**EVALUATION OF SORGHUM SK-5912 VARIETY (*Sorghum bicolor* L. Moench) AS DIETARY ENERGY SOURCE FOR BROILER CHICKENS**

**AUDU, OBED LAKURBE**

**APRIL, 2018**

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**BY**

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**PGS/14-15/3/P/1730**

**A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES ABUBAKAR TAFAWA BALEWA UNIVERSITY, BAUCHI IN PARTIAL FULLFILMENT OF REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D.) IN ANIMAL SCIENCE**

**DEPARTMENT OF ANIMAL PRODUCTION**

**FACULTY OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY**

**APRIL, 2018**

# DECLARATION

I hereby declare that this dissertation was written by me and it is a record of my own research work. It has not been presented before in any previous application for a higher degree. References made to published literature have been duly acknowledged.

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Student

The above declaration is confirmed.

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Prof. U. D. Doma

Chairman, Supervisory Committee

# CERTIFICATION

This dissertation entitled **“Evaluation of Sorghum SK-5912 Variety (*Sorghum bicolor* L. Moench) as Dietary Energy Source for Broiler Chickens”** meets the regulations governing the award of the degree of Doctor of Philosophy in Animal Science of Abubakar Tafawa Balewa University, Bauchi and is approved for its contribution to knowledge and literary presentation.

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# DEDICATION

This dissertation is dedicated to my wife Mrs. Mary Obed and mother Mama Mwalan Audu.

# ACKNOLEDGEMENTS

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# ABSTRACT

Four experiments were conducted to evaluate the effect of different levels of sorghum *SK-5912* as replacement for maize, white sorghum and pearl millet as dietary energy sources on the performance, blood components, carcass characteristics and cost benefits of broiler chickens. In the four experiments, 300 broilers chicks ‘*Marshal*’ were randomly allotted to five dietary treatments in a completely randomized design in which *SK-5912* replaced maize, white sorghum and pearl millet at 0, 25, 50, 75 and 100%, while in experiment 2, *SK-5912* was utilized with different plant protein sources. In experiment 1, results showed non-significance among the diets in all phases. Blood parameters and carcass characteristics were similar. The feed cost per kg gain was cheaper on *SK-5912* based diets. In experiment 2, at the starter phase DFI (43.49-51.17g; P<0.01), DWG (20.48-24.78g; P< 0.001) and FCR (1.90-2.23; P< 0.05) were affected. However, in both finisher and overall phases DFI, DWG and FCR were mostly not influenced by the dietary treatments, except in the overall phase that DFI (78.95-83.30g; P<0.01) differ. Blood components and carcass characteristics were also not influenced, and *SK-5912* based diets were cheaper. In experiment 3, at the starter, finisher and overall phases, DFI, DWG and FCR were mostly not affected. Although, FCR (1.75-1.99; P<0.05) differ at the starter phase. Most of the blood parameters and carcass characteristics were not affected by the levels of *SK-5912* except the total cholesterol (3.68-5.85mmol/L; P<0.01) and LDL (1.55-2.30mmol/L; P<0.05) that were affected, *SK-5912* based diets were better. Feed cost ₦ per kg gain was lower on treatment diets. In experiment 4, results showed non-significance at all the phases. Most of the blood components and carcass characteristics were not affected by the *SK-5912*, except small intestine length (151.88-194.63cm) (P<0.01), caecal weight (0.42-0.72%; P<0.01) and MCH (42.65-45.58pg; P<0.01) that were affected. Financial benefit was better on *SK-5912* based diets. It can be concluded that sorghum *SK-5912* can replace maize, white sorghum and pearl millet and be mixed with different plant protein sources in broiler diets without adverse effect on performance and reduction in feed cost.

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# CHAPTER ONE

## 1.0 INTRODUCTION

## 1.1 Background Information

Poultry plays a significant role in the provision of animal protein required by man to meet his daily protein intake. Also, capital invested in poultry business can be quickly returned, because birds are highly prolific, have efficient feed utilization and they are not discriminated against both religiously and nutritionally. According to Faniyi (2009), about two million Nigerians depend directly or indirectly on poultry production as source of income. Okonkwo and Akubuo (2001) also pointed out that about 10% of the Nigerian population is engaged in poultry production, mostly on subsistence and small or medium scale farms. The industry has assumed greater importance in improving employment opportunity and animal food production in Nigeria (Adebayo and Adeola, 2005).

The poultry industry has suffered more than any other livestock industry as a result of inadequate supply and cost of feed (Leplaideur, 2004), and feed cost is expected to continue in the upward swing (Conolly, 2012). Cereal grains constitute the major sources of energy in poultry diets in the tropics (Oluyemi and Roberts, 2013). However, maize has remained the chief energy source in compounded diets and constitutes about 50% of poultry ration (Ajaja *et al.*, 2002). It is sometimes very expensive, limited in supply and hence scarce. More so, other cereal grains used as dietary energy sources for poultry such as sorghum and pearl millet are highly competed for by animals and humans as food, especially in the drier areas of the country.

Sorghum (*Sorghum bicolor* L. Moench) is widely grown in the semi-arid and savannah regions of Nigeria. According to International Crop Research Institute for the Semi Arid tropics (ICRISAT, 2000), Nigeria was ranked the third largest producer of sorghum in the world with about six million tonnes of grains produced from 5.7 million hectares of land. Some improved varieties of sorghum have been developed by the ICRISAT and the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria, Nigeria. These are the yellow coloured Sorghum SK-5912 and the cream coloured ICSV 400 varieties. The industrial success in the use of sorghum and sorghum malt for brewing lager has contributed in raising the commercial production of this Nigerian sorghum variety SK-5912 and two other released ICRISAT-bred varieties ICRV 400 and ICSV III, (ICRISAT, 2003). Some of the most commonly cultivated sorghum varieties in Nigeria include; KSV3, SK5912, KSV8 and ICSV400 (AATF, 2011).

The sorghum SK-5912 is yellow in colour, high yielding, drought resistant, tolerant to striga and has relatively low tannin content, but it was found to be unsatisfactory by farmers as food. The variety had poor taste when prepared as Tuwo, the traditional stiff porridge, unacceptable black colour and poor overnight keeping quality, (ICRISAT, 2003). Sorghum SK-5912 variety was well tolerated by the experimental grower turkey and much variation was not observed on their haematological and serum biochemical parameters from the normal ranges (Etuk *et al*., 2015).The utilization of this improved variety will improve the poultry feed supply system at affordable cost.

## 1.2 Statement of the Problem

Poultry industry in Nigeria occupies a prominent position as a major source of animal protein supply to the citizen. Over the years, the growth of poultry industry has followed a pattern closely dictated by the economic fortunes of the countries. USDA (2013) reported that commercial poultry production in Nigeria was estimated at about USD 800 million. With the current increase in the population to about 194 million and the economic recession, more than 50% of the country’s poultry farms have closed down and another 30% forced to reduce their production capacity because of shortage of feed due to high cost of the conventional sources of ingredients which account for 60-70% of total cost of poultry production (Rafiu *et al,* 2014). Maize which forms the major energy source for poultry in Nigeria is becoming scarce and expensive because of direct competition with man, and the decline in its production due to unfavourable climate (Kwari *et* *al*., 2011b). This calls for urgent search for alternative energy sources for poultry feeds that are readily available, easy to cultivate despite the effect of climate change and have comparative nutritive values. More so, the pressure on maize and recently sorghum and pearl millet has been on the increase worldwide. These trend require serious diversification of energy feedstuff for poultry ( Etuk *et al*., 2012).

## 1.3 Justification of the Study

The possible alternative to maize in Nigeria is sorghum and millet which are readily available in the Northern part of the country where the effects of climate change such as desertification and drought is currently been experienced thereby forcing farmers to shift to the cultivation of crops that are drought resistant with high yield. Despite the fact that sorghum and millet also provide the birds with comparable energy level, but together with maize are highly competed for by animals and humans as food especially in the drier areas of the country. Therefore, the need for alternative energy sources that are available with relatively lower cost and low human demand require urgent attention to maximize poultry production. To combat this challenge, alternative ingredient resources were considered. One of such important alternative is sorghum SK-5912 variety also known as SAMSORG 17.

Sorghum SK-5912 variety was used in a trial, and the result showed that it can conveniently replace maize in turkey diets (Etuk *et al*., 2015). Although, there is paucity of information on its utilization in chickens rations, but its low tannin content coupled with low cost due to low human demand and availability has shown that the variety could be a suitable energy feedstuff for poultry.

## 1.4 Aim and Objectives of the Study

The specific objectives of this study were to evaluate:

1. The productive performance of broiler chickens fed Sorghum SK-5912 variety as a dietary energy source;
2. The haematological and serum biochemical parameters of broiler chickens fed sorghum SK-5912 variety in diets;
3. The carcass yield and gut characteristics of broiler chickens fed sorghum SK-5912 variety as a dietary energy source; and
4. The cost benefits of feeding sorghum SK-5912 variety as an energy source in the diets of broiler chickens.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

## 2.1 Poultry Population

The term poultry refers to all forms of domesticated birds such as the chickens, turkey, ducks, guinea fowls, pigeons, geese, quails, ostriches, peafowls, etc. (Ikani, 2001; Olomu, 2011). Rogers (1992) reported that, livestock population in Nigeria include cattle (13.9 million) Sheep (22.1 million) and goats (34.5 million) while poultry (214.3 million) consists of 82.4 million chickens and others like guinea fowl, turkey, ducks etc were 131.9 million. Similarly, Presidential committee on livestock and Dairy Development (2001) reported that Nigeria has estimated Livestock Population figures of: cattle (15.6 million) Sheep (28.6 million) goats (45.26 million) Pigs (5.2 million) and Poultry (118.5 million) while horses, camels and donkeys constituted 1 million.

According to *Avian Specialities Ltd.* (2011) the total poultry population in Nigeria is estimated at 133 million, consisting of about 123 million local chickens and 10 million exotic breeds. Poultry comes fourth among the major sources of animal protein for human consumption in Nigeria. It contributes about 10% of the total national meat production. Poultry are the most numerous animals in Nigeria and are the most commonly owned animals in households (Rogers, 1992; Adegbola, 1999; Presidential committee, 2001 and Avian Specialities Ltd., 2011).

## 2.2 Sorghum (Sorghum bicolor L. Moench)

Sorghum (*Sorghum bicolor* (L) Moench) which belongs to the tribe Andropogonae (FAO, 1995) and family graminea is known as guinea corn in West Africa and locally called Okababa, Dawa, and Okili in three major languages of Nigeria ( Adegbola, 2013). Sorghum originated from northeastern Africa where it was domesticated about 5,000 years ago (Mann *et al,* 1983) and it is the fifth most important cereal in the world after corn, rice, wheat, and barley with an annual production of about 57 million tonnes (FAOstat, 2012). It is considered as source of diet to over 500 million people in about 30 countries (Reddy *et al*., 2010; Dahlberg *et al*., 2011). In 2012, about 57 million tonnes was produced all over the world (FAOstat, 2012; Rao *et al*., 2005) and Africa accounts for 23.35 million tonnes. In West Africa alone about 12.3 million tonnes was produced in 2012 and Nigeria being the largest producer of the crop accounts for 6.9 million tonnes (FOAstat, 2012) worth about 990 million dollar. This makes the crop the largest staple cereal crop in Nigeria (NAERLS, 1996) and out of the total production only 120,000 tonnes are utilized by industries in the country (Murty et al., 1996). Bulk of the Sorghum produced in Nigeria is produced in Kaduna, Kano, Jigawa, Katsina, Borno, Plateau, Niger, Zamfara, Yobe, Kebbi, Bauchi, Adamawa and Gombe (Aba *et al.,* 2005; NAERLS, 2007) and thus one of the most important crops in the Savannah zones of the country (Onwueme and Sinha,1991). Some of the most commonly cultivated sorghum varieties in Nigeria include; KSV3, SK5912, KSV8 and ICSV400 (AATF, 2011).

### *2.2.1 Sorghum Nutrition*

Sorghum grain has 95 to 98% of the nutritional value of maize; vitamin content for corn and sorghum is similar but sorghum has a higher mineral content than maize (Balota, 2012). Sorghum grain has a lot of nutritional benefits due to its rich antioxidant properties (Green, 2012). It is higher in protein (11.5 to 16.5%) and calories than several other grains. One cup serving (100 g) of sorghum contain 143 g of carbohydrate and 326 calories most of which comes from carbohydrate, 12 g of dietary fibre, and would provide 47% of the recommended daily value for iron based on a 2,000 calorie intake (Green, 2012). 100 g (one cup serving) of sorghum contains 325 calories and has 10.8 mg of protein, 0 mg of sugar, 3.1 mg of fat, 6.0 mg of fibre and 0 mg of cholesterol. Sorghum contains the following vitamins and minerals: vitamins B1, B2 and B3, calcium (Ca), potassium (K), iron (Fe), phosphorous (P), and sodium (Na). 100 g (one cup serving) would provide 55% Recommended Dietary Allowance (RDA) of phosphorus, 19% RDA of potassium, 47% RDA of iron, 5.4% RDA of calcium and 0.5% RDA of sodium. Tables 1 – 6 provide in-depth explanations of the many positive attributes of sorghum and its products.

Although, the grain is low in sodium, it has a large amount of iron and a 100 g serving would meet over 50% of the recommended intake of iron for men and 24% for women; this is more iron than that in equal amount of brown rice (Olomu, 2011). Protein is one of the major components of sorghum; the primary function of dietary protein is to satisfy the body’s need for nitrogen and essential amino acid (FAO, 1995). The average starch content of sorghum is 69.5% (Jambunathan and Subramanian, 1988), and the crude fat content is 3% which is higher than wheat and rice (FAO, 1995). It contains no cholesterol, and like all other grains, has a fairly good amount of carbohydrates that could meet a good deal of recommended daily intake (Thompson, 2010).

Sorghum strengthens the immune system, helps in the elimination of toxic waste from the body, increases endurance, assists in blood cell building, boost appetite, relieves diarrhoea, aids rapid recovery, stimulates cardio-vascular system, stimulates free flow of blood, and lowers cholesterol levels. Sorghum consumption reduces the risk of certain types of cancer in humans (Gomez-Cordoves *et al*., 2001; Yang *et al*., 2009). The tannin content of sorghum especially, the brown grain could make it difficult for the human body to absorb other nutrients (Awika and Roonney, 2004), and this makes sorghum the grain of choice for those battling obesity.

In addition, sorghum helps to manage cholesterol; grain sorghum could be used as food ingredients or dietary supplement to control cholesterol levels in humans (Carr *et al*., 2005), and the bran of the grain may also help protect against diabetes and insulin resistance (Farrar *et al*., 2008). Sorghum is deficient in lysine, threonine and tryptophan, and the presence of some anti-nutritional factors such as tannins and phytate that interact with proteins, vitamins and minerals reduces the bio-availability of the grain (Ahmed *et al.*, 1996). However, malting, fermentation, and cooking are known to improve the protein digestibility of sorghum by reducing its tannin and phytate content (Ahmed *et al*., 1996).

### *2.2.2 Sorghum Composition*

The increase in the prices of maize due to competition with human diet has led to the scarcity of the commodity (Fapohunda *et al.*, 2008) and thus reducing the quantity of the commodity available for poultry feed formulation. Therefore, this necessitates the use of other energy sources such as sorghum and millet in order to reduce the cost of production (Tamburawa *et al*., 2012). The use of sorghum for human consumption is relatively low compared to maize (Olomu, 2011) because of enhanced socio-economic status of people in general and easy availability of other much preferred cereals at affordable price (Sheorain *et al*., 2000). Thus, sorghum is considered as a good alternative source of energy in livestock feeding (Olomu, 2011). Sorghum contains about 10.4 % crude proteins, 3.4 % Ether Extract, 2.5 % Crude Fibre, and 3264.02 kcal/kg metabolizable energy (Tamburawa *et al.*, 2012) as shown in Table 1. Proximate analysis conducted by Khan and Eggum (1978) reported that, sorghum contains significant amount of eleven (11) essential amino acids as shown in Table 2.

Table 1: Proximate composition of sorghum

|  |  |
| --- | --- |
| **Parameters** | **Nutrient value** |
| Dry matter (%) | 96.34 |
| Moisture (%) | 3.66 |
| Crude protein (%) | 10.40 |
| Ether extract (%) | 3.40 |
| Crude fibre (%) | 2.50 |
| Ash (%) | 3.80 |
| Nitrogen free extract (%) | 75.80 |
| Metabolizable energy (kcal./kg) | 3264.02 |

Source: Tamburawa *et al.* (2012)

Table 2: Essential amino acids composition of sorghum (g/16g N)

|  |  |
| --- | --- |
| **Amino acids** | **Composition** |
| Lysine | 2.7 |
| Tryptophan | 1.0 |
| Threonine | 3.3 |
| Isoleucine | 3.6 |
| Leucine | 11.2 |
| Tryosine | 3.6 |
| Phenylalanine | 4.4 |
| Histidine | 2.2 |
| Methionine | 2.3 |
| Cystine | 2.2 |
| Valine | 4.7 |

Source: Khan and Eggum (1978)

### *2.2.3 Uses of sorghum in poultry diets*

In an experiment conducted by Medugu *et al.* (2010) it was found that there was no difference in all the weight parameters considered when broiler chickens were fed maize based, millet based, low and high tannin sorghum based diets. Several authors reported that there were no significant differences observed on the egg and meat quality of layer and broiler chickens respectively when they were fed with maize and sorghum based poultry feed as reported by Reddy and Rao (2000). The report of Usman and Garba (2012) showed that, when *Isa brown* chicken were fed a maize and sorghum based diet, there was no significant differences in the egg weight, yolk weight, albumen weight, haugh unit and shell thickness. Difference was only recorded on the shell weight.

Various combinations of between 15 to 45 percent of maize and sorghum showed that there was no significant difference in the performance of both broiler and layer chicken (Subramanian and Metta, 2000). In the layer experiment where 3:1 ratio of maize to sorghum (yellow or white), 3:1 ratio of sorghum (yellow or white) to maize, whole maize and whole sorghum was used as 45 percent of the total feed composition and source of energy showed that there was no statistical difference in the feed consumed by the birds and the percentage of egg production (Subramanian and Metta, 2000). However, in the broiler experiment conducted by Subramanian and Metta (2000) showed that there was also no difference in the weight gain, bird weight and feed efficiency ratio when the birds were fed with various combination of maize and sorghum (yellow or white). The formulated feed was constituted of 60 percent cereal as the source of energy and thus 60 % maize, 1:3 ratio white sorghum to maize, 3:1 ratio white sorghum to maize, 1:3 ratio yellow sorghum to maize and 3:1 ratio yellow sorghum to maize were used.

