{a}	1.26^{a}	0.10
Creatinine(μmol/l)	68.67^{c}	81.00^{a}	69.00^{c}	77.00^{b}	83.33^{a}	89.33^{a}	74.00^{b}	86.33^{a}	64.67^{c}	6.65
AST(IU/l)	32.33^{c}	60.00^{a}	48.00^{b}	32.33^{c}	35.67^{c}	42.67^{b}	33.33^{c}	46.67^{b}	42.67^{b}	3.52
ALT(IU/l)	77.33^{b}	68.33^{c}	73.00^{b}	76.00^{b}	92.33^{a}	78.00^{b}	65.00^{c}	63.33^{c}	78.00^{b}	7.49
Alkaline phosphate(IU/l)	125.67^{a}	117.33b	128.00^{a}	117.0^{b}	152.00^{a}	92.33^{b}	102.33^{b}	132.00^{a}	125.0(	14.92
Total bilirubin (μmol/l)	13.00^{a}	12.67^{a}	10.33^{b}	8.00^{c}	10.67^{b}	13.33a	11.33^{bc}	14.67^{a}	11.00b	1.04
Glucose(mmol/l)	3.63^{a}	3.30^{a}	3.06^{a}	2.70^{b}	2.90^{b}	2.57^{b}	3.06^{a}	2.50^{b}	3.00^{a}	0.40
Cholesterol(mmol/l)	5.63	5.03	5.30	4.37	4.37	4.50	4.43	5.26	4.63	0.50
Calcium (mmol/l)	2.17	2.07	2.29	2.24	2.21	2.00	2.03	2.08	2.14	1.07
Phosphorus(mmol/l)	0.86	1.50	1.35	1.38	1.15	1.38	1.23	1.43	1.02	1.12

AST: Aspartate amino transferase ALT: Alanine amino transferase

abc: Means on the same row with different superscripts differ significantly ($p<0.05$)

NS: Not significant ($p>0.05$) SEM: Standard error of means

Table 4.12: Main effect of sorghum varieties and inclusion levels on carcass characteristics of Broiler chickens

		Sorghum Varieties					Inclusion levels		
Parameters	Maize	*Farfara*	*Kaura*	*ICSV400*	Red sorghu	SEM	50%	100%	SEM
Live weight(g)	2479^{ab}	2573.83^{ab}	2452.17^{b}	2488.50^{ab}	2681.00^{a}	85.89	2573.25	2624.50	121.82
Dress Weight (%)	86.13	88.32	86.74	85.11	86.74	1.50	86.70	86.81	2.12
Carcass Weight (%)	71.67	74.27	72.31	72.91	75.18	2.16	72.79	74.54	3.06
Dressing percent	75.67	74.42	75.52	74.92	73.42	1.06	75.46	74.67	1.50
Breast (%)	19.65	20.04	17.79	20.58	20.49	1.37	19.69	19.76	1.94
Drumstick (%)	9.88	9.72	10.09	0.24	10.22	0.42	9.53	10.11	0.59
Thigh (%)	14.45^{a}	14.31^{a}	14.04^{a}	14.33^{a}	11.30^{b}	0.18	12.17	11.91	1.15
Head (%)	2.48	2.31	2.70	2.36	2.73	1.28	2.42	2.63	0.39
Neck (%)	4.69^{b}	4.57^{c}	4.96^{b}	5.35^{ab}	5.93^{a}	0.27	5.30	5.11	0.38
Abdominal fat (%)	1.66^{c}	2.94^{ab}	2.34^{ab}	3.26^{a}	2.10^{b}	0.40	2.70	2.62	0.55
Wings (%)	8.36^{ab}	8.37^{ab}	8.93^{ab}	9.05^{a}	8.06^{b}	0.12	8.54	8.67	0.17
Back (%)	4.34^{c}	5.32b^{c}	5.97^{b}	7.10^{ab}	8.23^{a}	0.69	6.43	6.88	0.98

^{abc}: Means on the same row with different superscripts differ significantly ($p<0.05$)
NS: Not significant ($p>0.05$) SEM: Standard error of means

4.5.8. Interaction effect of sorghum varieties and inclusion level on carcass characteristics of broiler chickens

The interaction effects of sorghum varieties and inclusion levels on carcass characteristics is presented in Table 4.13 There were significant interactions (P<0.05) between dietary treatments (maize and different sorghum varieties) and inclusion levels (50 and 100). Dietary treatments and inclusion levels had significant (p<0.05) effect on live weight, dressing percentage, breast and abdominal fat while other parameters did not differs (p>0.05) significantly. 100% *farfara* and red sorghum had significant (p<0.05) and best numerical values (2654.67 and 2764.67g) for live weight. Birds fed maize based diet (79.67%), 50% *Kaura* (79.16%) and 50% *ICSV400* (78.64%) had the best performance as compared to other dietary treatments for dressing percentage. Birds fed 100% *Farfara* (21.38%), 50% *ICSV400* (21.84%) and 100% red sorghum (21.36%) had the best performance for breast. Abdominal fat had the highest numerical values for 100% *Farfara* (3.22%), 50 and 100% *ICSV400* (3.22 and 3.30%) among the dietary treatments.

Table 4.13: Interaction effect of sorghum varieties and inclusion levels on carcass characteristics

	Maize	*Farfara*		*Kaura*		*ICSV400*		Red sorghum		SEM
Parameters	100%	50%	100%	50%	100%	50%	100%	50%	100%	
Live weight (g)	2479^b	2493.00	2654.67^a	2411.67^b	2492.67^b	2391.00^c	2586.00^b	2597.67^b	2764.67^a	60.70
Dressed weight %	86.13	88.29	88.34	87.44	86.03	83.78	86.43	87.30	86.45	2.06
Dressing %	79.67^a	75.76^c	73.61^c	79.16^a	77.87^b	78.64^a	74.07^c	75.27^c	74.39^c	1.52
Carcass weight %	71.67	73.68	74.86	72.01	72.60	70.65	75.17	74.82	75.54	2.75
Breast %	19.65^b	18.70^b	21.38^a	18.58^b	16.99^c	21.84^a	19.29^b	19.61^b	21.36^a	0.29
Drumstick %	9.88	9.91	9.53	9.39	10.79	8.94	9.55	9.86	10.57	1.10
Thigh %	14.45	16.04	12.58	13.03	15.05	14.66	13.99	11.74	10.87	4.57
Head%	2.48	2.30	2.32	2.45	2.95	2.40	2.31	2.51	2.94	1.19
Neck%	4.69	4.43	4.71	4.71	5.17	5.37	5.32	6.22	5.64	2.19
Abdominal fat %	1.66^c	3.22^a	2.66^b	2.66^b	2.22^b	3.22^a	3.30^a	2.13^b	2.07^b	0.28
Wing %	8.36	8.18	8.57	8.57	8.77	9.14	8.96	8.06	8.06	1.24
Back %	4.34	4.72	5.93	5.93	3.04	7.69	6.51	5.72	6.22	2.13

^{abc}: Means on the same row with different superscripts differ significantly ($p<0.05$)

NS: Not significant ($p>0.05$) SEM: Standard error of means

4.5.9. Main effect of sorghum varieties and inclusion level on organ weight of Broiler Chickens

Table 4.14: shown the main effect of sorghum varieties and inclusion level on organ weights of broiler chickens fed the experimental diets. The sorghum varieties showed significant ($p<0.05$) differences in all the organs weight (liver, kidney, lungs, gizzard, heart, spleen and intestinal length) except in intestinal length which did not differ significantly ($p>0.05$) Birds fed maize based diet had the highest values for liver, kidney, gizzard, intestinal weight, and intestinal length. Inclusion levels (50 and 100%) had significant ($p<0.05$) effect on liver, kidney and intestinal weight. Birds fed *ICSV400* had the highest value for heart while those fed maize base diet had the least value (0.41%). The weight of liver, kidney and intestinal weight increases with an increase in inclusion level.

4.5.10. Interaction effect of sorghum varieties and inclusion levels on the organs weight of broiler chicken

The result of interaction effect of inclusion levels and sorghum varieties on organs weight of broilers chickens is shown in Table 4.15: In all the parameters measured kidney weight, gizzard weight, spleen weight, intestinal weight and intestinal length were influenced by the dietary treatment. Bird fed 50% *kaura* recorded the highest value (0.92%) for kidney while 100% *Farfara*, 50% red sorghum and 100% red sorghum had the lowest varieties (0.49, 0.43 and 0.42%, respectively). Highest gizzard weight was recorded for birds on the control diet, while the lowest value was obtained for birds on 50% red sorghum. Birds fed 50% *Farfara* recorded the highest value (0.13%) for spleen which was similar to bird fed 100% *Kaura*. Intestinal weight was significantly ($p<0.05$) higher in birds fed maize based diet while the lowest value was obtained in 50% *Farfara*. Bird fed maize based diet recorded the highest value (254.33cm) for intestinal length while the lowest value (203.33cm) was obtained in birds 50% *Farfara*.

Table 4.14 : Main effect of sorghum varieties and inclusion levels on organs weight of broiler chickens

	Sorghum varieties						Inclusion levels		
Parameters	Maize	*Farfara*	*Kaura*	*ICSV400*	Red sorghu	SEM	50%	100%	SEM
Liver %	2.66[a]	2.32[a]	2.33[a]	2.06[ab]	1.93[b]	0.12	2.28[a]	2.04[b]	0.17
Kidney %	0.64[a]	0.55[b]	0.79[a]	0.70[a]	0.43[c]	0.05	0.68[a]	0.55[b]	0.06
Lungs %	0.63[c]	0.74[b]	0.71[b]	1.09[a]	0.62[c]	0.09	0.82	0.76	0.12
Gizzard %	3.06[a]	1.80[b]	1.78[b]	1.84[b]	1.61[b]	0.22	1.95	1.57	0.31
Heart %	0.41[b]	0.46[b]	0.46[b]	0.55[a]	0.51[ab]	0.04	0.51	0.48	0.05
Spleen %	0.13	0.14	0.14	0.14	0.13	0.02	0.13	0.14	0.03
Intestinal weig	6.66[a]	5.02[b]	5.57[ab]	5.57[ab]	5.51[ab]	0.45	6.16[a]	5.13[b]	0.64
Intestinal lengt	235.83	203.33	234.33	228.17	219.33	2.50	232.33	226.50	3.43

[abc]: Means o n the same row with different superscripts differ significantly (p<0.05)
NS: Not significant (p>0.05) SEM: Standard error of means

Table 4.15: Interaction effect of sorghum varieties and level of inclusion on organs weight of broiler chicken

Parameters	Maize	*Farfara*		*Kaura*		*ICSV400*		Red Sorg		SEM
Parameters	100%	50%	100%	50%	100%	50%	100%	50%	100%	
Liver %	2.66	2.52	2.11	2.43	2.23	2.11	2.00	2.05	1.81	0.09
Kidney %	0.64[b]	0.60[b]	0.49[c]	0.92[a]	0.66[b]	0.77[b]	0.62[b]	0.43[c]	0.42[c]	0.03
Lungs %	0.63	0.70	0.78	0.74	0.67	1.17	1.02	0.66	0.58	0.60
Gizzard %	3.06[a]	1.97[c]	1.62[c]	2.24[b]	1.32[c]	2.02[b]	1.66[c]	1.56[c]	1.66[c]	0.16
Heart %	0.41	0.47	0.95	0.50	0.43	0.54	0.55	0.11[c]	0.48	0.20
Spleen %	0.13[c]	0.15[a]	0.13[c]	0.12[c]	0.16[a]	0.14[b]	0.14[b]	6.20[ab]	0.15[a]	0.01
Intestinal weight %	7.31[a]	5.22[ab]	4.81[b]	6.66[ab]	5.65[ab]	5.92[ab]	5.22[ab]	217.00[c]	4.81[b]	0.32
Intestinal length(cm)	254.33[a]	203.33[c]	214.33[c]	235.00[b]	236.67[b]	223.00[b]			221.67[b]	8.84

[abc]: Means on the same row with different superscripts differ significantly ($p<0.05$)
NS: Not significant ($p>0.05$) SEM: Standard error of means

4.5.11. Main effect of sorghum varieties and inclusion level on nutrient digestibility of broiler chickens

Table 4.16 Shown the results of dry matter, crude protein, crude fibre, ether extract, ash and nitrogen free extract digestibility by broilers fed maize based diet and different sorghum varieties broiler finisher diets. There were significant ($p<0.05$) differences in all the parameters analyzed across the treatments except for dry matter. The values obtained for percent crude protein, crude fibre, ash and nitrogen free extract digestibility were significantly ($p<0.05$) lower for birds fed red sorghum on the average compared to those fed other diets. 50% inclusion levels had significant ($p<0.05$) and higher values for crude fibre compared to 100% level of inclusion.

4.5.12. Interaction effect of sorghum varieties and inclusion levels on nutrients digestibility

Table 4.17 Shown the interaction effect of sorghum varieties and inclusion level on nutrient digestibility of broiler chicken. A significant difference ($p<0.05$) was observed in all the parameters measured except Nitrogen Free Extract. Crude protein digestibility was significantly higher on bird fed maize based diet which was statistically similar to birds fed 50 and 100% red sorghum, 100% *ICSV400,* 50 and 100% *kaura*. Bird fed 50% *farfara* recorded the highest value for either extract which was comparable to birds on 100% farfara, 50 and 100% red sorghum. Metabolizable energy digestibility was significantly ($p<0.05$) higher in birds fed 50% and 100% *ICSV400* and lowest value is obtained from 50 and 100% *kaura*.