The report of Issa (2009) revealed that, there was no significant differences in average daily gain, average daily feed intake, and gain to feed intake ratio of broiler chicks fed with maize and sorghum (Local and Improved Sorghum Varieties) for sixty days in an experiment conducted in west Africa (Nigeria, Niger, Senegal, Mali and Burkina Faso). However, Issa (2009) reported that there was also no significant differences observed when the carcass yield, gizzard weight, liver weight and fat weight of the broiler birds were measured. In a similar experiment conducted on layers by Issa (2009), it was also reported that there was no significant differences in the live body weight, average daily feed intake, average daily gain and gain to feed intake ratio. However maize based diet had the lowest mortality percentage compared to the sorghum based diet. It also showed that more sorghum based diet was consumed by the birds when compared to maize based diet. When the percentage of the laying rate was calculated it showed that sorghum based diet had higher percentages compared to maize while all the diets with which the layer birds were fed had the same egg weight.

### *2.2.4 Anti-nutritional factors in Sorghum*

Sorghum basically contains two important anti-nutritional factors, tannin, a polyphenolic compound located in the grain (Purseglove, 1972; Ologhobo *et al*., 1993; Kumar and D’Mello, 1995) and the cyanogenic glycoside, dhurrin located mainly in the aerial shoot and sprouted seeds (Olomu, 2011; Oduguwa and Fafiolu, 2004).

Atteh (2002) reported that sorghum, especially the brown variety contains high levels of tannins and Purseglove (1972) opined that sorghum grain with testa contain tannins in varying proportion depending on variety, with certain strains containing up to 5%. It has been reported (Aning *et al.*, 1998) that polyphenols are high in sorghum with brown pericarp and no testa and very low in unpigmented grains. This characteristic has been utilised to develop sorghum varieties and hybrids to deter birds (Carter *et al.*, 1989) because they are less palatable and tenacity of some bacteria is low (Schragle and Muller, 1990). Etuk and Ukaejiofo (2007) reported 0.42% tannin content in brown coat coloured sorghum while Subramanian and Metta (2000) reported that the local Indian sorghum variety and ICSV 112 variety developed by ICRISAT and grown in India contain no tannins. 0.40% tannin was reported for SAMSORG 17, a variety previously coded (SSV) -3 (SK5912) and developed from local collections of Kaura through mutation breeding at the Institute of Agricultural Research (IAR), Samaru, Nigeria. ICSV 400, released by ICRISAT in 1996 recorded tannin value of 0.69% (IAR, 1995; NCGRB, 2004, Etuk, 2008). Red sorghum on the other hand contains about 23g/kg tannins which when reconstituted reduced to 16g/kg (Kumar *et al.*, 2007).

Drying, soaking, grinding and pelleting has been reported to reduce tannin content in feedstuffs while diet supplementation with methyl group donors like choline and methionine reduce the problems associated with tannins in livestock (Singleton and Kratzer, 1969; Atteh, 2002).Tannins reduce protein digestibility through the formation of complexes and the inhibition of activities of proteolytic enzymes in digestive secretions (Ahn *et al.*, 1989; Kumar and D’Mello, 1995; Grosjean *et al.*, 1999). The affinity of tannins for protein has been observed to increase with increase in molecular size of tannins. However tannins with extremely large molecular weight lose their affinity for protein and become insoluble (Kumar and Horigome, 1986). Proteins with high proline content impart an open structure which contains readily accessible sites for hydrogen bond formation with tannins (Hagerman, 1989). The polyphenols in brown sorghum may have a binding effect on minerals (Aning *et al.,* 1998).

Recent studies also revealed that polyphenols of the procyanidins (CT) have an antioxidant property (Corder, 2006) while tannic acid has anti-bacterial, anti-enzymatic and astringent property as well as constringing action upon mucous tissues. The ingestion of tannic acid causes constipation so it can be used to treat diarrhoea in the absence of inflammation (Phytolab, 2007).

### *2.2.5 Effects of Tannins on Poultry and Pigs*

The main anti-nutritional effects of tannins are: reduction in voluntary feed intake due to reduced palatability, diminished digestibility and utilisation of nutrients, adverse effects upon metabolism and toxicity (Kumar and D’Mello, 1995; Atteh, 2002; Ola *et al.,* 2005). These effects may be achieved via several mechanisms. Tannins exert inhibitory effect on a broad spectrum of digestive enzymes at several sites in the digestive tracts of poultry (Longstaff and McNab, 1991; Ahmed *et al.*, 1991) and piglet (Jansman *et al.*, 1993). In a study with broiler chickens, Iji *et al* (2004) reported that ideal digestibility of energy, protein, arginine and leucine were reduced as dietary tannin level rose to 20g/kg diet and beyond while methionine and phenylalanine were only negatively affected at tannin levels of 25g/kg diet. Protein efficiency ratio (PER) and net protein ratio are negatively correlated with tannic acid (Oke *et al.*, 2004). Feed conversion ratio increased with increasing level of tannin up to 15g/kg diet while pancreatic and jejenal enzymes activities were not affected. This suggests that a wider range of factors may be involved in regulating the effect of tannins on poultry (Iji *et al.*, 2004).

Kumar *et al*. (2007) showed that tannin content of 16g/kg in red sorghum had no effect on nitrogen, calcium and phosphorus retention in broiler chickens. Similarly plasma albumin, globulin, protein, glucose, calcium, phosphorus, SGOT, SGTP and uric acid levels were not affected even at 100% replacement of maize with red sorghum. Mild histopathological changes in liver and kidney tissues as well as high cell mediated immune – response were, however, observed when raw red sorghum containing 23g tannins/kg were fed to the same group of broiler chickens. Elkins *et al.* (1978) reported that chickens fed high tannin sorghum developed leg abnormalities. Featherstone and Rogler (1975) showed that high tannin sorghum depressed growth in rats and chicken, which resulted from reduced protein and dry matter digestibility probably caused by interference of tannins with digestive action of trypsin and α-amylase either by binding the enzymes themselves or by combining with dietary protein to form indigestible complex. In laying birds, tannins decreased the rate of lay, adversely affect efficiency of feed utilisation and increase mortality (Rostangno *et al.*, 1973; Guillaume and Belec, 1977). The level of tannins present in sorghum seems to be the predominant factor that influences its nutritional value (Vilijoen, 1998). Polyethylene glycol (PEG) when used as a dietary supplement can improve the nutritional value of high tannin feedstuff (Hewitt and Ford, 1982) while malting increases the protein, soluble sugars and reduces the tannin content of sorghum (Kubiezek *et al.*, 1984). Boiling also reduces tannin content in taro cocoyam meals from 1.78mg/100g to 0.28mg/100g which resulted in negligible effect on carcass characteristics of broilers (Abdulrashid *et al.,* 2007).

## 2.3. Nutrition

Nutrition is the science that studies the nutrients needed by animals, why these nutrients are needed, how much of these are required in healthy diets, how they can be supplied in an economical way, and how the body utilizes them for maintenance, growth, work, production and reproduction (Olomu, 2011). Thus, nutrition is concerned with the nature of food and food nutrients, the requirements of animals for these substances and utilization of these nutrients by the animals. Poultry industry essentially converts nutrients in feedstuffs in to poultry meat and eggs for human consumption, for this to be achieved efficiently and economically application of nutritional principles is essential. Chickens have much more complex need for nutrients than all higher animals, because of their faster growth rate and relatively short digestive tract. Compound animals feed is usually made up of energy, filter materials, proteins, minerals and micro ingredients (Babatunde, 1988). A ration lacking in any of these nutrients in the right quality and quantity may not promote growth rate and reproduction.

## 2.4 Nutrients Requirements of Broiler Chickens

Nutrients requirements are the amount of a given nutrients required for maximum performance by the animal. Nutrient requirements are guidelines not standard per se, because of varying circumstances such as climatic factor, composition of feedstuffs, improper processing methods and inadequate feed mixing may warrant adjustment. Nutrients levels are expressed in amount of nutrients per kilogram of air dry feed as presented in Table 3.

### *2.4.1 Energy requirements*

The requirements for energy cannot be stated as the requirements for protein, amino acids, minerals and vitamins (Olomu, 2011). It is impossible to set the energy requirements in terms of unit/kg diet because birds adjust their feed intake to achieve the daily energy intake, chicks from day old to 6 weeks are however not able to adjust feed intake to dietary energy variation and thus consume slightly more energy as the energy level tends to be lower by 8-20% in the tropics than in the temperate countries (NRC, 1994). NRC,(1994) also recommended energy requirements of 3200 kcal./kg for both starter and finisher phases. Olomu (2011), recommended slightly lower value of 2800 kcal./kg and 3000 kcal./kg for starter and finisher phases respectively. Oluyemi and Roberts (2007), similarly recommended 2800 kcal./kg for starter chicks in the tropics. Olomu (2011), also reported that birds perform equally well on 10-15% energy levels below the recommended levels. However, the demerit of feeding birds low energy diets is that the birds tend to eat more to compensate for the energy deficiency thus resulting to higher values of feed conversion ratio.

### *2.3.2 Protein requirements*

Proteins are complex organic compounds of higher molecular weight containing Carbon, Hydrogen, Oxygen and Nitrogen, most of them Sulphur and some contain Phosphorus. Proteins upon hydrolysis are broken down to their units known as amino acids. There are about 20 known amino acids that can be classified based on nutritional requirements in to two depending on whether the animals’ tissue have the ability to synthesize it provided they have a satisfactory source of Nitrogen i.e. Non-essential amino acids the ones which cannot be made in the body or cannot be made in sufficient amount to meet the body’s need i.e. Essential amino acids (Olomu, 2011). Thus, when formulating poultry rations, proteins must be able supply all the essential amino acids in ample amount and total nitrogen for the birds to synthesize the other amino acids needed.

However, the recommended protein levels decreases as the birds get older. Under normal circumstance, birds eat more as they grow older. Therefore, the total protein consumed increases as the birds gets older and increases in weight. Although, the protein consumed per unit weight either reduces or remains constant. If protein levels of the diet remain constant throughout the life of the birds, more protein than necessary may be consumed (Olomu, 2011). If birds consumed more than their protein requirements, the excess protein is oxidized for energy, since proteins cannot be stored to any appreciable extent in the body. For this reason, proteins levels in poultry diets are precisely stated. The dietary protein requirements vary depending essentially on climatic factors and the age of the animal. In the tropics, studies have shown that the protein requirements of broilers at starter and finisher phases fall within 22-24% and 19-20% (Babatunde and Fetuga, 1976). Kekeocha (1984), recommended protein levels of 23% and 20% for starter and finisher phases respectively. However, NEP (1979), recommended 24 and 21 for starter and finisher phases respectively. Ross (2002), recommended crude protein levels of 22-25%, 20-22%, 18-20 and 17-19% for 0-10, 11-28. 29-42 and 43-56 days respectively for broilers that are to be raised to approximately 3kg live weight.

Aftab *et al.,* (2006), also recommended the minimum dietary crude protein levels to be 20.70, 18.00 and 16.20 for 0-21, 21-42 and 42-56 days respectively which can be used without any adverse effect on growth performance. They further suggested the use of crystalline amino acid to reduce dietary protein requirement for each phase of broiler growth by a factor of 10%. The amino acid levels are expressed as percentage of the diets and decrease as the recommended protein levels decreases. Amino acid requirements are approximately related to protein requirements (Olomu, 2011). Amino acid can be expressed as percentage of the recommended protein level or as amount per unit of energy. For example, the lysine requirement for broilers aged 0-6 weeks is 1.20% or can be expressed as percentage of protein 24-1.20/24×100 = 5%. As amount per 100/kcal of ME = 1.20/3000×100 = 0.04kg. Similarly, other amino acids can be expressed in terms of ME, crude protein and energy. Since amino acids are closely related to the protein and ME levels lower levels of protein and energy, necessitate lower levels of amino acids in diet (Olomu, 2011).

### *2.4.3 Mineral requirements*

Minerals are inorganic elements, frequently found as salts with either inorganic elements or compounds. Their bioavailability and metabolic functions are related to the forms in which they are found. Minerals give rigidity and strength to the skeletal structure and as constituents of organic compounds such as protein and lipids, which make up the muscle, organ, blood vessels and other soft tissue of the body (Nwachukwu, 2013). Mineral are cofactor in enzyme activation, maintenance of osmotic relations and acid-base equilibrium. Dietary requirements of minerals are more difficult to accurately define than that of the organic nutrients, because of many factors that determine the utilization of minerals. For example, interrelationship among minerals or relation between minerals and organic fractions may result in enhanced or decreased mineral utilization. The actual amount of mineral in the diet may also influence utilization, for example, if the diet contains more calcium than required, the efficiency of absorption is decreased. The major mineral are calcium (Ca), phosphorus (P), sodium (Na), potassium (K), magnesium (Mg), and chlorine (Cl). Most of the Ca in the diet of the growing bird is used for bone formation, whereas in the mature laying birds most dietary Ca is used for eggs shell formation (NRC, 1994). Mineral requirements is affected by climate, warm climates requires higher minerals. Olomu (2011), recommended 4-4.5% of Ca, 1-1.1% total phosphorus, for birds reared in the tropics or 4.5% Ca and 1.1% phosphorus for laying hens especially towards the end of the laying year to improve egg shell strength and quality.

Table 3: Nutrient requirements of broiler chickens as (%) or units per kg of diet (90% DM basis)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **0-3**  **weeks** |  |  | **3-6**  **Weeks** |  |  | **6-8**  **Weeks** |  |  |
| Energy | kcal | 3200 | 3000 | 2900 | 3200 | 3000 | 2900 | 3200 | 3000 |
| Protein | % | 23.00 | 21.56 | 20.84 | 20.00 | 18.75 | 18.10 | 18.00 | 16.90 |
| Arginine | % | 1.25 | 1.17 | 1.13 | 1.10 | 1.03 | 1.00 | 1.00 | 0.94 |
| Gly+serine | % | 1.25 | 1.17 | 1.13 | 1.14 | 1.07 | 1.03 | 0.97 | 0.91 |
| Histidine | % | 0.35 | 0.33 | 0.32 | 0.32 | 0.30 | 0.29 | 0.27 | 0.25 |
| Isoleucine | % | 0.80 | 0.75 | 0.73 | 0.73 | 0.68 | 0.66 | 0.62 | 0.58 |
| Leucine | % | 1.20 | 1.13 | 1.09 | 1.09 | 1.02 | 0.99 | 0.93 | 0.87 |
| Lysine | % | 1.10 | 1.03 | 1.00 | 1.00 | 0.94 | 0.91 | 0.85 | 0.80 |
| Methionine | % | 0.50 | 0.47 | 0.45 | 0.38 | 0.36 | 0.35 | 0.32 | 0.30 |
| Methionine+Lys | % | 0.90 | 0.85 | 0.82 | 0.72 | 0.68 | 0.66 | 0.60 | 0.56 |
| Phenylalanine | % | 0.72 | 0.68 | 0.65 | 0.65 | 0.61 | 0.59 | 0.56 | 0.53 |
| Phe+Tyr | % | 1.34 | 1.26 | 1.21 | 1.22 | 1.14 | 1.10 | 1.04 | 0.98 |
| Threonine | % | 0.80 | 0.75 | 0.75 | 0.74 | 0.70 | 0.68 | 0.68 | 0.64 |
| Tryptophan | % | 0.20 | 0.19 | 0.18 | 0.18 | 0.17 | 0.16 | 0.16 | 0.15 |

Source: NRC (1994)

Similarly, Olomu (2011) recommended 0.30-0.35% common salt to care for the birds. All other micro-ingredients are provided in ample amounts by the natural ingredients used in formulating poultry feed. The mineral requirement of broiler chickens is presented in Table 4.

### *2.4.4 Vitamin requirements*

Vitamins are group of food substances found only in living things, plants and animals. They are needed in a small amount for normal metabolism and good health. They have no caloric value but assist in metabolism, digestion and absorption of nutrients in the body (Olomu, 2011). Vitamins are broadly divided in to two classes based on their solubility. The fat soluble vitamins include vitamins A, vitamin D, vitamin E, and vitamin K, while the water soluble vitamins are folic acid, vitamin B12, vitamin B6, biotin, niacin, thiamine, riboflavin, pantothenic acid and ascorbic acid (Olomu, 2011). Vitamins are not always found in sufficient quantities or available forms in the common feedstuffs used for poultry diets therefore have to be supplied in the diets using vitamin and mineral premixes (Leeson, 2000). The levels recommended for chickens are generally applicable to guinea fowls except for vitamin E, the requirement of which is probably higher for guinea fowls 12-20mg/kg diet (Olomu,2011). Unlike protein and amino acids, vitamins and micro elements are not stated in terms of expected rate of feed consumption or energy content. However, in practice, the commercial vitamin premixes provide all the necessary vitamins for different classes of birds. The vitamins requirements of broilers and layer chickens are presented in Table 5.