Table 4.16: Main effect of maize and sorghum varieties and inclusion levels on nutrient digestibility

		Sorghum Varieties					Inclusion levels		
Parameters (%)	Maize	*Farfara*	*kaura*	*ICSV400*	Red sorgl	SEM	50%	100%	SEM
Dry matter	88.17	88.25	88.20	88.15	87.96	0.35	88.25	88.03	0.50
Metabolizable en	88.55[a]	88.21[b]	88.46[b]	89.44[a]	88.42[b]	0.31	88.82	88.45	0.44
Crude protein	89.05[a]	88.60[b]	88.93[b]	89.06[a]	88.24[b]	0.29	88.87	88.45	0.40
Crude fibre	67.84[a]	67.24[a]	67.19[a]	67.53[a]	66.47[b]	0.27	67.38[a]	66.83b	0.38
Ether extract	87.92[b]	92.18[a]	87.90[b]	88.42[b]	92.2[a]	0.30	90.15	90.20	0.42
Nitrogen free ext	78.62[a]	77.44[bc]	78.05[ab]	79.06[a]	76.55[c]	0.47	78.05	77.50	0.44

[abc]: Means on the same row with different superscripts differ significantly ($p<0.05$)
NS: Not significant ($p>0.05$) SEM: Standard error of means
DM: Dry matter,
CP: Crude protein,
CF: Crude fiber,
EE: Ether extract
NFE: Nitrogen free extract
ME: Metabolisable energy

Table 4.17: Interaction effect of sorghum varieties and inclusion levels on nutrient digestibility

Maize	*Farfara*	*Kaura*	*ICSV400*	Red sorghum

Parameters	100%	50%	100%	50%	100%	50%	100%	50%	100%	SEM
Dry matter%	88.17[a]	88.40[a]	88.10[a]	88.55[a]	87.86[b]	88.19[a]	88.19[a]	87.93[b]	87.99[b]	0.22
Crude protein%	88.93[a]	88.64[ab]	87.96[b]	89.09[a]	89.01[a]	88.76[a]	88.76[a]	88.41[a]	88.07[a]	0.20
Crude fiber%	67.84[a]	67.54[a]	66.94[b]	67.47[a]	66.92[b]	67.65[a]	67.65[a]	66.88[b]	66.07[b]	0.19
Ether extract%	87.92[b]	92.37[a]	91.98[a]	87.72[b]	88.08[b]	88.42[b]	88.42[b]	92.10[a]	92.32[a]	0.23
Ash%	86.48[a]	85.89[a]	83.05[b]	85.72[b]	85.44[b]	82.73[c]	84.81[b]	83.45[b]	81.47[c]	0.51
NFE%	78.62	77.45	77.43	78.69	77.40	79.38	78.74	76.66	76.44	0.33
ME(kcal/kg)	88.35[b]	88.56[c]	87.85[c]	88.60[b]	88.31[b]	89.42[a]	89.46[a]	88.67[b]	88.17[b]	0.22

[abc]: Means on the same row with different superscripts differ significantly ($p<0.05$)
NS: Not significant ($p>0.05$) SEM: Standard error of means
NFE: Nitrogen free extracts
ME: Metabolisable energy

4.2. DISCUSSIONS

4.2.1. Proximate Composition of maize and some sorghum varieties

The percent crude fibre and nitrogen free extract (NFE) was higher in maize compared to the values obtained for the sorghum varieties. This agreed with the findings of Mateo and Carandang, (2006) who reported higher value of fibre for maize than sorghum. This may be responsible for the high value of metabolizable energy (kcal/kg) compared to the values in sorghum varieties, respectively. However *kaura* had the highest value for metabolizable energy. Metabolizable energy was greater in maize (3466.29kcal/kg) than the sorghum varieties (3348.80 to 3280.62g/kg) except Kaura which had the highest metabolizable energy (3474.71g/kg). This is partly explained by the higher fat content in *Kaura*. This finding supported the reports of Aduku (1993); Olomu (1995); and NRC (1996) these workers reported higher value of metabolizable energy for maize compared to sorghum varieties. The higher percent crude protein found in red sorghum varieties compared to the value for maize, *farfara*, *ICSV 400* and *Kaura* were within the ranges reported by Olomu (1995); Ojewola and Oyim (2006). The similar values for percent ether extract for maize, F*arfara, Kaura*, red sorghum and *ICSV 400* respectively were lower than the ranges of 2.50 to 4.10% recorded by Abubakar *et al*. (2006); Etuk and Ukaejiofo (2007).

The Crude fibre found in maize and *Farfara* (4.74% and 4.43%) was in contrast to the findings of Ojewola and Oyim (2006) who reported ranges of 5.8- 7.92 crude fibre (CF) for sorghum . The low crude fibre obtained in this study may be due to the relaive low levels of polyphenols recorded in the sorghum varieties used. Since polyphenols are known to contribute to the lignin fraction of the dietary fibre. The percent ash was found to be high in red sorghum and *farfara* (3.53 and 3.50 %) compared to the values for maize. This result agreed with the reports of NRC (1996); Ojewola and Oyim (2006) who reported 3.83% ash for sorghum and finger millet.. Values obtained for crude protein, crude fibre and metabolizable energy in this study were lower than the most recently observation of Tukur (2011) who reported that sorghum contains 3,669kcal/kg of ME, 7.8% crude protein and 10.6% crude fibre. The differences observed in the proximate composition of the sorghum varieties in this study may be as a result varietal difference, climatic condition, soil type and agronomic practices as reported by (Becker, 1992)

4.2.2. Anti-nutritional Factors in the sorghum varieties and maize

The values obtained for tannins were within the range of 0.00 - 0.13 g/100mg which was below 2.6 g/Kg reported by Reza and Edriss (1997) for low tannins sorghum. Barry and McNabb (1999) reported above 50 g/kg DM for high tannin sorghum in animals. Phytate was within the range of 0.09- 0.20 g/100gm. Saponin was within the range of 0.08- 0.15 g/100mg. Maize was found to be significantly ($p<0.05$) higher in oxalate and flavonin compared to the sorghum varieties. Oxalate was lower than the range of 6.72- 13.44 g/Kg reported by Reza and Edriss (1997) in sorghum and millet.

The differences observed may be due to the differences in the cultivars, soil type and condition under which the crop was grown. The result of this study is not in accordance to the finding of Issa *et al.* (2007) who reported that coloured sorghum grains contain more tannin than white ones. *Farfara* variety (white sorghum) recorded the highest value (0.13mg/100g) for tannin followed by the red sorghum (0.12mg/100g) while *ICSV400* had the least value (0.13 g/100mg). The tannin content of sorghum is often thought to be closely related to darkness of seed color as reported by Sultan *et al.* (2014). The result of this study concord with that of Boren and Waniska (1992) who opined that the color of sorghum seed coat is not an adequate indicator of tannin content. The relative higher tannin observed in *Farfara* variety may be due to endosperm color, presence or absence of testa, intensifier gene or spreader gene. Randey and Miller (1981) opined that in the absence of a spreader gene some high tannin hybrid sorghum with white pericarp may appear white.

Cheng *et al.* (2009) stated that white sorghum without testa or with purple testa and yellow or red sorghum without testa have very low percentage of tannins (0.0 to 0.2% tannin); whereas white, yellow or red sorghums with brown testa have medium to high tannin content (1.2 to 12.8%) as observed in this study.

4.2.3. Mineral Composition of the sorghum varieties and maize

A significant difference ($p<0.05$) was observed in all the mineral element tested except copper which was statistically similar. The red sorghum was higher in magnesium, iron, and phosphorus while ICSV400 was significantly higher in sodium. This may be due to difference in agronomic practices and the type of fertilizer used. This result agreed with the finding of Hulse *et al.* (1980) and FAO (2012) who reported sorghum as a good source of magnesium, iron, zinc, and copper. The result shows that the varieties of sorghum are higher in P, Na, Mg, Fe, Zinc, than maize. This is in agreement with the findings of Balota (2012) who reported that sorghum has a higher mineral content than maize, it is also in line with the report of Adegbola *et al.* (2013) who reported that sorghum is high in calcium, iron, phosphorus and sodium. The difference observed in the sorghum varieties may be due to environmental conditions prevailing in the growing region as it has been reported to affect their mineral composition (FAO, 2012).

4.2.4. Experiment I: The replacement value of some sorghum varieties on the performance of broiler chickens (0-4wks)

4.2.4.1.The main effect of sorghum varieties and inclusion levels on the performance of broiler chicks (0-4wks)

The highest final body weight (534.50g) was found in *farfara* which was statistically similar to *ICSV400* while lowest value was recorded for birds fed red sorghum. The result of this study was in agreement with the feeding of Abute and Gomez (1984), who reported that sorghum was superior to maize in terms of live-weight gain. It also agrees to the finding of Jacob *et al.* (1996) and Nychole *et al.* (1998) who observed no negative effect of low tannin sorghum on live weight. The lower weight gain for birds fed red sorghum may be due to the low feed intake or it may be due to sorghum grain test weight, endosperm type and texture, low starch digestibility due to the resistance to digestive enzymes by the hard peripheral endosperm layer as reported by Wu *et al*.(2008), or low protein digestion due to the α-kafirin content of the sorghum grain as reported by Elkin *et al.* (1996) to have negative correlation with the mean essential amino acid digestibility and TMEn.

The similar ($p>0.05$) values for feed intake of birds fed control diet (maize) and those fed sorghum varieties, respectively agreed with the reports of Rama Rao *et al.* (2002) who reported similar values of feed intake in broilers fed sorghum, millets and maize. The insignificant difference ($p<0.05$) in feed intake between the experimental diets may be due to the low tannin level of all the sorghum varieties used in this study. The result of this study concord with the feeding of jacob *et al*. (1996a) and Nychol *et al* (1998) that failed to observed any negetive effect of tannins on feed intake by broilers chicks on low dietary tannin levels (1.3%CE and 1.57% CE, respsctively). Another explanation is either the astringent taste of tannins could not affect the high appetite of modern broiler breeds, or may be due to similar metabolizable energy concentrations of the diets since birds are known for eating to satisfy their energy requirements.

The best feed conversion ratio of 1.78 was obtained for birds fed *farfara* sorghum variety was higher than the value obtained by Cao *et al*. (1998) who reported feed:gain of 1.49 in broilers fed soft sorghum-based diets vs 1.68 for birds fed medium and hard sorghum-based diets. The differences in kafirin structure likely contribute to the differences in bird performance reported by Cao *et al*. (1998). Abdelrahaman and Hoseney (1984) reported that sorghum's cross-linked kafirins cause hardness.

The result of the feed conversion ratio also showed similar inconsistent trend as feed intake and body weight gain where birds fed *Farfara* which recorded the highest level of tannin had the better feed conversion ratio than *ICSV400* which has the lowest value. Therefore, other factors beside the type of tannin may also be responsible for the observed inconsistency in feed utilization such as starch granules, kernel characteristic, endosperm type and texture, test weight. Feed conversion ratio of birds fed *Farfara* diet was numerically higher than the feed conversion ratio of the other sorghum varieties. This may have contributed to the observed enhanced weight gain of the birds fed *Farfara*. The result of this finding was in agreement with the findings of (Nagra *et al.,* 1990; Reyes *et al.,* 2001: Rama Rae *et al.,* 2002, Sannanmani 2002; Tyagi *et al.,* 2003) who reported that the nutritional value of low tannin sorghum is comparable to that of corn for poultry feeding.

The inclusion levels showed no significant ($p>0.05$) difference on broiler performance. This result was in agreement with the finding of Spiridon *et al.* (1979) that reported no depressive effect of sorghum on growth performance and feed efficiency even at 100% replacement with maize in meat chickens. The 100% inclusion levels gave better performance at the starter phase this may be due to the higher protein content of the diets since the sorghum varieties are higher in protein than the maize which is required more by the birds at this stage for development.

4.2.4.2. Interaction effect of sorghum varieties and inclusion levels on the performance of broiler chicks (0-4wks)

The interaction effect showed no significant ($p<0.05$) difference in all the parameters measured except feed cost per kilogram gain and percentage mortality. However, the final weight and total weight gain was numerically higher in the sorghum varieties at 100% inclusion level except *Farfara* which was higher at the 50% level of inclusion. This indicate that the the birds on the sorghum diet can extract and utilized the required nutrients from the sorghum diets as the level of the anti-nutritional factors were not detrimental to the birds. The numerical low feed intake recorded in birds fed 100% red sorghum may be due to the high levels of tannin, phytate, saponin, oxalate and flavonoid since these anti nutrition factor have been reported to affect feed intake.

The interaction effect showed that feed cost per kilogram gain was cheaper in birds fed the sorghum varieties at 50% and 100% level of inclusion. This was partly explained by the higher final weight and low feed conversion ratio obtained in the 50 and 100% sorghum inclusion levels. This indicated that the four sorghum varieties can totally replace maize in broilers diet with better efficiency in terms of feed conversion ratio and feed cost per kilogram gain. This agree with the findings of Rama Rao *et al*. (2002) and Raju *et al.* (2003) who reported that low tannin sorghum can replace maize without altering growth performance.

Birds fed 100% maize based diets recorded the highest mortality rate compared to the sorghum varieties this may be due to the high levels of minerals recorded in the sorghum varieties. Since there is evidence that the enhancement of mineral status of broilers may improve feathering and the immune response of the birds (Arbor Acre, 2009). This shows that the sorghum varieties incorporated into the diet of broiler chicks did not affect mortality. This implies that all dietary corn can be replaced by low-tannin sorghum grain without significantly affecting broiler performance.

4.2.5. Experiment II: Replacement value of some sorghum varieties on the performance of broiler chickens (5-8wks)

4.2.5.1. Main effect of sorghum varieties and inclusion levels on the performance of broilers Chicken (5- 8 weeks)

The proximate composition of the broiler finisher diets showed similarities between the nutrient composition of maize and the different cultivars of sorghum which support the reports of Travis *et al.* (2006) and Torki (2007) that sorghum has similar nutrient composition to maize. Final weight showed that birds fed red sorghum diets were significantly ($p<0.05$) higher compared to those fed other diets. This finding contrast with the report of Luis *et al.* (1982) and Andrews and Kumar*,* (1992) who reported that birds fed sorghum based diet had low performance than the maize and millet based diets. The highest final body weight recorded by the birds fed red sorghum may be due to the relatively high crude protein content of red sorghum which reduces the harmful effects of tannin on the ground that tannin will not be able to bind with all the protein. Another possible explanation may be due to the age differences, since age is also known to affect digestibility of feedstuff. This fact has long been recognized when comparisons were made for AME values of some feedstuff fed to young and old birds with AME values tending to increase with age (Johnson, 1987).