Table 4: Mineral requirements of broiler chickens

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | **Class of broiler** |  |  |
| **Element** | **units** | **0-3 weeks** | **3-6 weeks** | **6-8 weeks** |
| **Macro** |  |  |  |  |
| Calcium | (%) | 1.00 | 0.90 | 0.80 |
| Chlorine | (%) | 0.20 | 0.15 | 0.12 |
| Magnesium | (mg) | 600.00 | 600.00 | 600.00 |
| Non-phytate Phosphorus | (%) | 0.45 | 0.35 | 0.30 |
| Potassium | (%) | 0.30 | 0.30 | 0.30 |
| Sodium | (%) | 0.20 | 0.15 | 0.12 |
| **Micro/Trace** |  |  |  |  |
| Copper | (mg) | 8.00 | 8.00 | 8.00 |
| Iodine | (mg) | 0.35 | 0.35 | 0.35 |
| Iron | (mg) | 80.00 | 80.00 | 80.00 |
| Manganese | (mg) | 60.00 | 60.00 | 60.00 |
| Selenium | (mg) | 0.15 | 0.15 | 0.15 |
| Zinc | (mg) | 40.00 | 40.00 | 40.00 |

Source: NRC (1994)

Table 5: Vitamins requirements of broilers and layers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Vitamin** | **Broiler and pullets** |  | **Laying hens** |  |
|  | **Olomu (2011)** | **Leeson and Summers (2000)** | **Olomu (2011)** | **Leeson and Summers (2000)** |
| Vitamin A (iu) | 4000.00 | 8000.00 | 8000.00 | 8000.00 |
| Vitamin D3 (iu) | 600.00 | 3500.00 | 2000.00 | 3500.00 |
| Vitamin E (iu) | 5.00 | 50.00 | 5.00 | 50.00 |
| Vitamin K (iu) | 2.00 | 3.00 | 2.00 | 3.00 |
| B12 (mg) | 0.01 | 0.01 | 0.01 | 0.01 |
| Biotin (mg) | 0.10 | 0.10 | 0.10 | 0.10 |
| Choline (mg) | 1000.00 | 400.00 | 400.00 | 400.00 |
| Folacine (mg) | 0.60 | 1.00 | 0.50 | 1.00 |
| Niacin (mg) | 20.00 | 40.00 | 20.00 | 40.00 |
| Pantothenate (mg) | 11.00 | 14.00 | 5.00 | 10.00 |
| Pyrodoxine (mg) | 5.00 | 4.00 | 4.00 | 3.00 |
| Riboflavin (mg) | 5.00 | 5.00 | 5.00 | 5.00 |
| Thiamine (mg) | 2.80 | 4.00 | 2.50 | 2.00 |

### *2.4.5 Fibre requirements*

McDonald and Whitesides (2002), define fibre as cell walls of plant tissue that mostly consist of lignin, cellulose as well as hemicelluloses. It is the composition of the plant cell that is resistant against enzymes in the small intestine. From the chemical point of view, fibre is non-starch polysaccharides. McNab and Boormann (2002), reported that non-starch polysaccharides could be divided in to two types, soluble and insoluble. Branton *et al.*(1997), reported that a non-contagious disease takes place in poultry everytime diet is enriched with NSP, that results in more risk of necrotic enteritis. According to Varastegani and Dahlan (2014), chickens that were fed with lower quantities of fibre suffered from cannibalism more than those that were fed higher fibre, and fibre ingredients in laying hens diet could decrease the ammonia emission in their manure. The effect of mash dietary fibre on performance and cannibalism in laying hens showed that diets consisting of high soluble NSP decreased the performance and the mortality because of cannibalism among laying hens (Varastegani and Dahlan, 2014). Abdelsamie *et al*. (1983), reported that high dietary fibre decreased growth, food utilization, enhanced relative length and weight of the intestine and caeca and increased the size of the gizzard. Several studies have been conducted to determine the general fibre requirement of birds (Olomu, 2011; Aduku, 2004; Mandal *et al*., 2004) and have recommended 5-6% for broilers and 6-7% for pullet layers and breeding hens. Recently, Ezieshi *et al*. (2011), reported that maize offal and millet offal can replace dietary maize up to 50 and 75% respectively with reduced cost of feed production. Birds fed the millet offal performed relatively better in terms of body weight gain and feed intake. Dietary fibre is useful in preventing constipation, increases bulk of faeces and excretion of mineral in the faeces (Church, 1991). Sources of dietary fibre are wheat offal, maize offal, rice bran, rice husk, sorghum offal, pineapple wastes, and cassava peels, yam peels, and cocoyam peels etc.

### *2.4.6 Water requirements*

Water is a very important part of the nutrient intake of monogastric animals. An animal may lose all its fat and up to half of its body protein and still live but the loss of just 10% of its body water may result to death (Olomu, 2011). Animals generally can survive for several weeks without feed but only survive few days without water. The process of living depends upon physiological and chemical reaction, all of which require water as the medium to act. Water is therefore critical to life and good health. In broiler production water is usually given *ad libitum*. Normally poultry consumes about two to three parts of every part of feed on a weight basis (i.e. 2-3 kg water per kg feed consumed; Olomu, 2011). During hot weather, consumption of water may rise to about 4 to 5 times the intake of feed. Olomu (2011) also recommended the daily water requirement for broiler chickens as shown in Table 6. The water requirements for livestock depends on several factors such as level of activity, environmental temperature, dryness of feed and type of production like eggs production which requires more water (Aduku, 2004). Salty diets increases thirst as well as high dietary protein content. Since faeces contains 75-85% water, it is obvious that increased production of faeces due to feeding a diet high in indigestible organic matter, or one containing mucilage will be accompanied by an increased excretion of water and a concomitant increased demand (Bolton and Blair, 1986). Water modifies the properties of bio-molecules such as nucleic acids, proteins and carbohydrates by forming hydrogen bonds with their polar functional groups. These interactions modify the properties of the bio-molecules and their conformations in solution (Nwachukwu, 2013). Water constitutes a physical end product of oxidative metabolism of foods. Water functions in maintenance of the composition of the internal environment that is essential for health which includes consideration of the distribution of water in the body and the maintenance of appropriate pH and electrolyte concentration (Nwachukwu, 2013). Water is essential for the control of body temperature by birds in hot environment.

Table 6: Daily water requirement of broiler chickens (litre/100 birds)

|  |  |
| --- | --- |
| **Age (weeks)** | **Quantity/100 birds (litre)** |
| 1 | 2 |
| 2 | 5 |
| 3 | 8 |
| 4 | 12 |
| 5 | 18 |
| 6 | 24 |
| 7 | 30 |
| 8 | 36 |

Source: Olomu (2011)

## 2.5 Importance of Energy in Animal Nutrition

Food is the source of energy for humans and animals. Carbohydrates and proteins which food supply to the body, may be used as energy in regulating body temperature and maintaining the vital physiological functions of growth activity, reproduction and production depending on age and specie of the animal. Animal get their energy from foods in a chemical form that is bound in molecule of carbohydrate, fat, protein and alcohol. The largest single dietary requirement of an animal is for energy Olomu, (2011). He also stated that, in terms of total cost energy is the most expensive item in animal diets, because of the amount required. Energy is usually measured in calories, but in monogastric nutrition, it is measured in kilo-calori (kcal).

### *2.5.1 Sources of energy for poultry*

Feedstuffs classified as high energy are those that are fed or added to a ration primarily for the purpose of increasing energy intake or increasing energy density of the ration. Energy from high energy feedstuffs is supplied either by readily available carbohydrate (sugar and starch) or by fat and oils. Such feedstuffs are labelled high energy in contrast to most roughage, because the available energy (digestible, metabolizable or net) is much greater per unit dry matter. In other words, the animals can obtain much energy from cereals than from typical roughage, even though, there may be very little differences in gross energy between straw and starch (McDonald *et al*., 1987).

### *2.5.2 Conventional cereals*

The name cereal is given to those members of the *Gramineas* which are cultivated for their seeds. Cereal grains are essentially carbohydrates concentrates, the main component of the dry matter being starch which is concentrated in the endosperm (McDonald *et al*., 1987). Cereals mostly used in the tropics are maize, rice and sorghum and to a lesser extent millet and wheat (Olomu, 2011). The nitrogenous components of 85-90 percent in cereals are in form of protein. These proteins occur in all tissues of cereal grains, but higher concentrations are found in the embryo and aleurone layer than in the starchy endosperm, pericap, and testa (McDonald *et al*.,1987). Within the endosperm, the concentration of protein increases from the centre to the periphery. Cereal proteins are generally deficient in lysine and methionine, the sulphur containing essential amino acids. Cereals constitute about 45-70% of dietary energy of poultry, swine and rabbits and provide 70% of energy in human diet in other parts of the world. Cereals contain fair amount of calcium, phosphorus and iron, although the presence of phytic acid interferes with the absorption of these minerals (Olomu, 2011). In addition, the lipid content of cereal grains varies with species wheat, barley, rye and rice contain 10-30g/kgDM, sorghum 30-40g/kgDM, maize and oats 40-60g/kgDM (McDonald *et al*.,1987). The oil is unsaturated with linoleic and oleic being the main acids. Cereals are deficient in calcium and rich in phosphorus, part of which is present as phytic acid that is concentrated in the aleurone layer. Cereal phytate chelates with dietary calcium and magnesium and thus limit their absorption from the gut. The degree of chelating increases from oats to barley, rye or wheat. Cereal grains are also deficient in vitamin D and vitaminA. However, they are good sources of vitamin E and thiamine with low content of riboflavin. Most of the vitamins are concentrated in the aleurone layer and the germ of the grain.

***2.5.2.1 Maize (Zea mays)***

A number of different types of maize exist, and the grain appears in a variety of colours, yellow, white, white or yellow. Maize contains cryptoxanthin a pigment that is a precursor of vitamin A. In United States of America, the yellow varieties are preferred in animal feeding. This tends to colour the carcass fat and useful in laying hens, where it contributes to the orange colouration of egg yolk (McDonald *et al*., 1987). Maize like other cereal grains has limitation as a food for farm animals, it is low in protein and the protein is of poor quality. Maize contains 730g starch/kgDM, low in fibre with high metabolizable energy value. The oil content varies from 40 to 60g/kgDM, high in linoleic acid an important factor in controlling egg size of hens. The crude protein is very variable and generally ranges from about 90 to 140g/kg DM. The maize kernel contains two main types of protein zein, occurring in the endosperm is quantitatively more important but is deficient in essential amino acids tryptophan and lysine. The other protein of maize glutein, occurring in lesser amounts in the endosperm and in the germ, is a better source of these two amino acids. Yellow maize contains a mixture of carotenoids, some of which like beta-carotene, cryptoxanthin and beta-zein have provitamin A activity (Olomu, 2011).

***2.5.2.2 Sorghum or Guinea corn (Sorghum bicolor (L.) Moench)***

It is widely grown in several parts of the world. Sorghum can be grown successfully on poorer soils and in drier conditions than maize (Olomu, 2011). It can be grown on salty, coastal soils and on land reclaimed from the sea. The chemical composition of sorghum indicates that it contains 9.50% crude protein, 2.50% fat and 2.70% fibre. However, sorghum generally contains much lower levels of xanthopylls and linoleic acid than maize. The protein content is slightly higher than that of maize and contains lower level of lysine and tryptophan. Some varieties of sorghum have high tannin content. Tannins are a group of compounds that bind proteins and impair digestion and reduce palatability. However, the tannin content of sorghum varies among varieties with the yellow variety having lower levels (Olomu, 2011).

***2.5.2.3 Millet (Pennisetum typhoids Stept)***

The name millet is frequently applied to several species of cereals which produce small grains and are widely cultivated in the tropics and warm temperate regions of the world. The most important members of this group include *Pennisetum amercanum* (Pearl bulrush millet), *Panicum milliaceum* (Presor or broom corn millet), *Setania italixa* (foxtail or Italian millet), *Eleusine coracana* (finger or birdsfoot millet), and *Echinochloe crusgalli* (Japanese or barnyard millet). Millet is a staple food of many people in some parts of the world. There are several varieties of millet grown in Nigeria, the Gero millet, Maiwa millet, and Dauro millet, similar to maiwa, but grown in cooler areas (Olomu, 2011).

Millet is resistant to drought thus grown extensively in areas where the climate is too dry and the rain too short for guinea corn and maize production. Pearl millet could potentially be incorporated in to poultry diets successfully. The protein content and the essential amino acid profile of pearl millet are relatively higher and more balanced than that of corn (Adeola and Rogler, 1994). Pearl millet has higher oil content than other common cereal grains (Hills and Hanna, 1990) and thus a better source of linolenic acid (Rooney, 1978), based on the performances of broilers and laying hens (Collins *et al.*, 1997) fed pearl millet. It appears to be superior to corn as a grain source of energy for poultry ration. However, it contains a high content of indigestible fibres due to the presence of hulls that are not easily removed by ordinary harvesting methods (McDonald *et al.*, 1997). Its tryptophan content is slightly higher than that of maize but closer to that of wheat, while the methionine, cysteine and lysine contents are higher than most grains, with lysine as the limiting amino acid (Olomu, 2011). Several studies have been carried out to determine the replacement levels of maize with pearl millet or sorghum and their effects on broiler chickens. For example, Davies *et al.* (2003), reported that either feeding broiler chicks for 16 days with diet in which pearl millet completely replaced corn or with 50% replacement for 0-42 days did not have adverse effect on the performance, body weight or carcass yield. Studies by Ramarao *et al.* (2002) and Raju *et al.* (2003) agreed that finger millet and sorghum or both can replace corn partially or wholly in practical broiler diets without any adverse effect. However, complete replacement of maize with millet or low tannin sorghum in broiler diets have been reported to have no adverse effect on their carcass and blood components (Medugu *et al.*, 2010).

### *2.5.3 Roots and Tubers*

Root crops used in feeding animals, especially in Nigeria are cassava, sweet potatoes and yam. Root crops are characterized by their high water content 75-90%, moderate in fibre 5-11% and low in crude protein content 2-6%. In general, they are low in calcium and phosphorus and high in potassium. Carbohydrates range from 50-75% of the dry matter, which are mainly sucrose that is highly digestible by ruminants and non-ruminants (Ekpenyong, 1986).

***2.5.3.1 Cassava (Manihot esculanta) meal***

Cassava is a tropical root crop of great potential in the livestock industry in Nigeria, because it yields as much as 75-80 tons/ha per year in experimental plots (Eshiett *et al.*, 1980) which is higher than rice, corn or other grains adapted to tropics. Apart from the ease of propagation and economy of production, cassava is relatively free from pests and poses minimal storage problems compared to other food crops (Eshiett *et al.*, 1980). The chemical composition of cassava indicates 65% water, 1-2% protein, 1.5% fibre, 0.3% fat and 1.4% ash. The dry matter is readily available carbohydrates. The dry cassava is equal in energy value to other root crops and tubers. It can therefore replace the grain portion of the diet, if the amount of supplementary protein is increased to compensate for the low protein content of cassava. The stalk and leaf portions of the plant are well utilized by ruminants, but not non-ruminants because of their high fibre content (Omote, 1990). Freshly harvested cassava roots and leaves are high in hydrocyanic acid, but fermentation and oven drying are effective processing methods of reducing HCN content.

***2.5.3.2 Sweet potatoes (Ipomea batatas)***

Nigeria climate favours the production of sweet potatoes both in the wet and dry seasons. Sweet potato has a relatively shorter growing period compared to other tropical root crops, and requires very little care and labour with a yield of about 47kg/ha in the dry season (Onwueme, 1978). It contains about 92% carbohydrates with 4.5% occurring as sugars, 5% crude protein, 3% ash, low in lipids and fibre with metabolizable energy rate higher than that of maize (Fetuga and Oluyemi, 1976). The utilization of sweet potatoes as livestock feed has been documented (Jobs *et al.*, 1979). Dehydrated sweet potato is fairly suitable as partial replacement for maize in the diet of chicks (Jobs *et al.*, 1979), broilers and pigs (Lee *et al.*, 1977). Potato has been found to had approximately 87-90% of the feeding value of maize, when supplemented with well balanced protein source (Lee *et al.*, 1977). Compared to other roots and tubers, sweet potato is a favourable replacement for maize (Fetuga and Oluyemi, 1976; Lee *et al.*, 1977).

### *2.5.4 Some Non-conventional energy feedstuffs*

The quest for the use of non-conventional feed ingredients with the intention of reducing feed cost of production in order to make animal protein available and affordable to the ever increasing human population have led researchers in to use of seeds, leaves and fruits gathered from the wild and /or immediate environment as replacement for the conventional dietary energy sources e.g. African locust bean (*Parkia biglobosa*) fruit pulps, wild cocoyam e.t.c.

Bot *et al*. (2013) reported that parkia pulps contain 11.52% CP, 12.49% CF, 3.09% EE, 4.08% Ash and 68.32% NFE. This high content of NFE makes it a good substitute for maize as an energy source in poultry diets. They also reported that parkia pulp contains 150.00mg/100g oxalate, 219.10mg/100g phytic acid and 3.32mg/100g tannins. The low level of anti-nutrients shows that parkia pulp is partially safe for incorporation in to poultry diets but some processing may be needed to reduce these anti-nutrients and improve its utilization by birds. They recommended 25% replacement level of maize with parkia pulp. When parkia pulps was fermented before incorporation in to the broiler chickens diet in another experiment the performance of the birds was good, and the authors recommended up to 30% level of replacement of fermented parkia pulp for maize (Lakurbe *et al*., 2017).

According to Ijadunola and Adejoro (2012), limitations such as the presence of anti-nutritional factors have made feed producers and other users refrain from the use of these non-conventional feedstuffs. However, Biotechnology has provided opportunities to eliminate or reduce such anti-nutrients. Wild cocoyam contains hydrogen cyanide, tannins, phytate and oxalate. Cooking, soaking, and fermentation are some of the processing methods recommended before wild cocoyam can be utilized by poultry. They recommended 10% level of inclusion after evaluating the growth performance and carcass characteristics of broiler chickens fed graded levels of soaked wild cocoyam as partial replacement for maize. The results showed non-significant difference among the internal organs.

## 2.6 Proteins

Proteins are complex organic compounds containing carbon, hydrogen and sulphur. The properties of a protein are determined by the number, kind and arrangement of the constituent amino acids. There are about twenty known amino acids that can be classified either in terms of metabolic fate as ketogenic and glucogenic or as essential or non-essential amino acids (Nwachukwu, 2013).

***2.6.1 Sources of Proteins***

### *2.6.1.1 Animal protein sources*

***2.6.1.1.1 Fish meals***

Fish protein sources are primarily of two types, those from fish caught for making meal and those made from fish residues remaining after processing for human food and other industrial purposes. Fish meal is defined as the clean dried ground tissue of non-decomposed whole fish or fish cuttings, with or without extraction of part of oil. It must contain more than 3% salt, whose amount must be specified (Cullision, 1982). The quality of fish meal may vary, if it is not well processed. Good quality fish meals are excellent sources of proteins and essential amino acids. It is high in essential amino acids, especially lysine that is deficient in the grains (NIOMR, 1991). It is also a good source of B-vitamins and most of the mineral elements. It is therefore a highly favoured ingredient for swine, poultry and rabbit feeds (Anonymous, 1988). Inclusion levels vary depending on the species, cost and age of the farm animals. For broiler chicks (0-6 weeks), turkey poults (0-8 weeks), duckling (0-3 weeks) and for pig starter, maximum level of 10% is recommended, while for older broiler chicks and ducklings and turkeys up to 12 weeks maximum of 7.5% and 5% for laying and breeding chickens (Olomu, 2011).

***2.6.1.1.2 Blood meal***

The blood meal is obtained by drying the blood of slaughtered animals and poultry and should be free of foreign matter. It is produced by passing steam through the blood until the temperature reaches 100°C. This ensures efficient sterilization and causes the blood to clot. It is then drained pressed to express occluded serum, dried by steam heating and ground (Olomu,2011). Blood meal is a dark chocolate-coloured powder with a characteristic smell. It contains about 800g/kg of protein, small amount of ash and oil, about 100g/kg of water. It is a nutritionally important source of protein. It is however very rich in lysine, arginine, methionine, cystine and leucine but very poor in isoleucine and contains less glycine than fish, meat and bone meals. Despite the poor amino acids balance, low biological value, and low digestibility, its protein also has very low degradability (Njoku, 1985). Blood meal is unpalatable, and its use results in reduced growth rates in animals and therefore not recommended for young stock. The inclusion rates in older birds are limited to about 10 to 20kg/ton of diet. Normal inclusion levels for older animals are about 50kg/ton of diet but usually supplemented with a high-quality protein source levels above 150kg/ton of diet tends to cause scouring. It is a good source of lysine but low in minerals and fibre (Odukwe, 1985).

### *2.6.1.2 Plant protein sources*

Plants proteins used in monogastric nutrition as alternatives or supplements to animal protein are leguminous seeds. Full-fat extruded soya bean meal and roasted soya bean have been reported as valuable sources of protein for poultry production and can replace groundnut cake as well as reduce conventional requirement for fish meal in mongastric diets (Fanimo and Tewe, 1994 and Bamgbose, 1995). Crude protein of most leguminous seeds ranges between 20-49% (Parr et al., 1988; Church 1991; Aduku, 1992; Nworgu *et al.*, 1997). Soya bean and groundnut cake contain between 43.0-48.1% and 44.0-49.9% crude protein respectively (Parr *et al.*, 1988; Church, 1991; Aduku, 1992; Nworgu *et al.*, 1999). Fat contents of most leguminous seeds range from 0.8% in pigeon pea (Parr *et al.*, 1988) to 27.7% in sun flower seed (Aduku, 1993), while their metabolizable energy levels range between 2200-3400kcal/kg (Church, 1991; Aduku, 1993; Nworgu *et al.*, 1977).

***2.6.1.2.1 Soya bean seed (Glycine max Merr)***

Full fat soya bean has an average protein content of about 40% ranging from 36 to 44% and average fat content of 18%, crude fibre of about 7.5%, ash content of about 5.5% and dry matter content of about 94.5%. The bulk of the protein is made up of a globulin, glycinin, legumelin and phaseolin. Soya bean is rich sourch of lysine and tryptophan that are deficient in most grains. It’s a good source of thiamine, riboflavin, niacin and carotene. The seed contains fair amount of calcium, phosphorus and other minerals (Olomu, 2011), but deficient in methionine, Kohlmeier (1993) reported a chemical composition of roasted soya bean as 7-12% moisture, 33-40% crude protein, 16-20% fat and 5 to 6% fibre. Raw soya bean contains several anti-nutritional factors such as trypsin inhibitors, lectins, saponins and goitrogen factors which can have deleterious effect on the performance of chickens (Ruiz *et al.*, 2004). However, these anti-nutritional factors are heat labile. Raw soya bean seeds must be processed before use. Processing methods such as wet cooking, roasting and extrusion have proved effective. However, overheating should be avoided this is because it can lead to the breakdown of the protein in the grain or meal, oxidation of sulphur amino acids and the reaction of lysine with reducing sugar to form an unavailable complex and reduction in metablizable energy. Feeding raw soya bean causes growth depression, poor feed efficiency and small egg in laying hens (Balloun, 1988).

***2.6.1.2.2 Groundnuts meal and/or cake (Arachic hypogaea Linn)***

This is the product obtained after extraction of the oil from groundnut seed and grinding the flake or cake. It is a widely used plant protein source in animal diets. It can be locally or industrially produced. Its crude protein contents ranges from 44 to 50% with varying energy value depending on the processing methods. Groundnuts meal is low in lysine and methionine and marginal in tryptophan and threonine. Groundnuts meal or cake based diets are supplemented with synthetic lysine and methionine or with fish meal to make up for the deficiency. Research has shown that groundnuts meal or cake can partly or wholly be used as protein source in the diets of finishing broiler or roaster chickens and roaster turkey (Olomu, 2011).

***2.6.1.2.3 Bambaranut (Voadzeia substerranea sivale)***

Bambaranut is a pulse, like most pulses it contains some anti-nutritional factors such as cyanogens, flatulence factors, tannins and trypsin inhibitors (Ensiminger *et al* ., 1990). Bambaranut is a protein rich seeds, cheap and available legume which may reduce feed cost and make production more profitable. It is the third most important legume after groundnut (*Arachis hypogeal*) and cowpea (*Vigna unguiculata*) in Africa (Sellschop, 1962 and Kay, 1979). According to Coudert (1984), the annual world production of Bambaranut is about 330,000 tons of which Africa produce half, with Nigeria being the major producing country. karikari (1974), also reported major Bambaranut producing countries as Nigeria (100,000 tonnes), Niger (30,000 tonnes) and Ghana (20,000 tonnes). Though grown extensively in Nigeria (Enwere, 1998), yet one of the less utilized and unexploited legumes. The chemical composition varies, for example, Ekenyem and Onyeagoro, (2006) reported 15.75% crude protein, 6.75% crude fibre, 4.75% ether extract, 1.95% ash,60.89% NFE and 2478.63 kcal/kg gross energy. Similarly, Gohl (1981) reported crude protein of 17.7%, carbohydrate 61.7%, fat 6.3% and crude fibre 4.9%. Bambaranut waste, a by-product of bambaranut milling industry, has been reported to contain 18.30% crude protein, 20% crude fibre, 5.36% ether extract, 41.64% NFE, 10.2% moisture and 16.74% of gross energy (Ani and Omeje, 2007). Bambaranut is economically important because it is an inexpensive source of high quality protein.

***2.6.1.2.4 Cotton seed (Gossypium spp) meal***

This is a residue after the extraction of oil from cotton seed and grinding the resulting flakes or cakes. Delinted and decorticated cottonseed meal has a protein content of 41-42% (Olomu, 2011). The protein is of good quality but has the common disadvantage of oil seed protein with low content of cystine, methionine and lysine. The calcium content is low and since the calcium to phosphorus ratio is about 1:6, deficiency of calcium may easily arise. It’s a good source of thiamine but a poor source of carotene. Cotton seed may contain from 0.3 to 20g/kg DM of a yellow pigment known as gossypol. Kernels of cotton seed may have gossypol concentration of 4 to 17g/kg DM (McDonald *et al.*, 1995). Gossypol is a polyphenolic aldehyde (alkanal) which is an anti-oxidant and polymerization inhibitor toxic to simple stomarched animals. The general symptoms of gossypol toxicity are depressed appetite, loss of weight and death from circulating failure. It may cause a characteristics discoloration of yolk and albumen of eggs. Birds and pigs can tolerate low levels of gossypol in diets. The free gossypol content of cotton seed meal decreases during processing and varies according to the methods used. Screw-pressed materials have 200-500mg free gossypol, prepressed solvent extracted meals 200-700 and solvent-extracted 1000-5000mg/kg respectively (McDonald *et al.*, 1995). The report recommended inclusion levels of cotton seed meal of 50 to 100kg/ton in both pig and poultry diets. Research has shown that delinted and decorticated cotton seed meal can use to replace 50-70% of required quantities of chemical composition of cotton seed meal is 42.30% crude protein, 1.70% crude fat, 11.20% crude fibre, 7.70% ash, and 27.40% NFE (Olomu, 2011).

***2.6.1.2.5 Sunflower seed (Helianthus annuus) meal***

Sunflower seed is especially grown for its oil and to a lesser extent for confectionary market (Olomu, 2011). Sunflower seed contains about 31% crude protein, 20% crude fibre and over 40% oil (Olomu, 2011). The high fibre content of the seed, limits its use in poultry and swine diets. Olomu (2011), recommended a maximum inclusion level of 10% for pig starter and grower diets, 25% for lactating sows, 10% for chicks and poults and 20% or less for pullets and laying diets.

***2.6.1.2.6 Pigeon pea (Cajanus cajan)***

Pigeon pea occupied an important place in human and animal nutrition. India produces about 85% of the world supply of pigeon pea (Umaid and Ramanartha, 1981). Pigeon pea seed contains 6.4-12.2% moisture, 6.8-10.1% crude fibre, 1.4-3.2% lipids, 41.3-48.6% carbohydrates, 15.4-21.9% crude protein, 39.3-45.2% non-reducing sugar, 2.1-3.1 reducing sugar, 3.4-3.7% ash, 0.10-0.17% calcium and 0.20-0.79% phosphorus (Shrisvastara and Bajpa, 1987). Nwachukwu and Bangbose (1997), reported on proximate composition of a Nigerian variety was similar to those of Shrisvastara and Boypa (1987) except in minerals, the reducing and non-reducing sugar contents. Like other grain legumes, pigeon pea cotain considerate amount of protease inhibitor namely trypsin and chymotrypsin inhibitors that are heat labile (Singh, 1988). Pigeon pea seed has successfully replaced groundnut cake up to 50% level in finisher ration for broilers (Amaefule and Obioha, 1995). Alokan and Bamgbose (1997), also reported that pigeon pea can replace 40% groundnut cake in the diet of growing rabbits. The use of dehulled, boiled or raw pigeon pea seed meal at inclusion levels not exceeding 30% can support growth and high feed conversion efficiency in broilers (Amaefula and Obioha, 1997). Pigeon pea seed meal can replace soya bean meal at 33% level in broiler starter diet without any deleterious effect on the chick’s performance and its utilization in broilers production is highly economical (Nwachukwu *et al*., 2004).

**2.7 Utilization of some plant proteins in practical broiler rations**

Vegetable proteins are rich and valuable sources of proteins for human as well as farm animals. Reports indicate that the total use of these products by the livestock feed industry in developed countries are soya bean up to 45%, rape seed 23% and sunflower 11% (Parr., 1998; McDonald *et al.*, 1995). Similarly, reports on utilization of vegetable proteins in Nigeria feed industry indicated that soya bean and groundnut cake have the highest inclusion levels in monogastric diets (Oyenuga, 1968; Aduku, 1992; Nworgu *et al.*, 1997). Levels of inclusion of soya bean in poultry diets ranged from 15% (Kwari *et al.,* 2004) to 26% (Nworgu *et al.*, 1997) with satisfactory results when combined with groundnut cake at different levels. Aduku (1992), has suggested the inclusion of up to 50% soya bean cake and 35% groundnut cake in separate broiler starter diets in combination with other feed ingredients like cereal grains, beni seed, cotton seed meal and blood meal. Other vegetable proteins utilized in poultry diets include lablab purpureus at inclusion levels up to 50% of the diet (Abeke *et al .*, 2003). African locust bean (*Parkia biglobosa*) at inclusion levels ranging from 35.6-55% of total dietary composition as a source of energy and protein (Ari, 1999; Kwari and Igwebuike, 2001; Ahmed and Olorede, 2003) and jack beans (Akinmutimi *et al*, 2000). Similarly, Mucuna *valvet beans* has been fed to broiler chickens by Esonu, (2001) and Iyayi, (2001) at inclusion levels not beyond 5% resulting to cost effective feeds. The reports on levels of inclusion of Bambaranuts meal in broiler rations have been consistent. Processing methods and the age of birds are the critical factors for example, Onwudike and Eguakun (1994) reported 40% inclusion of treated Bambaranuts meal.

Bello *et al.* (2005) reported 30% inclusion level of toasted bambaranuts meal, while Ekenyem and Onyeagoro (2006) reported 15% inclusion of raw bambaranuts meal in all cases there were no deleterious effect on the birds performance. Similarly, Nwanbe and Elechi (2009) reported that soya bean meal can be replaced with potash boiled bambaranuts meal up to 100% level without any deleterious effect on the bird’s blood constituents. According to Oloyede *et al.* (2010) fermented bambaranuts meal, when fed to broiler chicks along side with raw and toasted, gave a better performance even at 35% inclusion level.

## 2.8 Factors affecting feed intake in poultry

Feeding constitute about 70% of the cost of production of poultry (Smith, 2001). Utilization of alternatives feed ingredients can reduce the cost of production and enhance profitable poultry venture. It is also important that wastage of feed is controlled (Smith, 2001).

***2.8.1 Temperature***

The body temperature of the domestic chickens ranges from 38.9ºC for the day old chicks to 41.9ºC for the adult (Oluyemi and Roberts, 2013). The maintenance of normal body temperature range is critical for optimal productivity. Temperature ranges of 32.2ºC – 35.0ºC, 29.7ºC – 32.2ºC have been recommended for the first, second and third weeks for the domestic chickens respectively (Oluyemi and Roberts, 2013; Jagdish, 2005). In the tropics, there is usually no need for heat after four weeks particularly during hotter parts of the year (February – April). Heat should be available for unexpected cold spells especially at night for up to eight weeks (Oluyemi and Roberts, 2013). Depressed production and increased mortality rates occur when temperature rise above 29ºC for laying hens (Oluyemi and Roberts, 2013). Growth rate and feed intake of broilers between three and eight weeks is affected in a linear manner by ambient temperatures between 7ºC and 21ºC. Both growth and feed intake decrease by 0.12 percent for each degree rise in temperature over this range. Feed conversion ratio is highest at a temperature range of 21-26ºC (Smith, 2001). Day length: in general feed intake and body weight gains are higher in male than female birds (NRC, 1994).

***2.8.2 Humidity***

At 21ºC, the relative humidity ranges between 48-90% and this range does not affect either the growth rate or feed conversion ratio but at 29ºC with increasing humidity range from 30 to 70% has been reported to slow the growth rate of broilers and cause stress (Smith, 2001). High humidity in the chicken pen can cause the death of young poultry during rainy season. Low humidity causes dehydration while high humidity stimulates the growth of mould and proliferation of pathogens like coccidian in the litter. The optimum relative humidity for birds in the tropics is between 50-70% (Oluyemi and Roberts, 2013). Table 7 shows some data on the performance of broiler chickens such as weight gain and feed consumption.

Table 7: Average weight, feed consumption and feed efficiency of broiler chickens

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Age (wks)** | **Body wgt. (g)** | **Feed consumption / bird(g)** | **Feed consumption/ wk cumulative (g)** | **Feed efficiency/wk g feed / g gain** | **Feed efficiency/wk cumulative g feed/g g** |
| 0 | 40 | - | - | - | - |
| 1 | 125 | 110 | 110 | 1.29 | 1.29 |
| 2 | 300 | 245 | 345 | 1.46 | 1.36 |
| 3 | 510 | 365 | 720 | 1.74 | 1.53 |
| 4 | 785 | 495 | 1215 | 1.80 | 1.63 |
| 5 | 1106 | 600 | 1815 | 1.87 | 1.70 |
| 6 | 1450 | 790 | 2605 | 2.30 | 1.85 |
| 7 | 1805 | 855 | 3460 | 2.42 | 1.96 |
| 8 | 2155 | 1030 | 4490 | 2.93 | 2.12 |
| 9 | 2495 | 1120 | 5610 | 3.26 | 2.28 |

Source: Olomu, 2011

## 2.9 Feed Utilization (FCR and FE)

Feed accounts for 70-80% of cost in poultry production (Smith, 2001; Madubuike and Ekenyem, 2001, Mandal *et al.*, 2004). Efficient feed utilization is of critical economic importance in a profitable poultry production. The feed conversion ratio (FCR) and feed efficiency (FE) are the terms use to measure the degree of feed efficiency. The quality of feed and age of birds affect the FCR or FE. Feed conversion ratio for growing bird represent the amount of feed consumes or required for 1kg gain in live weight (Olomu, 2011).

Feed efficiency is the reverse of feed conversion ratio i.e. the amount gain in kg weight obtained from every 1kg feed intake.

### *2.9.1 Significance of feed conversion ratio*

Feed conversion ratio is closely related to the quality of feed, quality of birds, wastage of feed and management of disease problem (Mandal *et al.*, 2004; Jagdish, 2005). The FCR for broiler from 0-6 weeks of age ranges from 1.8 to 2.0 (Oluyemi and Roberts, 2013; Mandal *et al.*,2004). If the value is higher than this range, it implies that either the ration is not properly balanced, does not contain optimum calorie/protein ratio or poor strain quality of the birds. Poor management and disease condition of the birds can also cause higher FCR. FCR values are generally better in hotter than cooler climates. However, FCR implies efficient feed utilization, less wastage of nutrients, less excreta voided, less foul smell in the poultry house, better litter condition and less environmental pollution (Mandal *et al.*, 2004).

## 2.10 Avian Blood Chemistry

Blood consists of red blood cells, white blood cells and the platelets that are suspended in a plasma liquid medium. The plasma protein consists of haemoglobin, albumin and the immunogloblin, while the white cells are of three groups namely granulocytes, monocytes and lymphocytes. Blood functions include, transport of oxygen, food materials, metabolic waste, maintenance of acid-base and water balance and body temperature (Murray *et al*., 2000). Avian haematological studies are always performed for research purposes in order to evaluate the effect of rearing techniques (Cerolini *et al.,* 1986), feeding regimes (Frachini *et al.*, 1988), environmental condition and toxicity levels. Values of Hb, PCV and RBC can be used for diagnostic purposes.

### *2.10.1 Avian haematology*

In general blood volume of poultry is between 80-100ml/kg body weight (Sjaastad *et al.*, 2005). Red blood cell (RBC) or erythrocytes count falls within 2.5-3.2 ×106/mm3 for chickens, (Akinmutimi *et al.*, 2004; Swenson, 2004). Other haematological studies indicate, haemoglobin concentration (90g/l) and white blood cells (WBC) or leucocytes count 20-30×109 (Sjaastad *et al.*, 2005), the packed cell volume (PCV) values of chicken ranges from 28-40 % or 10-21ml/kg body weight (Mitruka and Rownsley, 1977; Akinmitimi *et al.*, 2004). Similarly, another reports on Avian haematology, indicates a range of 29.00-38.90%, PCV, 93-118g/dl haemoglobin, 2.70-3.40 ×109/l red blood cells count and 11.60-17.30×106/l, white blood cell count for broiler chickens, while those of cockerels are 30.43% PCV, 117.8g/dl haemoglobin, 3.81×109/l RBC and 12.15×106/l WBC (Kwari *et al.*, 2004; Omoikhoje *et al.*, 2004; Ameen *et al.*, 2007; Iyayi *et al.*, 2008). Similarly, Swenson, (1993) reported erythrocytes ranges of MCV 115-1,254 ft, MCHC 21-23g/l and MCH 25-27mg/dl are useful in measuring the size and the Hb content of erythrocytes or diagnosing diseases, toxicity level and anaemia.