The significantly ($P<0\ .05$) low weight gain of birds fed *Kaura* compared to birds fed other dietary treatments was probably due to the test weight, endosperm type and texture, low starch digestibility due to the resistance to digestive enzymes by the hard peripheral endosperm layer as reported by Wu *et al.*(2008), low protein digestion due to the α-kafirin content of the sorghum grain as reported by Elkin *et at*, (1996) to have negative correlation with the mean essential amino acid digestibility and TMEn.

Birds fed *kaura* diet had similar feed intake and body weight gain as those fed the control diet. This observation perhaps may be due fact that the metabolizable energy concentration of the diets were similar and for the fact that birds eat to satisfy their energy requirements. This finding agreed with the reports of Nagra *et al.* (1990); Rama Rao *et al.* (2002) and Tyagi *et al.* (2003) these workers reported that replacement of maize with low tannin sorghum did not reduce the final body weight, body weight gain, feed intake and feed conversion ratio compared to maize based diet. Feed conversion ratios of birds fed red sorghum diets were significantly ($p<0.05$) better compared to birds fed other diets. This may have been contributed by the observed enhanced weight gain of the birds fed these diets.

4.2.5.2. Interaction effect of sorghum varieties and inclusion levels on broiler performance (5-8wks)

Birds fed 50% red sorghum were significantly higher in final body weight and total weight gain which was statistically similar to birds fed 100% red sorghum and 50% *farfara* which were in contrast to the result of the starter phase. This indicated that broiler starter tolerate lower concentration of the anti nutritional factors in red sorghum, while broiler finishers tolerated higher concentration. This is likely due to their better developed organs. It may also be due to the difference in feedstuff digestibity as a result of difference in age, since age is also known to affect digestibility of feedstuff. This fact has long been recognized when comparisons were made for AME values of some feedstuff fed to young and old birds with AME values tending to increase with age (Johnson, 1987). Another possible reason may be due to the saponin content of the sorghum varieties. Yejuman *et al*. (1998) opined that saponin has the potentials as dietary additive with optimum level in diet favoring higher growth rate and better feed efficiency. It was also reported by Seeman *et al.* (1974) that saponin from variety of sources has been shown to assist the absorption of nutrients by increasing the permeability of the small intestine mucosa.

Feed cost per kilogram gain was cheaper in birds fed the sorghum varieties at 50% and 100% level of inclusion. This indicates that the birds on the sorghum diets were able to utilize the required nutrients from the diets as the levels of antinutritional factors were not detrimental to the birds. This implies that the four sorghum varieties can totally replace maize in broiler finisher diets with better efficiency in terms feed conversion ration and feed cost per kilogram gain. However red sorghum at 50% levels of inclusion was the cheapest. This may be due to the capacity of the digestive track for carbohydrate digestion and absorption appeared to be utilized to a greater extent when fed the mixed starch sources than when fed only a single source. Hence, starch digestibility also varies depending on the combination of starch sources in the diets. Since at the finisher phase energy becomes more critical and at the same time protein requirement decreases.

Raju *et al.* (2003) also observed no depressive effect of sorghum on growth and feed efficiency even at 100% replacement. The better performance observed with the birds fed the sorghum varieties were in agreement with the finding of (Rama Rao *et al.* (2002) which showed that low tannin variety of sorghum can replace maize without altering growth performance

4.2.5.3. Main effect of sorghum varieties and inclusion level on Haematological parameters of broiler chickens

The haematological values obtained in this study were within the normal range for healthy birds as reported by Ahaotu *et al.* (2013). Oladele and Ayo (1999) indicated that there is evidence in literature that haematological characteristics of livestock suggest their physiological disposition to the plane of nutrition. According to Ewuola *et al.,* (2004) haematological indices are a reflection of the effect of dietary treatments on the animals in term of quality, type and amount of feed ingested and were available for the animals to meet its physiological, biochemical and metabolic necessities. It may then be suggested that, the different diets imposed on the broiler chickens were balanced in their nutrients to support relatively high performance and maintain the normal haematological profile of the broiler chickens. Ahaotu *et al.* (2013) reported ranges of 9.33-10.2 g/dl and 28.10-30.67% respectively, for both haemoglobin and PCV. The better value of PVC in *Kaura* and red sorghum was an indication that the birds efficiently utilized the *Kaura* and red sorghum than *farfara* and *ICSV*

400. This was in agreement with the findings of Wildeus *et al.* (2003) who observed no effect of condensed tannin on PVC values.

The value for haemoglobin obtained in this study supported the findings of Patra *et al.* (2010) who reported a range of 7-13g/dl for haemoglobin. The highest value are found in red sorghum and *Kaura* which is an indication of efficient oxygen transportation (Solomon *et al.,* 1998), Iyayi *et al.,* (2006), attributed low haemoglobin value to iron deficiency which may result in anaema. The relatively higher value for haemoglobin in red sorghum may be associated to its iron content (Solomon *et al.,* 1998). It may also be due to its crude protein content Edozein and Switzer (1977) reported that haemoglobin value increased with increasing dietary protein. Emetial *et al*. (2004) observed that poor nutrient utilization might result in variation in Hb value. It appeared also that the quality of sorghum protein was not high enough to elicit elevated Hb despite the high quality.

The inclusion levels shows no significant ($p>0.05$) difference for mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC) and red blood cells. This may be an indication that the sorghum varieties can be incorporated in the diet of broiler without adverse effect on haematological parameter.The value of white blood cell for the experimental birds recorded in this study ranges from $9.20x10^9/l$-$5.58x10^9/l$. This was in accordance to the normal range (6.95-18.65x106/mm) reported for a healthy chicken by Kempest (2010).The values obtained in this study disagreed with the report of Adyemo and Longe (2007) who reported a lower value of 35-54% for birds fed cotton seed cake from 0-8weeks of age.

The high values for lymphocytes and neutrophils suggest the resistance of the birds to disease conditions, for example high lymphocyte value would be observed in viral and bacterial infection as high neutrophil values would be recorded in parasite infection Therefore the 100% replacement of maize with the sorghum varieties in the diets of broiler did not influence their physiological and pathological status adversely.

4.2.5.4. Interaction effect of sorghum varieties and inclusion levels on the haematological parameters of broiler chickens

The interaction effect shows significant ($p<0.05$) difference in hemoglobin, packed cell volume. The highest value for haemoglobin and PCV was obtained in birds fed 100% ICSV400 this may be due to the low anti nutrition content of the sorghum varieties. Since haemoglobin are known to be positively correlated to protein quality and protein level (Krirchgesserier et al., 1977). The reduction in the haemoglobin and PCV values of the birds fed 50% *kaura*, 50% *ICSV400* and 100% *farfara* may be an indication of low protein level. However, the haemoglobin and PCV values obtained in this study were within the ranges that can be considered as normal physiologically acceptable levels (Ewuola *et al.,* 2004).