### *2.10.2 Serum protein*

Serum proteins, albumin and globulin ranges for broilers are 4.02-8.36g/dl, 2.10-3.39g/dl and 3.91-6.28g/dl respectively (Mitruka and Rownsley, 1977), while serum albumin for cockerels 4.75g/100ml (Iyayi *et al.*, 2008) and serum protein for layers and cockerels are 5.4 and 3.6g/100ml respectively (Swenson, 2004). Normal chicken blood contains albumin and globulin levels of 1.7-2.0g/dl and 2.0-2.9g/dl respectively (Fajimi *et al.*,1993; Onifade, 1995). In general, blood proteins are formed in the liver and plasma protein synthesis is markedly reduced in severe liver damage or prolonged dietary protein deficiency, (Duke, 1999).

### *2.10.3 Serum enzymes*

Alanine Amino transferase (ALT) and Aspartate Amino transferase (AST). When certain types of cells are damaged, they may leak enzymes in to the blood, where they are measured as indicators of cell damage. ALT (EC 2.6.1.2) is markedly elevated in hepatitis and from other acute liver damage, while AST (EC 2.6.1.1) has a similar role, but found in other tissues such as heart and not so specific to liver. When these tissues are injured or inflamed, the level of ALT in the blood usually rises, however, when body tissue or an organ, heart or liver is damaged additional AST is released in to the blood stream. The amount of AST in the blood is related to the tissue damage or liver damage usually caused by toxic substances. However, higher blood levels of AST and ALT have been associated with protein energy malnutrition (PEM). Varley *et al.* (1980) reported breakdown of tissues in Protein-Energy Malnutrition (PEM), metabolizing the amino acid released from tissue breakdown enhances the process of transamination, leading to increased activity of AST and ALT. ALT catalyses the transfer of amino group between L-alanine and glutamate to meet physiological needs, while AST catalyses the transfer of amino and keto groups between a-amino and a-keto acids.

### *2.10.4 Effect of nutrition on blood composition*

Nutritional anaemia in lower animal is due to a reduction in the red blood cells (RBC) production. Generally, malnutrition especially PEM indicates lower PCV and Hb concentration which are microscopic status of the red blood cells and are due indicators of anaemia. Swenson (1977), reported that low blood glucose indicates low protein intake. Fast growing animals have high serum albumin, Hb concentration and glucose with low concentration of potassium (K) (Swenson, 1977), Scott (1970), indicates that there is rather high correlation between blood glucose and energy consumption and that plasma- free acids are mostly highly related to energy consumption. Increase in dietary energy levels increases abdominal fat pad and hence performance (Jackon *et al.*, 1982). This observation has been made previously by Waldoup *et al.* (1976).

### *2.10.5 Haematological and serum biochemical reference values of normal domestic chickens*

Haematological and serum biochemical parameters are good indicators of the physiological and health status of animal and its changes are important in assessing the response of animals to various physiological situations (Isidahomen *et. al.,* 2011). Haematological and serum biochemical values can be influenced by nutrition, environmental factors, management and infections. Isidahomen *et al*. (2011) reported that haematological and serum biochemical indices of local and exotic chickens in Nigeria were different with higher values recorded in the Nigerian local chickens compared to their exotic counterpart. The normal reference values of haematological and biochemical indices as reported by Wikivet (2013) are presented in Table 8.

Table 8: Normal haematological and serum biochemical values for broiler chickens

|  |  |
| --- | --- |
| **Parameters** | **Values (ranges)** |
| Packed Cell Volume (%) | 35.90 – 41.00 |
| Haemoglobin (g/dl) | 11.60 – 13.68 |
| Red blood cells (×106/ml) | 4.21 – 4.84 |
| White blood cells (×103/ml) | 4.07 – 4.32 |
| Total protein (g/dl) | 4.63 – 4.81 |
| Albumin (g/dl) | 3.28 – 3.48 |
| Globulin (g/dl) | 1.15 – 1.53 |
| Creatinine (mg/dl) | 0.88 – 0.95 |
| Urea (mmol/l) | 4.46 – 4.54 |
| Glucose (mg/dl) | 44.10 – 45.50 |
| Cholesterol (mg/dl) | 31.30 – 32.40 |
| Salt (iµ/l) | 10.60 – 11.90 |

Source: Wikivet (2013)

## 2.11 Poultry Carcass

Several researchers have reported different values depending on the type of diets, feeding regime and management. For example, 65.5% by Oluyemi and Roberts (2013), 71-75% by Aduku and Olukosi (2000), 70-80% by Iheukwumere *et al.* (2001), 84.75% by Ahmed and Olorede (2003), 69.23-74.73% by Anyachie and Madubuike (2007) and 75.95% by Tuluen and Igba (2007) were reported for carcass yield of broiler chickens. Studies on the carcass yield of cockerels have also been documented. The reports indicated carcass yield of 66-77% by Awesu *et al.* (2000), 64 -70% by Salami *et al.* (2004) and 62.3-62.5% by Azharul *et al.* (2005). Cut up pieces expressed as percentage of live weight have been reported as 17.4% for the breast, 8.21% for the wings, 24.62% for the legs, 12.05% for the back, 4.38% for the neck and 3.51% for the giblet. The thighs and drumsticks represent 12.95% and 11.67% respectively (Oluyemi and Roberts, 2013). Anyachie and Madubuike (2007), report indicates 18.29% for the breast, 12.56% for the thighs, 10.55% for the drumsticks, 8.99% for the wings, 13.78% for the back and 4.27% for the giblets.

Increase in the broilers viscera weight has been associated with high fibre diets (Onifade, 1995) and may be attributed to increase in the activity of the gizzard, intestines and caeca, in handling bulky feeds or the presence of some toxic stimulating substances. Atuahene *et al.* (1986) reported significant differences in the viscera weight of *Bosek* broilers, fed cotton seed meal. Similarly, Ge and Morgan, (1993) reported that feeding raw soya bean (RSF) to mice for 2-4 weeks increased the pancreatic and intestinal growth rate, caused by hypertrophy with some hyperplasia. However, they concluded that, the hypertrophy and hyperplasia of the mucosal layer resulted in the increased intestinal weight.

**2.12 Economics of Broiler Production**

The cost of production and net profit per broiler determine the fate of broiler productivity (Kefyalew, *et al.*, 2015). For instance, economics of production of broiler chickens fed sorghum or millet as replacement for maize was studied by Medugu *et al.* (2010). The authors reported that the highest cost per kg feed was in maize-based diet compared to sorghum-based diet. The sorghum based diet was the cheapest. Feed cost per weight gain was lowest in the millet-based diet followed by the sorghum and highest in the maize-based diet, and therefore concluded that advantage of reduced cost of feeding the birds exist with the complete replacement of maize by millet or sorghum in broiler chickens diet.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

## 3.1 The Study Area

The experiments were conducted between February, 2016 and June, 2017 at the Poultry Production Unit (PPU) of Gombe State Ministry of Animal Husbandry and Nomadic Affairs, Gombe. Gombe town is located between latitude 10°17ˈ23ˈˈN and longitude11º10ˈ2ˈˈE and at an altitude of 508M above sea level. The climate of Gombe is characterized by two well-defined seasons. The rainy season (May-October) and dry season (November-April), it has the mean maximum monthly temperature of 37°C, minimum of 12ºC, and relative humidity of 94% in August and 10% in December, (World Atlas, 2015).

## 3.2. Experimental Feed Ingredients and Processing

Feed ingredients for the experiments were purchased from markets in Gombe town which include maize, white sorghum, pearl millet, soyabean, soyabean meal, industrial groundnut cake, local groundnut cake, fish meal,bone meal, premix, salt, lysine, methionine and wheat offal. Sorghum SK-5912 grains were obtained from Bojude market, Kwami LGA, Gombe state. Whole soya beans were winnowed to remove dirts, put inside a jut bag and placed in boiling water for 30 minutes after which, the soya beans were sun-dried for 3-4 days until the soya beans were properly dried. The boiled soya beans were then cleaned and milled in a hammer mill and incorporated in to the experimental diets. The other feed ingredients were also milled before incorporation in to the diets. The chemical composition of sorghum SK-5912 variety is presented in Table 9.

Table 9: Chemical composition of sorghum SK-5912

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Values** | **Standard Values (Olomu, 20011)** |
| Dry matter (%) | 96.56 | 92.50 |
| Crude protein (%) | 10.96 | 9.50 |
| Crude fibre (%) | 2.71 | 2.70 |
| Ether extract (%) | 3.12 | 2.50 |
| Total Ash (%) | 2.19 | 1.20 |
| Nitrogen free extract (%) | 77.58 | 76.60 |
| Tannins (mg/kg) | 4.43 | - |
| Phytic acid (mg/kg) | 326.89 | - |
| Hydrocyanic acid (%) | 3.41 | - |

## 3.3 Experiment 1: Replacement value of sorghum SK-5912 for maize in the diets of broiler chickens

### *3.3.1 Experimental Birds and Management*

Three hundred (300) unsexed, day old ‘*Marshal*’ broiler chicks were used for the experiment. Two before the arrival of the birds, the experimental pens and feeders and drinkers were thoroughly washed, cleaned, disinfected and dried. A week to their arrival, wood shavings were spread 8cm depth on the floor. Electrical appliances, feeders and drinkers were all put in place. Upon arrival of the chicks brooding commenced immediately, heat was provided by the use of 200W electric bulbs. The chicks were fed commercial starter diet for one week prior to the commencement of the experiment. Thereafter, the birds were randomly allotted to five experimental diets and replicated four times of 15 birds per replicate in a completely randomized design (CRD). The experimental diets and clean drinking water were provided *ad* *libitum* throughout the experimental period. The birds were vaccinated against Gumboro (Infectious bursal disease) on the 11th and 25th day while against Newcastle disease *(Lasota*) on the 20th day. All birds were reared on deep litter in an open sided poultry house.

### *3.3.2 Experimental Diets*

Fiveexperimental diets for both starter (23%CP) and finisher phases (20%CP) were formulated in which sorghum SK-5912 replaced maize at 0, 25, 50, 75, and 100% coded as diets 1 (control), 2, 3, 4, and 5 respectively, using boiled soya bean as plant protein. Both starter and finisher diets were fed for (4) weeks each. Percentage composition of graded levels of sorghum SK-5912 as replacement for maize in broiler starter and finisher diets are presented in Tables 10 and 11 respectively.

Table 10: Percentage composition of graded levels of Sorghum SK-5912 as replacement for maize in broiler starter diets (1-4 weeks)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Ingredients** | **1** | **2** | **3** | **4** | **5** |
| Maize | 48.55 | 36.41 | 24.28 | 12.14 | 0.00 |
| Sorghum (SK-5912) | 0.00 | 12.14 | 24.28 | 36.41 | 48.55 |
| Boiled Soya bean | 33.65 | 33.65 | 33.65 | 33.65 | 33.65 |
| Wheat offal | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| Fish meal | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 |
| Bone meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| +Premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Methionine | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Total | 100 | 100 | 100 | 100 | 100 |
| **Calculated Analysis** |  |  |  |  |  |
| Crude protein (%) | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 |
| ME (Kcal/kg) | 2950 | 2900 | 2900 | 2900 | 2850 |
| Crude fibre (%) | 4.00 | 4.00 | 4.00 | 3.80 | 3.80 |
| Ca (%) | 1.44 | 1.45 | 1.45 | 1.46 | 1.46 |
| P (%) | 0.74 | 0.77 | 0.80 | 0.82 | 0.86 |
| Lysine (%) | 1.20 | 1.21 | 1.23 | 1.24 | 1.25 |
| Methionine (%) | 0.37 | 0.36 | 0.35 | 0.34 | 0.33 |

*+A bio-organics nutrient supplement containing Vit. A; 4000000 i.u,Vit. D3; 800000 i.u, Vit. E; 9200mg; Niacin 11000mg; Vit. B2 2000mg; Vit. B6, 1200mg; Vit. B12 6mg; Vit. K3 800mg; Pantothenic acid 3000mg; Biotin 24mg; Folic acid 300mg; Choline Chloride 120000mg; Cobalt 80mg; Copper 1200mg; Iodine 400mg; Iron 8000mg; Manganese 16000mg; Selenium 80mg; Zinc 12000mg; Anti-oxidant 500mg.*

Table 11: Percentage composition of graded levels of Sorghum SK-5912 as replacement for maize in broiler finisher diets (5-8 weeks)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Ingredients** | **1** | **2** | **3** | **4** | **5** |
| Maize | 53.04 | 39.78 | 26.52 | 13.26 | 0.00 |
| Sorghum (SK-5912) | 0.00 | 13.26 | 26.52 | 39.78 | 53.04 |
| Boiled Soya bean | 26.16 | 26.16 | 26.16 | 26.16 | 26.16 |
| Wheat offal | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| Fish meal | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Bone meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| +Premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Methionine | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Total | 100 | 100 | 100 | 100 | 100 |
| **Calculated Analysis** |  |  |  |  |  |
| Crude protein (%) | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| ME (Kcal/kg) | 3000 | 2950 | 2950 | 2900 | 2900 |
| Crude fibre (%) | 4.24 | 4.16 | 4.08 | 4.00 | 3.92 |
| Ca (%) | 1.32 | 1.32 | 1.32 | 1.33 | 1.33 |
| P (%) | 0.77 | 0.80 | 0.83 | 0.86 | 0.89 |
| Lysine (%) | 1.09 | 1.11 | 1.12 | 1.13 | 1.15 |
| Methionine (%) | 0.49 | 0.49 | 0.48 | 0.47 | 0.46 |

*+A bio-organics nutrient supplement containing Vit. A; 4000000 i.u,Vit. D3; 800000 i.u, Vit. E; 9200mg; Niacin 11000mg; Vit. B2 2000mg; Vit. B6, 1200mg; Vit. B12 6mg; Vit. K3 800mg; Pantothenic acid 3000mg; Biotin 24mg; Folic acid 300mg; Choline Chloride 120000mg; Cobalt 80mg; Copper 1200mg; Iodine 400mg; Iron 8000mg; Manganese 16000mg; Selenium 80mg; Zinc 12000mg; Anti-oxidant 500mg.*

## 3.4 Experiment 2: Utilization of sorghum (SK-5912) variety with different plant protein sources by broiler chickens

### *3.4.1 Experimental birds and management*

Three hundred (300) unsexed, day old ‘*Marshal*’ broiler chicks were used for the experiment. Two before the arrival of the birds, the experimental pens and feeders and drinkers were thoroughly washed, cleaned, disinfected and dried. A week to their arrival, wood shavings were spread 8cm depth on the floor. Electrical appliances, feeders and drinkers were all put in place. Upon arrival of the chicks brooding commenced immediately, heat was provided by the use of 200W electric bulbs. The chicks were fed commercial starter diet for one week prior to the commencement of the experiment. Thereafter, the birds were randomly allotted to five experimental diets and replicated four times of 15 birds per replicate in a completely randomized design (CRD). The experimental diets and clean drinking water were provided *ad* *libitum* throughout the experimental period. The birds were vaccinated against Gumboro (Infectious bursal disease) on the 11th and 25th day while against Newcastle disease *(Lasota*) on the 20th day. All birds were reared on deep litter in an open sided poultry house.

### *3.4.2 Experimental Diets*

Fiveexperimental diets for both starter (23%CP) and finisher phases (20%CP) were formulated in which maize was included at 49.68% in diet 1 (control) and was replaced by sorghum SK-5912 at 49.68% for other diets in the starter phase. In the finisher phase, maize was included at 53.91% in diet 1 (control) and was replaced by sorghum SK-5912 at 53.91% in the other diets. Differently processed soya beans and ground nuts cakes were used as the plant protein sources as follows: Boiled soya beans for diets 1 and 2, and Soya bean meal, Industrial groundnuts cake and local ground nuts cake for diets 3, 4 and 5 respectively. Both the starter and finisher diets were fed for four (4) weeks each. Percentage composition of dietary levels of sorghum SK-5912 with different plant protein sources fed to broiler chickens at the starter phase and finisher phase are presented in Tables 12 and 13 respectively.

Table 12: Percentage composition of dietary levels of Sorghum SK-5912 with different plant protein sources fed to broiler starters (1-4 weeks)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Ingredients** | **1**  **(MBSB)** | **2**  **(SBSB)** | **3**  **(SSBM)** | **4**  **(SIGNC)** | **5 (SLGNC)** |
| Maize | 49.68 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sorghum (SK-5912) | 0.00 | 49.68 | 49.68 | 49.68 | 49.68 |
| Plant protein sources | 32.52 | 32.52 | 32.52 | 32.52 | 32.53 |
| Wheat offal | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| Fish meal | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 |
| Bone meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| +Premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Methionine | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Total | 100 | 100 | 100 | 100 | 100 |
| **Calculated Analysis** |  |  |  |  |  |
| Crude protein (%) | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 |
| ME (Kcal/kg) | 2950 | 2900 | 2850 | 2800 | 2800 |
| Crude fibre (%) | 4.10 | 4.02 | 3.95 | 3.88 | 3.80 |
| Ca (%) | 1.44 | 1.45 | 1.45 | 1.46 | 1.46 |
| P (%) | 0.74 | 0.77 | 0.80 | 0.82 | 0.86 |
| Lysine (%) | 1.20 | 1.21 | 1.23 | 1.24 | 1.25 |
| Methionine (%) | 0.37 | 0.36 | 0.35 | 0.34 | 0.33 |

*+A bio-organics nutrient supplement containing Vit. A; 4000000 i.u,Vit. D3; 800000 i.u, Vit. E; 9200mg; Niacin 11000mg; Vit. B2 2000mg; Vit. B6, 1200mg; Vit. B12 6mg; Vit. K3 800mg; Pantothenic acid 3000mg; Biotin 24mg; Folic acid 300mg; Choline Chloride 120000mg; Cobalt 80mg; Copper 1200mg; Iodine 400mg; Iron 8000mg; Manganese 16000mg; Selenium 80mg; Zinc 12000mg; Anti-oxidant 500mg.* MBSB = Maize + Boiled Soya Bean, SBSB = Sorghum SK-5912 + Boiled Soya Bean, SSBM = Sorghum SK-5912 + Soya Bean Meal, SIGNC = Sorghum SK-5912 + Industrial Groundnuts Cake, SLGNC = Sorghum SK-5912 + Local Groundnuts Cake.