All the blood indices measured showed that the sorghum varieties at both 50 and 100% levels of inclusion were able to support normal broiler growth. The PVC and Hb values recorded in this were within the normal levels for healthy broilers as reported by Ewuola *et al.* (2004). Babatunde and Pond (1987) have established that packed cell volume and heamoglobin were directly related to the nutritional balance of the diet fed to the animal.

4.2.5.5. Main effect of sorghum varieties and inclusion level on blood Biochemical parameters of broiler chickens

No significant ($p<0.05$) difference was observed for total protein (TP) in this study for the main effect of sorghum varieties and inclusion levels. However, The values obtained for total protein was lower than the range of (5.00-7.00g/dl) and 8.32 to 8.70g/dl reported by Anon (1980) and Njidda *et al.,* (2010), but in agreement with values 4.55 to 6.46 g/dl reported by Udoiyoung *et al.* (2000). This observation showed that the protein levels in the diets were sufficient to sustain the normal protein level in blood. The albumin values obtained in this study were in agreement with the value (23-29g/dl) reported by kwari *et al.,* (2014).

Birds on *ICSV400* based diet had the highest value for globulin which was stastically (P<0.05) similar to birds on *farfara.* However*,* birds fed maize based diets and *Farfara* also recorded the lowest value for albumin:globulin. The higher level of globulin and the lower albumin:globulin is an indication of better disease resistance and immune response (El-kardawy, 1995). No significant (p>0.05) difference was observed for Alanine amino transferase (ALT) in birds fed the experimental diets. Positive correlation between Alanine amino transferase and growth performance, protein quality and quantity of the diet was reported by Balogun (1982). Hence the insignificant difference recorded in the birds' performance among the sorghum varieties and inclusion levels.

Alkaline phosphates which is an enzyme associated with liver, kidney and intestinal damage did not show any significant (P>0.05) difference among birds fed different sorghum varieties based diets. The values obtained in this study were within the range for healthy birds as reported (RIZVI and Shakoori, 2000). Aspartate Amino transferase (AST) varies among the birds fed differnt sorghum varieties based diets. The relative higher values recorded in *Farfara* and red sorghum though not significant (P>0.05) may be due to the relatively high tannin content when compared to the other varieties. Since elevated AST value is an indication of liver or muscle damage. However the value obtained in this study was lower than 230 IU/L considered abnormal as reported by (Rizvi and Shakoo, 2000). Total Biluribin is produced by the breakdown of aged red blood cells in the body, it is normally excreted from the body, but when the liver is diseased the level of bilirubin in the blood increases (Horigone *et al.,* 1988). Total bilirubin was high in the maize based diet this may be due to the high oxalate content or low mineral content since, mineral are known to improve the immune system of the birds.

The Cholesterol level recorded in this study (4.68-5.63) was slightly higher than the normal range of (3.23-5.17mmol/L) for birds as reported by Patra *et al.,* (2010. The higher level of Cholesterol recorded in the control group could be due to higher feed intake. No significant ($p>0.05$) difference was observed in the glucose level across the treatment means. The calcium values recorded in this was in agreement with the findings of Clement *et al.* (2010) who reported calcium in the range of 2.20-2.30mmoL/L. The values of phosphorus recorded in this study were higher than the values (0.85-1.10mmoL/L) reported by Clement *et al.* (2010)

Inclusion levels showed no significant ($p>0.0$) difference in all the parameters measured. Aletor and Egberongbe (1992) opined that serum protein and glucose are most consistently affected by diet fed to the animal. This indicates that the four sorghum varieties can totally replace maize in the diets of broiler chickens without adverse effect on health status of the birds. The values for serum biochemistry did not showed any advantage of maize over the sorghum grains it was concluded that the four sorghum varieties used in this study can be used to replace maize without adverse effect on serum biochemistry.

4.2.5.6. Interaction effect of sorghum varieties and inclusion levels on the blood biochemical parameters of broiler chicken

Birds fed the sorghum varieties at 50% level had higher value for total protein when compared to the birds on 100% level of inclusion. However, birds fed maize based diets had the highest value for total protein (5.67g/dl). This suggest that the birds fed maize based diet was lower in protein content followed by the sorghum varieties at 50% level of inclusion as reported by Egbunike *et al.*(2009). Blood albumin values indicated significant difference among the different dietary treatments .This could be the reason why they have comparable total protein content among the different groups. This observation agreed with the observation of Anon, (1980) and Allison (1955) who reported changes in protein reserve in animal as indicated by serum total protein to be associated with alteration in the albumin. Blood cholesterol showed no significant difference among the dietary treatments in blood cholesterol was expected because of the comparable dry matter intake of the different diets. The diets contained similar crude fat levels which may invariably lead to comparable dietary fat intake.

Alkaline phosphate which is an enzyme associated with liver, kidney and intestinal damage increases with an increased in level of inclusion among birds fed different sorghum varieties based diets this may be due to the antinutritional content of the sorghum varieties except in birds fed red sorghum which may be due to the higher mineral content of the sorghum variety. The values obtained in this study were within the range for healthy birds as reported (Rizvi and Shakoori, 2000).

The Glucose level varies among the treatment groups, the control group recorded the highest value. The reduced blood glucose concentration in 50% and 100% level of inclusion could be attributed to the lower feed intake and or lower activities of enzymes involved in carbohydrate catabolism. (Soliman *et al*., 2008; Zhao *et al.,* 2010). However, the values recorded were still within the normal physiological ranges, revealing that the health status of birds may not be compromised as observed in this study. Blood calcium values revealed no significant difference among the dietary treatments. The blood calcium levels are the most important factors in the formation and maintenance of the bones. Minerals are known to be part of hormones and as activators of enzymes (NRC, 1999). The values recorded in this study were similar to those recorded by Clement *et al.* (2010)

4.2.5.7. Main effect of sorghum varieties and inclusion level on Carcass Characteristics of broiler chicken

Birds fed red sorghum had higher live weights and carcass weights compared to those on other diets. This conforms to the reports of Davis *et al.* (2003) and Medugu *et al*. (2010) that sorghum can be well-utilized to produce broiler chickens with superior carcass quality compared to maize and millet based diets. There were no variations in dressing percent across dietary treatments. The non-significant difference observed in drumstick and breast muscle agreed with the finding of kwari *et al.* (2011) who reported similarities in the values of breast muscle and drumstick for birds fed low tannin sorghum based diets. The non-significantly (P>0.05) difference observed in breast indicate that the tannin present in the diet did not exert any effect on the availability of methianine and cysteine as the breast yields is influenced by the methionine and cysteine level in diet (williams, 1997).

The sorghum varieties showed significant (p<0.05) effect on the abdominal fat. Birds fed *ICSV400* had the highest value this was in contrast with the finding of Mohammed *et al*. (2013) when they substituted yellow maize for sorghum in broiler diets. But in contrast to the finding of Daghir *et al.* (2003) who substituted yellow maize for sorghum on broiler diets. However, in contrast to the finding of Daghir *et al*. (2003) and this may be attributed to the inclusion of high oil maize being used in their study. The similarities observed between maize and the other sorghum cultivar for carcass characteristics in this experiment was in line with the reports of Issa *et al.* (2007) and Medugu *et al.* (2010) who observed no differences (P>0.05) in carcass yield of broiler fed sorghum compared with maize.