Table 13: Percentage composition of dietary levels of Sorghum SK-5912 with different plant protein sources fed to broiler finishers (5-8 weeks)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Ingredients** | **1**  **(MBSB)** | **2**  **(SBSB)** | **3**  **(SSBM)** | **4**  **(SIGNC)** | **5 (SLGNC)** |
| Maize | 53.91 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sorghum (SK-5912) | 0.00 | 53.91 | 53.91 | 53.91 | 53.91 |
| Plant protein sources | 25.29 | 25.29 | 25.29 | 25.29 | 25.29 |
| Wheat offal | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| Fish meal | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Bone meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| +Premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Methionine | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Total | 100 | 100 | 100 | 100 | 100 |
| **Calculated Analysis** |  |  |  |  |  |
| Crude protein (%) | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| ME (Kcal/kg) | 2950 | 2950 | 2900 | 2850 | 2850 |
| Crude fibre (%) | 4.08 | 4.01 | 3.93 | 3.85 | 3.77 |
| Ca (%) | 1.71 | 1.71 | 1.71 | 1.72 | 1.72 |
| P (%) | 0.73 | 0.76 | 0.79 | 0.82 | 0.85 |
| Lysine (%) | 1.10 | 1.12 | 1.13 | 1.14 | 1.16 |
| Methionine (%) | 0.43 | 0.42 | 0.40 | 0.39 | 0.38 |

*+A bio-organics nutrient supplement containing Vit. A; 4000000 i.u,Vit. D3; 800000 i.u, Vit. E; 9200mg; Niacin 11000mg; Vit. B2 2000mg; Vit. B6, 1200mg; Vit. B12 6mg; Vit. K3 800mg; Pantothenic acid 3000mg; Biotin 24mg; Folic acid 300mg; Choline Chloride 120000mg; Cobalt 80mg; Copper 1200mg; Iodine 400mg; Iron 8000mg; Manganese 16000mg; Selenium 80mg; Zinc 12000mg; Anti-oxidant 500mg.* MBSB = Maize + Boiled Soya Bean, SBSB = Sorghum SK-5912 + Boiled Soya Bean, SSBM = Sorghum SK-5912 + Soya Bean Meal, SIGNC = Sorghum SK-5912 + Industrial Groundnuts Cake, SLGNC = Sorghum SK-5912 + Local Groundnuts Cake.

## 3.5 Experiment 3: Replacement value of Sorghum (SK-5912) variety for white sorghum in the diet of broiler chickens

### *3.5.1 Experimental birds and management*

Three hundred (300) unsexed, day old ‘*Marshal*’ broiler chicks were used for the experiment. Two before the arrival of the birds, the experimental pens and feeders and drinkers were thoroughly washed, cleaned, disinfected and dried. A week to their arrival, wood shavings were spread 8cm depth on the floor. Electrical appliances, feeders and drinkers were all put in place. Upon arrival of the chicks brooding commenced immediately, heat was provided by the use of 200W electric bulbs. The chicks were fed commercial starter diet for one week prior to the commencement of the experiment. Thereafter, the birds were randomly allotted to five experimental diets and replicated four times of 15 birds per replicate in a completely randomized design (CRD). The experimental diets and clean drinking water were provided *ad* *libitum* throughout the experimental period. The birds were vaccinated against Gumboro (Infectious bursal disease) on the 11th and 25th day while against Newcastle disease *(Lasota*) on the 20th day. All birds were reared on deep litter in an open sided poultry house.

### *3.5.2 Experimental Diets*

Fiveexperimental diets for both starter phase (23%CP) and finisher phase (20%CP) were formulated in which sorghum SK-5912 variety replaced white sorghum at 0, 25, 50, 75 and 100% tagged as diets 1 (control), 2, 3, 4, and 5 respectively, using boiled soya bean as plant protein. Both the starter and the finisher diets were fed for four (4) weeks each. Percentage composition of graded levels of sorghum SK-5912 variety as replacement for white sorghum fed to broiler chickens at the starter phase and finisher phase are presented in Tables, 14 and 15 respectively.

Table 14: Percentage composition of graded levels of sorghum SK-5912 as replacement for white sorghum broiler starter diets (1-4 weeks)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Ingredients** | **1** | **2** | **3** | **4** | **5** |
| White Sorghum | 50.64 | 37.98 | 25.32 | 12.66 | 0.00 |
| Sorghum (SK-5912) | 0.00 | 12.66 | 25.32 | 37.98 | 50.64 |
| Boiled Soya bean | 31.56 | 31.56 | 31.56 | 31.56 | 31.56 |
| Wheat offal | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| Fish meal | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 |
| Bone meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| +Premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Methionine | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Total | 100 | 100 | 100 | 100 | 100 |
| **Calculated Analysis** |  |  |  |  |  |
| Crude protein (%) | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 |
| ME (Kcal/kg) | 2900 | 2900 | 2900 | 2900 | 2900 |
| Crude fibre (%) | 3.64 | 3.64 | 3.64 | 3.64 | 3.64 |
| Ca (%) | 1.46 | 1.46 | 1.46 | 1.46 | 1.46 |
| P (%) | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| Lysine (%) | 1.30 | 1.30 | 1.30 | 1.30 | 1.30 |
| Methionine (%) | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 |

*+A bio-organics nutrient supplement containing Vit. A; 4000000 i.u,Vit. D3; 800000 i.u, Vit. E; 9200mg; Niacin 11000mg; Vit. B2 2000mg; Vit. B6, 1200mg; Vit. B12 6mg; Vit. K3 800mg; Pantothenic acid 3000mg; Biotin 24mg; Folic acid 300mg; Choline Chloride 120000mg; Cobalt 80mg; Copper 1200mg; Iodine 400mg; Iron 8000mg; Manganese 16000mg; Selenium 80mg; Zinc 12000mg; Anti-oxidant 500mg.*

Table 15: Percentage composition of graded levels of Sorghum SK-5912 as replacement for white sorghum in broiler finisher diets (5-8 weeks)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Ingredients** | **1** | **2** | **3** | **4** | **5** |
| White Sorghum | 55.31 | 41.48 | 27.66 | 13.83 | 0.00 |
| Sorghum (SK-5912) | 0.00 | 13.83 | 27.66 | 41.48 | 55.31 |
| Boiled Soya bean | 23.79 | 23.79 | 23.79 | 23.79 | 23.79 |
| Wheat offal | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| Fish meal | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Bone meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| +Premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Methionine | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Total | 100 | 100 | 100 | 100 | 100 |
| **Calculated Analysis** |  |  |  |  |  |
| Crude protein (%) | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| ME (Kcal/kg) | 2950 | 2950 | 2950 | 2950 | 2950 |
| Crude fibre (%) | 3.71 | 3.71 | 3.71 | 3.71 | 3.71 |
| Ca (%) | 1.43 | 1.43 | 1.43 | 1.43 | 1.43 |
| P (%) | 0.88 | 0.88 | 0.88 | 0.88 | 0.88 |
| Lysine (%) | 1.09 | 1.09 | 1.09 | 1.09 | 1.09 |
| Methionine (%) | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |

*+A bio-organics nutrient supplement containing Vit. A; 4000000 i.u,Vit. D3; 800000 i.u, Vit. E; 9200mg; Niacin 11000mg; Vit. B2 2000mg; Vit. B6, 1200mg; Vit. B12 6mg; Vit. K3 800mg; Pantothenic acid 3000mg; Biotin 24mg; Folic acid 300mg; Choline Chloride 120000mg; Cobalt 80mg; Copper 1200mg; Iodine 400mg; Iron 8000mg; Manganese 16000mg; Selenium 80mg; Zinc 12000mg; Anti-oxidant 500mg.*

## 3.6. Experiment 4: Replacement value of sorghum (SK-5912) variety for Pearl Millet in the diet of broiler chickens

### *3.6.1. Experimental birds and management*

Three hundred (300) unsexed, day old ‘*Marshal*’ broiler chicks were used for the experiment. Two before the arrival of the birds, the experimental pens and feeders and drinkers were thoroughly washed, cleaned, disinfected and dried. A week to their arrival, wood shavings were spread 8cm depth on the floor. Electrical appliances, feeders and drinkers were all put in place. Upon arrival of the chicks brooding commenced immediately, heat was provided by the use of 200W electric bulbs. The chicks were fed commercial starter diet for one week prior to the commencement of the experiment. Thereafter, the birds were randomly allotted to five experimental diets and replicated four times of 15 birds per replicate in a completely randomized design (CRD). The experimental diets and clean drinking water were provided *ad* *libitum* throughout the experimental period. The birds were vaccinated against Gumboro (Infectious bursal disease) on the 11th and 25th day while against Newcastle disease *(Lasota*) on the 20th day. All birds were reared on deep litter in an open sided poultry house.

### *3.6.2 Experimental Diets*

Fiveexperimental diets for both starter (23%CP) and finisher phases (20%CP) were formulated in which sorghum SK-5912 variety replaced white sorghum at 0, 25, 50, 75 and 100% coded as diets 1 (control), 2, 3, 4, and 5 respectively, using boiled soya bean as plant protein. Both the starter and the finisher diets were fed for four (4) weeks each. Percentage composition of graded levels of sorghum SK-5912 as replacement for pearl millet fed to broiler chickens at both starter phase and finisher phase are shown in Tables 16 and 17 respectively.

Table 16: Percentage composition graded levels of Sorghum SK-5912 as replacement for pearl millet in broiler starter diets (1-4 weeks)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Ingredients** | **1** | **2** | **3** | **4** | **5** |
| Pearl Millet | 49.75 | 37.31 | 24.88 | 12.44 | 0.00 |
| Sorghum (SK-5912) | 0.00 | 12.44 | 24.88 | 37.31 | 49.75 |
| Boiled Soya bean | 32.45 | 32.45 | 32.45 | 32.45 | 32.45 |
| Wheat offal | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| Fish meal | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 |
| Bone meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| +Premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Methionine | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Total | 100 | 100 | 100 | 100 | 100 |
| **Calculated Analysis** |  |  |  |  |  |
| Crude protein (%) | 23.00 | 23.00 | 23.00 | 23.00 | 23.00 |
| ME (Kcal/kg) | 2800 | 2800 | 2850 | 2900 | 2900 |
| Crude fibre (%) | 3.67 | 3.92 | 4.17 | 4.42 | 4.67 |
| Ca (%) | 1.47 | 1.46 | 1.46 | 1.46 | 1.46 |
| P (%) | 0.95 | 0.93 | 0.90 | 0.87 | 0.85 |
| Lysine (%) | 1.32 | 1.33 | 1.34 | 1.34 | 1.35 |
| Methionine (%) | 0.52 | 0.53 | 0.54 | 0.55 | 0.56 |

*+A bio-organics nutrient supplement containing Vit. A; 4000000 i.u,Vit. D3; 800000 i.u, Vit. E; 9200mg; Niacin 11000mg; Vit. B2 2000mg; Vit. B6, 1200mg; Vit. B12 6mg; Vit. K3 800mg; Pantothenic acid 3000mg; Biotin 24mg; Folic acid 300mg; Choline Chloride 120000mg; Cobalt 80mg; Copper 1200mg; Iodine 400mg; Iron 8000mg; Manganese 16000mg; Selenium 80mg; Zinc 12000mg; Anti-oxidant 500mg.*

Table 17: Percentage composition of graded levels of Sorghum SK-5912 as replacement for pearl millet in broiler finisher diets (5-8 weeks)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Ingredients** | **1** | **2** | **3** | **4** | **5** |
| Pearl Millet | 54.34 | 40.76 | 27.17 | 13.59 | 0.00 |
| Sorghum (SK-5912) | 0.00 | 13.59 | 27.17 | 40.76 | 54.34 |
| Boiled Soya bean | 24.76 | 24.76 | 24.76 | 24.76 | 24.76 |
| Wheat offal | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| Fish meal | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Bone meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| +Premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Methionine | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Total | 100 | 100 | 100 | 100 | 100 |
| **Calculated Analysis** |  |  |  |  |  |
| Crude protein (%) | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| ME (Kcal/kg) | 2850 | 2850 | 2900 | 2950 | 2950 |
| Crude fibre (%) | 3.74 | 4.02 | 4.29 | 4.56 | 4.83 |
| Ca (%) | 1.33 | 1.33 | 1.33 | 1.32 | 1.32 |
| P (%) | 0.88 | 0.85 | 0.83 | 0.82 | 0.76 |
| Lysine (%) | 1.11 | 1.12 | 1.12 | 1.13 | 1.14 |
| Methionine (%) | 0.46 | 0.48 | 0.49 | 0.50 | 0.51 |

*+A bio-organics nutrient supplement containing Vit. A; 4000000 i.u,Vit. D3; 800000 i.u, Vit. E; 9200mg; Niacin 11000mg; Vit. B2 2000mg; Vit. B6, 1200mg; Vit. B12 6mg; Vit. K3 800mg; Pantothenic acid 3000mg; Biotin 24mg; Folic acid 300mg; Choline Chloride 120000mg; Cobalt 80mg; Copper 1200mg; Iodine 400mg; Iron 8000mg; Manganese 16000mg; Selenium 80mg; Zinc 12000mg; Anti-oxidant 500mg.*

**3.7 Experimental Design**

All experiments were conducted in a completely randomized design (CRD), ( Steel and Torrie, 1980).

**3.8 Data Collection**

### *3.8.1 Performance parameters*

Feed consumption, Weight changes, and feed conversion ratio constituted the performance parameters. Feed intake was determined by subtracting the left over every morning from the quantity offered the previous day. Birds were weighed at the beginning of each experiment and weekly thereafter and weight changes were calculated by the difference between two consecutive weeks. Feed conversion ratio, on the other hand, was calculated by dividing the quantity of feed consumed by the weight gain as follows:

### *3.8.2 Mortality*

All records of mortality were taken and where it occurred post-mortem examination is carried out to ascertain the cause of death throughout the study period.

### *3.8.3 Blood Parameters*

At the end of each experiments (1, 2, 3, and 4) blood samples were collected to determine the haematological and serum biochemical parameters. The birds were randomly selected, fasted overnight and bled early in the morning to avoid temporarily elevation of blood metabolites by feeding (Bush, 1975). Packed cell volume (PCV), haemoglobin (Hb), white blood cells (WBC), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and MCHC are haematological parameters measured. Serum parameters measured include total protein, albumin, globulin, creatinine, alaninetransferase (ALT), and aspartate aminotransferase (AST). Samples for haematological study were collected in to sample tubes containing ethylene diamine tetra-acetic acid (EDTA) as anticoagulant. Serological samples were collected in to anticoagulant free tubes. Serum was obtained after the blood samples have been allowed to stand for 2 hours at room temperature and centrifuged at 2,000 revolutions per minute (rpm) for 10 minutes using a Biotech 521 bucket centrifuge to separate the plasma from the serum. Blood samples were analyzed for haematological parameters according to routine clinical methods (Baker *et al*., 1998).

***3.8.3.1. Packed cell volume (PCV) or Haematocrit***

The PCV was determined using wintrobe’s micro-haematocrit method. The method uses small blood samples (50 microlitres) capillary tubes and micro-centrifuge. An un-calibrated capillary tube, 75cm long and 1mm in diameter was used. The blood samples were gently mixed in the collection tubes by capillary attraction and were removed when two-third of it are filled with blood. One end of the tube was sealed by a hot flame and then placed with sealed end outwards in the centrifuge. This was spun at 2000 rpm for 5 minutes to allow the centrifugal force to separate the blood in to cells and plasma. The PCV for each sample was read using Hawskley microhaematocrit reader (Gelman-Hawskley, limited, UK) graded in percentages.

***3.8.3.2. White blood cells (WBC) or leucocyte***

The improved haemocytometer method was used for the determination of leucocyte counts. Blood was drawn to the 0.5 unit mark on the stem of the white cell pipette and diluting fluid to the 1 unit mark. This produced a dilution of 1:2. The WBC diluting fluid (Turk’s solution) contained 1% glacial acetic acid, which destroys the erythrocytes, tinged with gentian violet (0.01%) which stained the leucocytes. Up to half of the pipette content was blown out and discarded to expel the cell-free fluid from the pipette. The cells in the 4 corner primary squares were counted using the Neubauer chamber. The × 10 objective and × 10 eye piece were used in the counting. The white blood cells counts were obtained by calculation as follows:

Let N= Number of cells counted in 4mm2

Since the depth of the chamber = 1/10mm

N cells are counted in 4/10mm3(i.e 4×1/10mm3) of dilute blood.

1mm3 of diluted blood contains N×10/4cells

Since blood was diluted 1 in 20 (1:20)

1mm3 *of blood contains N×10/4×20/1 = 50Ncells*

***3.8.3.3. Haemoglobin (Hb) concentration***

The Hb concentration of the samples was estimated, using the acid haematin or Sahli method. The blood was diluted in a solution of HCl, which converted haemoglobin to haematin. The graduated tube was filled to the 20-unit mark with 0.1N HCl. About 0.02ml of blood was added, mixed well and allowed to stand for 10 minutes. The acid (0.1N HCl) was added drop by drop mixing between each addition until colour matched the standard. The amount of solution in the graduated tube was read on the calibration, which gave the haemoglobin concentration as a percentage (%). The percentage was converted to g/l by multiplying the values by 1.46 (WHO, 1980).

The serum biochemical indices include the level of total protein, albumin, globulin, cholesterol,creatinine, glucose, Alanineaminotranferase (ALT) and Aspatateaminotransferase (AST). Samples of blood for biochemical study were collected in anti-coagulant free tubes and allowed to clot. Sera were obtained after the blood samples has been allowed to stand for two hours at room temperature and centrifuged for ten minutes at 2,000 rpm to separate the plasma from the serum. Serum is preferred for the estimation of biochemical substances because many of these substances are present in different concentration in the serum and it is concentration in the serum, which changes in disease or abnormal condition and therefore aids in diagnosis (Bush, 1991). The biochemical indices were determined using Sigma assay kits.

### *3.8.4 Carcass Evaluation*

At the end of the finisher phase, forty birds (eight birds per treatment) were randomly selected from the five treatment diets and fasted for 12 hours before slaughtering. Each bird was weighed and slaughtered. The weights of the dressed carcass were taken and internal organs weights were measured using sensitive balance (CAMRY-EHA251) while their lengths were also measured using measuring rule.

### *3.8.5 Chemical Analysis*

The proximate composition of sorghum SK-5912 grains and experimental diets were determined according to the methods of AOAC (2006).

***3.8.5.1 Crude protein***

Crude protein content of the various samples was determined by the kjeldahl procedure (AOAC, 2006). The equipment used as the kjeltec systems were manufactured by *Tecator Ltd. Hogunas,* Sweden. Three stages digestion, distillation and titration were involved.

***(a) Digestion***

About 1g of the sample was weighed in to a clean, dry digestion tube. One kjel tablet, as catalyst was added. Thereafter, 20ml of conc. Tetraoxosulphate VI acid (H2SO4) were added and the digestion tube placed on the digestion block. Digestion continued until all the samples were completely digested, leaving a colourless solution. The colourless solution was cooled and diluted with 80ml of distilled water. 10ml of the diluted solution was pipette out in to another digestion tube for distillation.

***(b) Distillation***

About 20ml of saturated solution of boric acid containing bromocresol green and methyl red indicator was measured in to a 250ml conical flask. The conical flask was placed under the tip of the condenser in the distillation unit, so that the out-let of the tip was below the surface of the boric acid. 10ml of the sodium hydroxide (NaOH) solution was carefully added down the side of the digestion tube and immediately connected to the distillation unit. The alkali dispensing level was released to start the distillation, for 5 minutes therein the ammonia released was collected in the boric acid.

***(c) Titration***

The green distillate was titrated against 0.1N HCl until a neutral grey end point was obtained. The volume of the acid was recorded. The same procedure was followed for the blanks.

The crude protein of the sample was calculated thus:

% = *14.0 × (ml of titrant sample of titrant of blank) × molarity of standard acid.* ..(5)

*g of sample × 10*

The crude protein (%) = N × 6.25 (factor for feed)

***3.8.5.2. Ether extract***

Previously dried samples (1.0g) were weighed in to a thimble. The mouth of the thimble was plugged with fat-free absorbent cotton. The receiving flask was weighed and then thimble with sample introduced in to soxhlet filled with petroleum ether by pouring it through the condenser at the top through a glass funnel. The apparatus was placed in a water bath at 60ºC and fixed by clamps to a retort stand. The cold water circulation in the condenser was turned on. After extraction, the thimble with the material was removed from the soxhlet, reassembled and heated in a water bath to recover all the petroleum ether from the flask. The flask which contained only the crude fat was disconnected, dried in a hot-air oven at 100ºC for 1 hour, and cooled in desiccators and weighed. The ether extract (EE) content was calculated thus:

EE% = *wt of flask containing oil – wt of empty flask after extraction × 100* .... (6)

*Wt of dried sample taken*

***3.8.5.3 Crude fibre***

One gram (1.0g) of the sample was weighed in to a 500 ml conical flask and 100 ml digestion reagent added. The digestion reagent was prepared by mixing 500 ml Conc. Trioxonitrate acid (HNO3) and 20.0g trichloroacetic acid in the flask containing the sample and the digestion reagent was boiled and refluxed for exactly 40 minutes, counting from the time heating commenced. After 40 minutes, the flask was removed from the heater and cooled. The solution was filtered through a 15cm. No. 4 Whatman ashless paper. This was washed several times with hot water and with petroleum ether. The filter paper at this stage was opened out and the residue poured in, and air-dried overnight at 105ºC. After the drying, the residue was cooled in desiccators and weighed. The residue was washed at 600ºC, cooled and weighed. The crude fibre was calculated thus:

*Crude fibre = (wt after oven drying – wt of ash + wt of paper × 100)* ... (7)

***3.8.5.4 Total ash***

The ash content was determined by incinerating 1.0g of the sample in a furnace at 600ºC for 3 hours. The residue or ash was cooled in desiccators and weighed.

Ash = *weight of residue × 100*  ..... (8)

*Weight of dried sample*

***3.8.5.5 Nitrogen free extracts (NFE)***

This was obtained by calculation

*% NFE = 100% - (%CP + %EE + %CF + %Ash + %Moisture)* ... (9)

***3.8.5.6 Dry matter and /or Organic matter***

Dry matter was calculated by subtraction after drying samples to constant weight in an oven at 105ºC.

*%DM = 100 – Moisture+Organic matter (calculated by deducting the %ash from % dry matter)* ...... .... (10)

***3.8.5.7 Metabolizable energy***

Metabolizable energy was calculated according to the methods of Ichaponani (1980).

ME (kcal./kg) = 432 + 27.91 (CP + NFE + 2.25 × EE) .......(11)

***3.8.5.8 Calcium and Phosphorus***

The percentage calcium and phosphorus of the samples were determined by the wet method, using acid digestion of the samples followed by the use of Atomic Absorption Spectrophotometer (AAS). Five standard solutions with known calcium contents were prepared. The test tubes containing these solutions were placed in a spectrophotometer and reading for the standard solution on the x-axis and the percentage calcium content of the sample. The sample procedure was used for the determination of phosphorus, the Spectrophotometer reading of the standard solutions with known phosphorus content (%) was used to plot the calibration graphs.

***3.8.6 Economic Analysis***

The economic analysis of broiler production was calculated to assess the cost benefits of replacing maize with sorghum SK-5912 variety, and its utilization with different plant protein sources as well as replacement for white sorghum and pearl millet as dietary energy sources for broiler chickens.

1. Feed cost per kilogram of each diet.
2. The cost of feeding birds on the respective diets throughout the period of the study.
3. Feed cost per kilogram weight gain.

The cost of the diets (₦/kg) was calculated based on the prevailing market price (₦/kg) of the ingredients used in the formulation as at the time of the study.

## 3.9 Statistical Analysis

All data generated were subjected to analysis of variance (ANOVA) technique as described by Steel and Torrie, (1980), using Minitab software statistical package (Minitab, 2014). Differences between treatment means were separated using Duncan Multiple Range Test (Duncan, 1955).

# CHAPTER FOUR

## 4.0 RESULTS

## 4.1 Chemical and calculated composition of Sorghum SK-5912 and experimental diets

The proximate composition of sorghum SK-5912 variety is presented in Table 9. The results showed that it has crude protein averages 10.96%, crude fibre is 2.71%, ether extract 3.12%, total ash 2.19% and NFE 77.58%.While the tannin content is 4.43mg/kg, phytic acid 326.89mg/kg and hydrocyanic acid 3.41%.

**4.2. Experiment 1: Performance, Blood Composition, Carcass Characteristics, and Cost Benefit Analysis of Broiler Chickens fed Sorghum SK-5912 Variety as Replacement for Maize**

**4.2.1. *Productive performance of broiler chickens fed dietary levels of sorghum SK-5912 variety***

The productive performances of broiler chickens fed sorghum SK-5912 variety based diets are presented in Table 18. The initial weight of the broiler chicks were similar and ranged from 81.67 to 83.75g on diets 2 and 1 respectively. The body weights at 4 weeks were also similar values obtained are between 733.02 to 855.91g on diets 2 and 1 respectively. The total body weight gain varied from 1567.50 to 1841.50g on broiler chickens fed diets 2 and 1. Values recorded for final weight ranged from 1668.10 to 1925.50g on diets 2 and 1 respectively.

***4.2.1.1. Starter phase (1-4 weeks of Age)***

The daily feed intake (DFI) at the starter phase varied from 50.20 to 54.00g in broiler birds fed diets 3 and 1 respectively. However, values obtained did not differ significant among the treatment groups. The daily weight gain (DWG) values varied between 24.01 and 27.55g in broiler chicks fed diets 5 and 3 respectively. The DWG followed the same trend as the DFI and were similar. The feed conversion ratio did not differ and varied between 1.84 and 2.17 on diets 3 and 2 respectively. The mortality values range between 1 and 3 birds on diets 5 and 2 respectively.

***4.2.1.2. Finisher phase (5- 8 weeks)***

The daily feed intake ranged from 117.51 to 122.77g for broiler chickens fed diets 4 and 2 respectively. The result showed no significant difference at the finisher phase. The daily weight gain varied from 40.35 to 49.49g for birds on diets 3 and 1 respectively. All the daily weight gain values obtained at the finisher phase did not differ. The feed conversion ratio (FCR) ranged between 2.47 and 3.01 for birds on diets 1 and 3 respectively. The FCR observed on all the dietary levels of sorghum SK-5912 were similar. Two birds each died on diets 1 and 5, whereas no mortality was recorded on the other diets.

***4.2.1.3. Overall phase (1-8 weeks)***

The overall daily feed intake ranged from 80.44 to 83.38g for broiler chickens fed on diets 4 and 2 respectively. The result showed that there was no significant difference at the overall phase. The daily weight gain varied from 31.73 to 36.83g for birds on diets 2 and 1 respectively. All the daily weight gain values obtained in broiler birds fed the dietary treatment did not differ significantly at the overall phase. The feed conversion ratio (FCR) ranged between 2.27 and 2.64 for birds on diets 1 and 2 respectively. The FCR values observed on all the dietary levels of sorghum SK-5912 were similar. The mortality rate of the chickens during the overall phase ranged from 2 to 4 and no evidence of any disease regarding the death.

Table 18: Performance of broiler chickens fed graded levels of sorghum SK-5912 as replacement for maize

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **1**  **(0%)** | **2**  **(25%)** | **Diets**  **3**  **(50%)** | **4**  **(75%)** | **5 (100%)** | **SEM** |
| **Productive performance** |  |  |  |  |  |  |
| Initial weight (g) | 83.75 | 81.67 | 82.85 | 82.63 | 82.95 | 0.76NS |
| Body weight at 4 wks (g) | 855.91 | 733.02 | 803.99 | 758.08 | 755.05 | 14.26NS |
| Final body wgt. at 8wk(g) | 1925.30 | 1668.10 | 1742.00 | 1755.40 | 1679.90 | 29.32NS |
| Total weight gain (g) | 1841.50 | 1567.50 | 1659.20 | 1672.80 | 1596.90 | 29.22NS |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **Starter phase (1-4 wks)** |  |  |  |  |  |  |
| Daily feed intake (g) | 54.00 | 52.44 | 50.20 | 51.31 | 50.58 | 1.21 NS |
| Daily weight gain (g) | 26.89 | 24.18 | 27.55 | 25.60 | 24.01 | 1.03 NS |
| Feed Conversion Ratio | 2.02 | 2.17 | 1.84 | 2.01 | 2.12 | 0.07 NS |
| Mortality (Number) | 2 | 3 | 2 | 2 | 1 | - |
| **Finisher phase (5-8 wks)** |  |  |  |  |  |  |
| Daily feed intake (g) | 120.07 | 122.77 | 120.76 | 117.51 | 119.17 | 1.96NS |
| Daily weight gain (g) | 49.49 | 41.34 | 40.35 | 43.46 | 42.04 | 3.27NS |
| Feed conversion ratio | 2.47 | 3.00 | 3.01 | 2.74 | 2.97 | 0.20NS |
| Mortality (Number) | 2 | 0 | 0 | 0 | 2 | - |
| **Overall phase (1-8wks)** |  |  |  |  |  |  |
| Daily feed intake (g) | 83.07 | 83.38 | 81.24 | 80.44 | 80.76 | 1.28NS |
| Daily weight gain (g) | 36.83 | 31.73 | 33.19 | 33.46 | 31.94 | 1.32NS |
| Feed conversion ratio | 2.27 | 2.64 | 2.46 | 2.42 | 2.56 | 0.10NS |
| Mortality (Number) | 4 | 3 | 2 | 2 | 3 | - |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

NS= Not significant, SEM = Standard Error of Means

* + 1. ***Blood Parameters***

The results of the haematological and serum biochemistry are presented in Tables 20 and 21. The haematological values observed include packed cell volume which ranges between 32.15 to 39.88% on diets 1 and5 respectively, white blood cells 24.57 to 25.76×103/µL for diets 1 and 5, red blood cells 2.17 to 2.32× 106/ µL for diets 1 and 3, haemoglobin 10.20 to 10.90g/dl on diets 1 and 4 respectively, and mean corpuscular volume (MCV) values ranged between 148.55 to 159.75fl for diets 1 and 5, mean corpuscular haemoglobin (MCH) were between 46.25 to 48.30pg for diets 3 and 4, mean corpuscular haemoglobin concentration ( MCHC) values ranged between 29.70 to 31.75g/dl on diets 5 and 1, and platelet 135.00 to 212.75×103/µL on diets 3 and 5 respectively. All of these were not significantly affected by the dietary levels of sorghum SK-5912 variety.

The results of the serum biochemical indices observed showed that total protein values ranged between 36.00 to 48.00 g/l on diets 5 and 2 respectively, where as albumin ranged between 10.50 to 14.00 g/l on diets 4 and 1 respectively, and globulin 25.00 to 35.50 g/l for diets 5 and 2 respectively. Also values obtained for creatinine were between 2.34 and 7.10 µmol/L on diets 3 and 1, while total cholesterol values were between 2.83 and 7.15 mmol/l on diets 5 and 4, and High Density Lipoprotein values were 1.18 to 2.70 mmol/l on diets 5 and 1 respectively, while Low Density Lipoprotein values of 1.48 to 2.25 mmol/l for 5 and 4, values observed for triglycerides were between 0.50 to 1.90 mmol/l on diets 5 and 1respectively. Similarly, values observed for aspartate amino transferase (AST) ranged between 58.75 and 204.00IU/L for diets 5 and 2 respectively, and alanine amino transferase (ALT) ranged between 14.50 and 68.00IU/L on diet 5 and diets 3 and 4 respectively.

Table 19: Haematological values of broiler chickens fed graded levels of sorghum SK-5912 as replacement for maize

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** |  |  | **Diets** |  |  |  |
| **1** | **2** | **3** | **4** | **5** | **SEM** |
| PCV (%) | 32.15 | 32.98 | 34.90 | 34.55 | 39.88 | 0.92 NS |
| RBC (×103/µL) | 2.17 | 2.26 | 2.32 | 2.26 | 2.29 | 0.06 NS |
| Hb (g/dl) | 10.20 | 10.60 | 10.70 | 10.90 | 10.80 | 0.26 NS |
| MCV (fl) | 148.55 | 151.68 | 150.55 | 153.20 | 159.75 | 3.48 NS |
| MCH (pg) | 47.10 | 47.43 | 46.25 | 48.30 | 47.35 | 0.41 NS |
| MCHC (g/dl) | 31.75 | 31.28 | 30.75 | 31.55 | 29.70 | 0.64 NS |
| WBC (×103/µl) | 24.57 | 25.10 | 25.13 | 25.14 | 25.76 | 2.52 NS |
| PLT (×103/µL) | 156.50 | 187.00 | 135.00 | 202.50 | 212.75 | 33.68 NS |

NS= Not significant, SEM= Standard error of mean, PCV= Packed Cell Volume, RBC= Red Blood Cell, WBC= White Blood Cell, Hb= Haemoglobin Concentration, MCV= mean corpuscular volume, MCH= mean corpuscular haemoglobin, MCHC= mean corpuscular haemoglobin concentration, PLT= Platelet.

Table 20: Serum biochemical values of broiler chickens fed graded levels of sorghum SK- 5912 as replacement for maize

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** |  |  | **Diets** |  |  |  |
| **1** | **2** | **3** | **4** | **5** | **SEM** |
| Total Protein (g/L) | 45.00 | 48.00 | 39.50 | 41.50 | 36.00 | 2.81 NS |
| Albumin (g/L) | 14.00 | 12.50 | 12.00 | 10.50 | 11.00 | 2.34 NS |
| Globulin (g/L) | 31.00 | 35.50 | 27.50 | 31.00 | 25.00 | 2.71 NS |
| Creatinine (µmol/L) | 7.10 | 2.58 | 2.35 | 2.60 | 5.90 | 1.64 NS |
| Cholesterol (mmol/L) | 5.65 | 5.18 | 5.65 | 7.15 | 2.83 | 0.97 NS |
| HDL (mmol/L) | 2.70 | 2.40 | 1.45 | 1.55 | 1.18 | 0.22 NS |
| LDL (mmol/L) | 1.50 | 1.88 | 2.05 | 2.25 | 1.48 | 0.23 NS |
| Triglyceride(mmol/L) | 1.90 | 0.95 | 1.00 | 1.10 | 0.50 | 0.40 NS |
| AST (IU/L) | 121.50 | 204.00 | 95.50 | 122.00 | 58.75 | 15.54 NS |
| ALT (IU/L) | 49.50 | 31.00 | 68.00 | 68.00 | 14.50 | 9.85 NS |
|  |  |  |  |  |  |  |

NS= Not significant, SEM= Standard error of mean, AST= Aapartate Amino Transferase, ALT= Alanine Amino Transferas,

* + 1. ***Carcass and visceral organs characteristics of broiler chickens fed graded levels of sorghum SK-5912 variety as replacement for maize***

The carcass characteristics of broiler chickens fed dietary levels of sorghum SK-5912 as replacement for maize are presented in Table 19. The live weight of birds slaughtered varied between 1.71 and 1.82 kg for those fed diets 5 and 1 respectively. However, the dietary levels of sorghum SK-5912 did not significantly influenced the live weight of broiler chickens at the end of the trial. The plucked weight (1.55 to 1.67 kg) and eviscerated weight (1.29 to 1.43 kg) were not affected by the dietary treatments. The dressing percentage values of 70.20 to 73.49% were obtained in broiler chickens fed diets 2 and 5 respectively. The dressing percentage did not differ significantly across the dietary treatments. The lungs values of 0.52 and 0.60% obtained in diets 4 and 1, the heart values of 0.50 and 0.55% obtained in diets 1, then 2 and 5, the liver values of 1.69 and 2.08% obtained in diets 4 and 1 were not significantly different across the dietary levels of sorghum SK-5912.

The values of large intestine weight varied between 0.33% (diet 5) and 0.16% (diets 1 and 2) and were significantly (P<0.001) affected by the dietary levels of sorghum SK-5912. The values of kidney weight varied between 0.21% (diet 5) and 0.28% (diet 1) and that of abdominal fat varied between 1.08% (diet 5) and 1.39% (diet 1), likewise gizzard values of 2.27% (diet 4) and 2.56% (diets 1 and 2). However, all did not differ across the dietary treatment. The caecal weight values of (0.40% diet 1) and 0.53 (diet 3), pancreas weights of 0.25% (diet 4) and 0.32% (diet 3), small intestine weight values of 2.39% (diet 5) and 3.10% (diet 1) and spleen weight values of 0.13% (diets 3 and 5) and 0.19% (diet 4) were also not influenced by the dietary levels of sorghum SK-5912 variety. Values obtained for abdominal fat varied between 1.08% on diet 5 to 1.39% on diet 1 and was not affected by the dietary treatments. The values obtained for small intestine length varied between148.00 cm for diet 4 and 171.88 cm for diet 1, and small intestine weight varied between 2.39 % on diet 5 and 3.10% on diet 1, and all were not significantly affected by the dietary treatments. Large intestine lengths differ significantly at P<0.001, values obtained varied between 7.77 cm on diet 5 and 10.14 cm on diet 2, across the dietary levels of sorghum SK-5912.