Similar pattern of carcass traits has also been reported in Japanese quail fed diets based on sorghum and yellow corn (Ragab *et al.,* 2002). The result of carcass obtained in this study were similar to the findings of Rama Rae *et al.* (2002); Tyagi *et al*. (2003) and Sannamani (2002) who reported that feeding of sorghum in place of maize did not affect eviscerated yield. From the result of this study broiler fed 100% sorghum recorded the highest value for breast weight followed by 50% level of inclusion, while the control had the least value though not statistically (P>0.05) different. This indicates that the four sorghum varieties used in this study can be well-utilized to produce broiler chickens with superior carcass quality compared to maize.

4.2.5.8. Interaction effect of sorghum varieties and inclusion level on Carcass Characteristics of broiler chicken

The interaction effect of the sorghum varieties and inclusion levels showed significant (p>0.05) effect in live weight, dressing percentage, breast and abdominal fat. However, Carcass yield across the treatment groups were all within the range reported in literature (Jourdian, 1980; Olayem and Roberts, 2000; Jadhaw and Siddiqui, 2010). The higher value for abdominal fat in 50 and 100% level of inclusion may be due to the slightly high either extract recorded in the sorghum varieties. This is in accordance to the report of Moran (1980) who reported an increase in abdominal fat content of broiler with increase fat content of the diets but contrary to the report of Sibir *et al.* (1999) who observed a decreased in abdominal fat of growing rabbits with increase in the dietary replacement of un- processed sorghum.

The breast and abdominal fat components of finisher broiler are very important in assessing carcass quality. Broiler with better develop breast meat are considered superior while heavy deposit of abdominal fat in finisher broiler indicates poor finishing (Salam and Borrman, 1999). Birds fed 100% *Farfara* and 100% red sorghum had the highest breast weight this indicate that the *Farfara* and red sorghum varieties can totally replace maize in broiler diets with superior carcass quality.

4.2.5.9. Main effect of sorghum varieties and inclusion level on organs weight of broiler chickens

The values obtained for the internal offal such as the gizzard, heart, kidney and intestinal length were significantly (p>0.05) affected by dietary treatment, indicating that there were variations among these organs. The liver detoxifies toxic substances while the spleen removes the waste materials from the blood for excretion by the liver (Akinmutimi, 2004). The expectation was that the birds fed red sorghum variety will record the higher value for liver since it had higher value for most of the anti-nutritional factors tested but in contrary the bird fed maize based diet recorded the higher value the reason for this is not known. But this indicate that the higher value recorded in the control group may not be related to the diet. The higher gizzard weight value (3.06%) observed in birds fed the control diet could be linked to the slightly higher feed intake. The higher value recorded in the 50% and 100% sorghum inclusion level compared to the control group for heart, ceacum, intestinal length and intestinal weight may be due to the effect of the tannin, present in the sorghum varieties. Heavier weight of organs could be an indication of hyper trophy (Korong *et al.,* pond, 1989).

The weights of the intestine were significantly affected by the maize and sorghum varieties. This finding agreed with the report of Rama Rao *et al*. (2002). The high intestinal weight recorded in birds fed maize based diet may be due to high feed intake could also be as a result of slightly high level of fibre found in maize based diets. This is in consonance with the plethora of reports that fibre content of diets is related to length of intestine and also the longer the small intestine, the larger the area available for nutrient absorption to the animal, hence better utilization is ensured. These observations may support the assertions of Montagne *et al.* (2003) who indicated that some fibre sources when used in adequate quantities may enhance intestinal development and hence, some productivity indicators. Praes *et al*. (2011) in an interactive study between varying protein and dietary fibre levels concluded that diet with no fibre addition encouraged the best intestinal development parameter results in the duodenum; while in the jejunum and ileum, diets with the addition of fiber resulted in better intestinal development. The inclusion level shows a decrease in liver, kidney and intestinal weight with an increase in the level of inclusion this indicate that the trypsin inhibitor present in the sorghum varieties did not result in structural alteration of the kidney, liver and intestinal weight.

4.2.5.10. Interaction effect of sorghum varieties and inclusion level on organs weight of broiler chickens

The interaction effect showed significant ($p<0.05$) effect in all the organs weight measured except lung, liver and heart. The liver detoxifies toxic substances while the spleen removes the waste materials from the blood for excretion by the liver (Akinmutimi, 2004), the insignificant difference observed in the treatment groups indicates that the anti nutritional factors present in the diets did not adversely affect the health status of the birds. The higher value for gizzard weight was obtained in Birds fed maize based diet this may be due to the high fed intake recorded in this group. Birds fed 50% *Farfara* had the highest value for spleen which was comparable to those on 100% *Kaura* and red sorghum this may be due to the high tannin and trypsin inhibitor recorded in this sorghum varieties.

Birds fed maize based diet had the highest value for intestinal weight and intestinal length this may be due to the high feed intake in this group. It could also be as a result of slightly high level of fibre found in maize based diets.In any case, it was observed that the values of all the parameters investigated were within the values reported for healthy poultry birds of similar age (Makinde *et al*., 2014; Olomu, 2011; Oluyemi and Roberts, 2000).

4.2.5.11. Main effect of sorghum varieties and level of inclusion on Nutrient Digestibility of Broilers chicken

There were significant difference ($p<0.05$) in all the parameters analyzed across treatments except for dry matter for varietal effect, inclusion levels showed significant ($p<0.05$) difference in crude fibre. Red sorghum recorded the list value for crude protein, ether extract, ash, digestibility may be due to the high anti-nutrition content of the sorghum variety. It may also be due to test weight, endosperm type and texture, low starch digestibility due to the resistance to digestive enzymes by the hard peripheral endosperm layer as reported by (Wu *et al*., 2008), low protein digestion due to the α-kafirin content of the sorghum grain as reported by Elkin *et al.* (1996) to have negative correlation with the mean essential amino acid digestibility and TMEn.

However, reduction in protein digestibility cannot be explained clearly because it is still difficult to say whether it is due to reduced digestibility of dietary protein or to an increased secretion of endogenous protein due to tannin-endogenous enzyme complexes (Horigome *et al.,* 1988) or mucosal hyper secretion of gut Mitjavilla *et al*. (1977) or both. The relatively low digestibility of metabolizable energy in red sorghum and

Farfara may also be due to the chemical nature of the starch, particularly amylose and amylopectin content. The starch digestibility was reported to be higher in low amylase (waxy) sorghum than in normal sorghum, maize and pearl millet grains (Hibberd *et al.,* 1982).

4.2.5.12 Interaction effect of sorghum varieties and level of inclusion on Nutrient Digestibility of Broilers chicken

The interaction effect of the sorghum varieties and inclusion level showed significant ($p<0.05$) effect in all the parameter measured except nitrogen free extract. Nutrients digestibility obtained in this study was higher than those reported by Nyamambi *et al.* (2007).The crude fiber and fat digestibility were lower than those reported by Adama *et al.* (2007). Birds fed fed 100% *Farfara* this may be to the high level of tannin and trypsin inhibitors found in this sorghum variety. Liener and kakade (1980) reported that the presence of trypsin inhibitors are in part responsible for the depressions in the nutritional value of protein and tannin is also known to bind protein to form complexes which have an inhibitory effect on peptide digestion as reported by Oke (1969) and Oboh (1986).

No adverse effect on the digestibility of ether extract was observed. Lipase is known to play a pivotal role in the digestibility of fat contents of ingredients. An increased activity of lipase in the intestinal contents of rats due to dietary inclusion of tannins has been reported by Horigome *et al.* (1988). These results indicate that tannins have less affinity for lipase. Therefore, it is possible that presence of sorghum tannins in the gut did not adversely affect the activity of lipase and subsequently no adverse effect on the digestibility of ether extract. Observed significant ($p<0.05$) difference in digestibility of all nutrients due to differences in dietary composition was attested to by the reports of several researchers (Alu, 2012) who fed main energy diets in broilers.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. SUMMARY

An experiment was conducted to evaluate the effect of replacing maize with different sorghum varieties (*Farfara, ICSV400*, *Kaura* and red sorghum on the performance of broiled chickens

The proximate and nutritional evaluation of the sorghum varieties in this study showed that the sorghum varieties has high crude protein content ranging from (10.078-11.53%) compared to maize which has (9.24%). The metabizable energy value recorded in the sorghum varieties are (3280.62, 3474.71, 3348.80 and 3281.22kcal/kg) which was relatively comparable to the value obtained for maize (3466.29kgcal/kg). This is an indication that the sorghum varieties could be a potential source of energy for poultry and other livestock

Most of the anti nutrients recorded in this study showed that the sorghum varieties are relatively low in the anti-nutritional contents, the tannin content of the sorghum varieties ranges from (0.09-0.13100mg/g) the tannin content of the sorghum varieties indicated that the sorghum varieties used in this study are low in tannin and may not have detrimental effect on the bird if incorporated in poultry diets.

Biological studies

Experiment I: The experiment was conducted to determine the replacement value of some sorghum varieties on the performance of broiler starter (0-4wks). There were significant ($p<0.05$) differences in final body weight and mortality for varietal effect. Inclusion levels (50 and 100%) had no significant ($p>0.05$) effect on performance characteristics.

Birds fed *Farfara* and *ICSV400* had significantly ($p<0.05$) the highest values for final body weight (534.50 and 524.75g) compared to birds fed other diets. The interaction effect showed significant ($p<0.05$) difference in feed cost per kilogram gain and mortality. Birds fed the sorghum varieties at both 50 and 100% level of inclusion where cheaper than those fed maize based diets. This indicates that the sorghum varieties can replace maize in broiler chickens diets without adverse effect on performance with a least cost.

Experiment II: the experiment was conducted to evaluate the replacement value of some sorghum varieties on the performance of broiler finisher (5-8wks). There were significant ($p<0.05$) differences in final body weight, feed cost per grain, feed conversion ratio and mortality for varietal effect. Inclusion levels (50 and 100%) had no significant ($P<0.05$) effect on the performance characteristics. Birds fed red sorghum had significantly ($p<0.05$) the highest values for final body weight (2387.63g) higher feed efficiency (1.76) than those fed other dietary treatments and was cheaper (₦201.86).

The interaction effect showed significant ($P<0.05$) effect on final body weight, total weight gain and feed cost per kilogram grain. The result of this study showed that low tannin variety sorghum, can replace maize without altering growth performance.

Effect of some sorghum varieties on haematological parameters of broilers chickens (5-8wks) No significant (p,0.05) difference was observed in the haematological parameters for both varietal and inclusion levels effects. The interaction effect showed significant ($p<0.05$) difference in haemoglobin and PCV. However, the haemoglobin and the PCV values obtained in the study were with the range that can be considered as normal physiological acceptable level.

Effect of some sorghum varieties on serum biochemistry of broiler chickens (5-8wks) the main effect of sorghum varieties and inclusion levels showed significant ($p<0.05$) effect on albumin, globulin, globulin, creatinine, and bilirubin. The interaction effect showed significant ($p<0.05$) effect all the parameter measured expect cholesterol, calcium and phosphorus. However, the values for serum biochemistry did not showed advantage of maize over the sorghum on grains this indicate that the sorghum varieties can replace maize without adverse effect ion serum biochemistry.

Effect of some sorghum varieties on carcass characteristics of broilers chickens (5-8wks) Variety influences live weight, thigh, neck, abdominal fat, wing and back inclusion level had no significant ($p>0.05$) effect on carcass characteristics. The interaction effect showed significant ($p<0.05$) difference in live weight, dressing percentage, breast weight and abdominal fat. Birds fed 100% f*arfara* and red sorghum recorded the highest values for breast weight (21.38 and 21.36%, respectively). This indicates that *farfara* and red sorghum varieties can total replace maize in broiler diets with superior carcass quality.

Effect of some sorghum varieties on organ weight of broilers chickens (5-8wks)

A significant ($p<0.05$) difference was observed in all the organ weight (liver, kidney, lungs, gizzard, heart, spleen and intestinal length) except in intestinal weight for varietal effect inclusion levels had significant ($p<0.05$) effect for liver, kidney and intestinal weight. The interaction effect showed significant (<0.05) effect in all the parameters measured except liver, lungs and heart. However, the values obtained for all the parameters investigated were within the value reported for healthy poultry bird of similar age.

Effect of some sorghum varieties on carcass characteristics of broilers chickens (5-8wks) There were significant ($p<0.05$) difference in all the parameters analyze across treatment except for dry matter for varietal effect inclusion levels showed better fibre digestibility at 50% level of inclusion (67.3%). The interaction effect showed lower digestibility for bird's feed red sorghum on the average compared to birds fed other diets except for ether extract digestibility (92.20%)

5.2. CONCLUSION

From this study, the following conclusions are drawn:

That there exists positive and practical merits for the replacement of maize with the sorghum varieties at 50 and 100 % inclusion levels in the nutrition of broiler birds as evidenced by the comparable to superior performance of birds fed diets containing sorghum varieties for growth, haematological, biochemical and carcass traits. Inclusion levels at 50 and 100 % also revealed synergistic effect for most studied traits at both phase.

The feeding of sorghum varieties at different inclusion levels (50 and 100) had no adverse effect on health status of the broiler chickens.

*ICSV*400 at 100% for starter phase to reduced cost of production and improve their productivity.

Red sorghum at 50% inclusion level at finisher phase to reduced cost of production and improves their productivity.

5.3. RECOMMENDATIONS

1. The four sorghum varieties used in this study can be used to total replace maize in the diets of broiler chicken
2. *ICSV400* at 100% for starter phase is recommended as the best factor combination for broiler nutrition for growth performance.
3. Red sorghum at 50% inclusion at finisher phase is recommended as the best factor combination for broiler nutrition for growth performance.

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