Table 21: Carcass and visceral organs characteristics of broiler chickens fed graded levels sorghum SK-5912 as replacement for maize

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** |  |  | **Diets** |  |  |  |
| **1** | **2** | **3** | **4** | **5** | **SEM** |
| Live weight (kg) | 1.82 | 1.79 | 1.79 | 1.79 | 1.71 | 0.06 NS |
| Plucked weight (kg) | 1.67 | 1.61 | 1.65 | 1.63 | 1.55 | 0.07 NS |
| Eviscerated weight (kg) | 1.43 | 1.40 | 1.29 | 1.43 | 1.32 | 0.08 NS |
| Carcass weight (kg) | 1.32 | 1.26 | 1.28 | 1.31 | 1.26 | 0.06 NS |
| Dressing percentage | 71.89 | 70.20 | 71.69 | 73.00 | 73.49 | 1.48 NS |
| Lungs weight (%) | 0.60 | 0.55 | 0.54 | 0.52 | 0.55 | 0.06NS |
| Heart weight (%) | 0.50 | 0.55 | 0.54 | 0.52 | 0.55 | 0.06 NS |
| Liver weight (%) | 2.08 | 1.79 | 1.95 | 1.69 | 1.84 | 0.18 NS |
| Kidney weight (%) | 0.28 | 0.26 | 0.25 | 0.26 | 0.21 | 0.03 NS |
| Abdominal fat weight (%) | 1.39 | 1.32 | 1.14 | 1.22 | 1.08 | 0.15 NS |
| Gizzard weight (%) | 2.56 | 2.56 | 2.45 | 2.27 | 2.43 | 0.18 NS |
| Small intestine weight (%) | 3.10 | 2.87 | 2.53 | 2.41 | 2.39 | 0.26 NS |
| Small intestine length (cm) | 171.88 | 157.50 | 167.88 | 148.00 | 160.75 | 7.93 NS |
| Large intestine weight (%) | 0.16b | 0.16b | 0.20ab | 0.18ab | 0.33a | 0.17\*\*\* |
| Large intestine length (cm) | 9.40 | 10.14 | 9.58 | 8.40 | 7.77 | 1.21 NS |
| Caaecal weight (%) | 0.40 | 0.49 | 0.53 | 0.50 | 0.46 | 0.04 NS |
| Caecal length (cm) | 17.19 | 16.25 | 16.75 | 16.69 | 15.88 | 0.64 NS |
| Pancreas weight (%) | 0.31 | 0.26 | 0.32 | 0.25 | 0.28 | 0.03 NS |
| Spleen weight (%) | 0.18 | 0.17 | 0.13 | 0.19 | 0.13 | 0.03 NS |

abcMeans bearing different superscripts within the same row differ (\*\*\*=P<0.001), NS=Not Significant, SEM=Standard Error of Mean.

* + 1. ***Cost benefit analysis of broiler chickens fed sorghum SK-5912 variety as replacement for maize***

The cost effectiveness analysis of broiler chickens production fed sorghum SK-5912 variety based diets is shown in Table 22. The total feed intake at the starter phase varied between 1.41 and 1.51kg on diets 3 and 1 respectively. All the values observed on the dietary treatments were lower than the value on the control diet. The feed cost (₦/kg) ranged from ₦134.04 on diet 5 to ₦163.46 on diet 1. The values decreased with increasing levels of sorghum SK-5912. The total feed cost (₦) ranged from ₦190.34 diet 5 and ₦246.82 on diet 1. The total weight gain (kg) ranged from 0.67kg to 0.77kg on diets 5 and 3 respectively during the starter phase. The value on the control diet (0.75kg) is only lower compared to diet 3 (0.77kg). The feed cost in ₦ per kg gain varied between ₦259.58 to ₦329.09 on diets 3 and 1 respectively and were cheaper on other treatment diets than on the control diet ₦329.09.

At the finisher phase, the total feed intake values varied between 2.62kg to 2.70kg for diets 5 and 2 respectively. The values of feed cost (₦/kg) ranged from ₦111.64 to ₦144.85 on diets 5 and 1. The values reduced with increasing level of sorghum SK-5912 variety. Similarly, the values of total feed cost decreased with increasing level of sorghum SK-5912 variety and varied from ₦292.50 to ₦382.40 on diets5 and 1 respectively. The total weight gain in kg ranged from 0.89 to1.09kg on diets 3 and 1 respectively. The value on diet 1 (1.09kg) was higher than all other values among the treatment groups. Feed cost ₦/kg gain values varied between ₦314.52 and ₦360.65 on diets 5 and 2 respectively. Except the values on diet 2 (₦360.65), all other values are lower compared to the value on the control diet (₦350.83).

The overall total feed intake varied between 4.03 and 4.17kg on diets 4 and 2 respectively. The values observed on diets 2 was higher then followed by the control diet (4.15kg). The feed cost in ₦ per kg gain ranged from ₦111.64 to ₦144.85 on diets 5 and 1 respectively and decreased with increasing levels of sorghum SK-5912 variety. The total feed cost values varied between ₦496.27 and ₦639.76 on diets 5 and 1 respectively.

The total weight gain had the highest the highest observed value on the control diet (1.84kg) and the least was diet 2 (1.59kg). The highest value observed for feed cost ₦ per kg weight gain was on diet 1 (₦347.70) and the least on diet 4 (₦305.68). The feed cost in ₦ per kg gain of all the treatment groups were lower compared to the value on the control diet and there is a cost saving on all the treatment diets. The percentage cost saving varied between 0.38% on diet 2 and 12.09% on diet 4.

Table 22: Cost benefit analysis of broiler chickens fed graded levels of sorghum SK-5912 as replacement for maize

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Parameters** | **1** | **2** | **3** | **4** | **5** |
| **Starter phase** |  |  |  |  |  |
| Total feed intake (kg) | 1.51 | 1.47 | 1.41 | 1.44 | 1.42 |
| Feed cost (₦/kg) | 163.46 | 142.60 | 141.76 | 137.90 | 134.04 |
| Total feed cost (₦) | 246.82 | 209.62 | 199.88 | 198.58 | 190.34 |
| Total weight gain (kg) | 0.75 | 0.68 | 0.77 | 0.72 | 0.67 |
| Feed cost ₦/kg gain | 329.09 | 308.26 | 259.58 | 275.81 | 284.09 |
| **Finisher phase** |  |  |  |  |  |
| Total feed intake (kg) | 2.64 | 2.70 | 2.66 | 2.59 | 2.62 |
| Feed cost (₦/kg) | 144.85 | 121.55 | 120.25 | 116.95 | 111.64 |
| Total feed cost (₦) | 382.40 | 328.19 | 312.96 | 302.90 | 292.50 |
| Total weight gain (kg) | 1.09 | 0.91 | 0.89 | 0.96 | 0.93 |
| Feed cost ₦/kg gain | 350.83 | 360.65 | 351.64 | 315.52 | 314.52 |
| **Overall performance** |  |  |  |  |  |
| Total feed intake (kg) | 4.15 | 4.17 | 4.07 | 4.03 | 4.04 |
| Feed cost (₦/kg) | 154.16 | 132.08 | 132.01 | 127.43 | 122.84 |
| Total feed cost (₦) | 639.76 | 550.77 | 537.28 | 513.54 | 496.27 |
| Total weight gain (kg) | 1.84 | 1.59 | 1.66 | 1.68 | 1.60 |
| Feed cost ₦/kg gain | 347.70 | 346.39 | 323.66 | 305.68 | 310.17 |
| Cost saving (₦) | 0.00 | 1.31 | 24.04 | 42.02 | 37.53 |
| % cost saving | 0.00 | 0.38 | 6.91 | 12.09 | 10.79 |
| Ranking cost ₦/kg gain | Diet 1> | Diet 2> | Diet 3> | Diet 5> | Diet 4 |

**Experiment 2: Performance, Blood Composition, Carcass Characteristics, and Cost Benefit Analysis of Broiler Chickens fed Sorghum SK-5912 variety with different plant protein sources**

**4.3.1. *Productive performance of broiler chickens fed graded levels sorghum SK-5912 variety with different plant protein sources***

The productive performance of broiler chickens fed sorghum SK-5912 variety with different plant protein sources are presented in Table 23. The initial weight of the broiler chicks varied between 51.23 to 53.87g on diets 4 and 2 respectively. The body weight at week 4 differ significantly (P<0.01) among the different treatment groups within a range of (624.55 - 746.28g). The final weight ranged from 1422.60 to 1539.40g on diets on diets 3 and 1 respectively. The total body weight gain varied from 1371.20g to 1487.20g on broiler chickens fed diets 3 and 1 respectively.

***4.3.1.1. Starter phase (1-4 weeks of Age)***

The daily feed intake at the starter phase varied from 43.49g to 51.17g in broiler birds fed diets 5 and 2 respectively and values obtained were significantly (P<0.01) affected by the dietary levels of the treatment groups. The daily weight gain was also significantly (P<0.001) affected by the dietary treatments, values observed varied between 20.48 to 24.78g in broiler diets fed diets 4 and 1 respectively. The feed conversion ratio varied from 1.90 to 2.23 on diets 4 and 1 respectively and were significantly (P<0.05) influenced by the dietary means. The mortality values ranged between 1 to 2 birds.

***4.3.1.2. Finisher phase (5- 8 weeks)***

The daily feed intake ranged from 112.96 to 124.43g for broiler chickens fed on diets 1 and 5 respectively. The result showed that there was no significant difference at the finisher phase. The daily weight gain varied from 31.94 to 39.88g for birds on diets 3 and 4 respectively. All the daily weight gain values obtained in broiler birds fed the dietary treatment did not differ significantly (P>0.05) at the finisher phase. The feed conversion ratio ranged between 3.13 and 4.18 for birds on diets 4 and 3 respectively. The feed conversion ratios observed on all the dietary treatments were similar. The mortality rate of the chicks during the finisher phase ranged from 0 to 1 for birds on diets 3 on one hand and those on 1, 2, 4, 5 on the other.

***4.3.1.3. Overall phase (1-8 weeks)***

The overall daily feed intake ranged from 79.70 to 83.30g for broiler chickens fed on diets 4 and 1 respectively. The result showed that daily feed intake was significantly (P<0.01) affected by the dietary treatments at the overall phase. The daily weight gain varied from 27.43 to 29.75g for birds on diets 3 and 1 respectively. All the daily weight gain values obtained in broiler birds fed the dietary treatments did not differ significantly at the overall phase. The feed conversion ratio ranged between 2.70 and 3.03 for birds on diets 1 and 3 respectively and values observed on all the dietary groups were similar. The mortality rate of the chicks during the overall phase ranged from 1.00 to 3.00 for birds on diets 3 and those on 2, 4, 5 respectively.

Table 23: Performance of broiler chickens fed graded levels of sorghum SK-5912 using different plant protein sources

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **1** | **2** | **Diets**  **3** | **4** | **5** | **SEM** |
| **Productive performance** |  |  |  |  |  |  |
| Initial weight (g) | 52.18 | 53.87 | 51.37 | 51.23 | 51.99 | 1.97NS |
| Body weight at 4 wks (g) | 746.11 | 746.28 | 720.00 | 624.55 | 648.20 | 29.10\*\*\* |
| Final weight (g) | 1539.40 | 1500.60 | 1422.60 | 1501.80 | 1500.40 | 25.45 NS |
| Total weight gain (g) | 1487.20 | 1446.70 | 1371.20 | 1450.60 | 1448.40 | 25.83 NS |
| **Starter phase (1-4 wks)** |  |  |  |  |  |  |
| Daily Feed Intake (g) | 47.54bc | 51.17a | 49.83ab | 45.56cd | 43.49d | 3.09\*\* |
| Daily Weight Gain (g) | 24.78a | 24.73a | 23.88ab | 20.48b | 21.29ab | 2.79\*\*\* |
| FCR | 1.90a | 2.07ab | 2.09b | 2.23c | 2.05ab | 2.79\*\*\* |
| Feed Conversion Ratio | 1.90a | 2.07ab | 2.09b | 2.23c | 2.05ab | 0.13\* |
| Mortality (Number) | 1 | 2 | 1 | 2 | 2 | - |
| **Finisher phase (5-8 wks)** |  |  |  |  |  |  |
| Daily feed intake (g) | 121.96 | 124.20 | 123.86 | 123.48 | 124.43 | 1.69NS |
| Daily weight gain (g) | 36.06 | 34.29 | 31.94 | 39.88 | 36.57 | 2.99NS |
| Feed conversion ratio | 3.43 | 3.76 | 4.18 | 3.13 | 3.55 | 0.35NS |
| Mortality (Number) | 1 | 1 | 0 | 1 | 1 | - |
| **Overall phase (1-8wks)** |  |  |  |  |  |  |
| Daily feed intake (g) | 80.01ab | 83.30a | 82.41ab | 79.70b | 78.95b | 3.14\*\* |
| Daily weight gain (g) | 29.75 | 28.94 | 27.43 | 29.01 | 28.97 | 1.15NS |
| Feed conversion ratio | 2.70 | 2.91 | 3.03 | 2.76 | 2.75 | 0.13NS |
| Mortality (Number) | 2 | 3 | 1 | 3 | 3 | - |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

abc Means bearing different superscripts within the same row differ \* = (P< 0.05), \*\* = (P< 0.01), \*\*\* = (P< 0.001),NS= Not significant; SEM= Standard error of means

* + 1. ***Blood Parameters***

The results of the haematological and serum biochemistry are presented in Tables 25 and 26. The haematological values observed include packed cell volume which ranges between 33.80 to 38.40% on diets 1 and3 respectively, white blood cells 24.51 to 26.16×103/µL for diets 1 and 3, red blood cells 2.19 to 2.53× 106/ µL for diets 5 and 3, haemoglobin 10.18 to 11.94g/dl on diets 5 and 3 respectively, and mean corpuscular volume (MCV) values ranged between 125.18 to 156.32fl for diets 1 and 4, mean corpuscular haemoglobin (MCH) were between 45.80 to 46.83pg for diets 4 and 5, mean corpuscular haemoglobin concentration ( MCHC) values ranged between 29.35 to 31.18g/dl on diets 4 and 3, and platelet 75.75 to 191.13×103/µL on diets 1 and 3 respectively. All of these were not significantly affected by the dietary treatments.

The results of the serum biochemical indices observed showed that total protein values ranged between 40.50 to 52.75g/l on diets 1 and 4 respectively, albumin ranged between 12.25 to 19.50g/l on diets 4 and 3, and globulin values of 24.25 to 40.50 g/l for diets 1 and 4. Also values obtained for creatinine are between 2.30 and 16.70µmol/L on diets 2 and 5, while total cholesterol values were between 3.35 and 5.78mmol/L on diets 5 and 3, and High Density Lipoprotein was significantly (P<0.05) affected and values observed ranged between 1.28 to 2.83mmol/L on diets 4 and 1 respectively, while Low Density Lipoprotein values of 1.33 to 2.00mmol/L for diets 1 and 4, values observed for triglycerides are between 0.75 to 1.50 mmol/L on diets 4 and 2 respectively. Similarly, values observed for aspartate amino transferase (AST) ranged between 70.50 and 219.25IU/L for diets 5 and 1 respectively, and alanine amino transferase (ALT) values ranged between 13.00 and 67.50IU/L on diet 5 and 2 respectively, and all were similar.

Table 24: Haematological values of broiler chickens fed graded levels of sorghum SK-5912 with different plant protein sources

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** |  |  | **Diets** |  |  |  |
| **1** | **2** | **3** | **4** | **5** | **SEM** |
| PCV (%) | 33.80 | 36.65 | 38.40 | 37.28 | 33.90 | 1.74 NS |
| RBC (×106/µL) | 2.26 | 2.39 | 2.53 | 2.39 | 2.19 | 0.11NS |
| Hb (g/dl) | 10.33 | 11.05 | 11.94 | 10.90 | 10.18 | 0.35 NS |
| MCV(fl) | 125.18 | 153.70 | 150.85 | 156.32 | 152.47 | 7.93 NS |
| MCH (pg) | 45.83 | 46.30 | 46.95 | 45.80 | 46.83 | 0.82 NS |
| MCHC (g/dl) | 30.55 | 30.15 | 31.18 | 29.35 | 30.98 | 0.79 NS |
| WBC (×103/µL) | 24.51 | 25.32 | 26.16 | 26.00 | 24.82 | 4.82 NS |
| PLT (×103/µL) | 75.75 | 186.00 | 191.13 | 129.50 | 90.25 | 24.35 NS |

NS= Not significant, SEM= Standard error of mean, PCV= Packed Cell Volume, RBC= Red Blood Cell, WBC= White Blood Cell, Hb= Haemoglobin Concentration, MCV= mean corpuscular volume, MCH= mean corpuscular haemoglobin, MCHC= mean corpuscular haemoglobin concentration, PLT= Platelet.

Table 25: Serum biochemical values of broiler chickens fed graded levels of sorghum SK- 5912 with different plant protein sources

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** |  |  | **Diets** |  |  |  |
| **1** | **2** | **3** | **4** | **5** | **SEM** |
| Total Protein (g/L) | 40.50 | 47.00 | 47.75 | 52.75 | 45.50 | 2.20 NS |
| Albumin (g/L) | 16.25 | 14.50 | 19.50 | 12.25 | 12.50 | 1.56 NS |
| Globulin (g/L) | 24.25 | 32.50 | 28.25 | 40.50 | 33.00 | 2.02 NS |
| Creatinine (µmol/L) | 4.83 | 2.30 | 2.75 | 8.68 | 16.70 | 4.02 NS |
| Cholesterol (mmol/L) | 5.00 | 5.20 | 5.78 | 4.83 | 3.35 | 0.42 NS |
| HDL (mmol/L) | 2.83a | 2.10b | 1.48c | 1.28c | 1.33c | 0.43 \* |
| LDL (mmol/L) | 1.33 | 1.75 | 1.83 | 2.00 | 1.90 | 0.27 NS |
| Triglyceride(mmol/L) | 1.25 | 1.50 | 0.98 | 0.75 | 0.95 | 0.30 NS |
| AST (IU/L) | 219.25 | 149.00 | 127.00 | 132.25 | 70.50 | 18.62 NS |
| ALT (IU/L) | 29.50 | 67.50 | 62.25 | 51.25 | 13.00 | 6.89 NS |
|  |  |  |  |  |  |  |

abc Means bearing different superscripts within the same row differ \* = (P<0.05), NS= Not significant, SEM= Standard error of mean, AST= Aspartate Amino Transferase, ALT= Alanine Amino Transferase

* + 1. ***Carcass and visceral organs characteristics of broiler chickens fed graded levels of sorghum SK-5912 using different plant protein sources***

The carcass characteristics of broiler chickens fed dietary levels of sorghum SK-5912 variety using different plant protein sources are presented in Table 24. The live weight of birds slaughtered varied between 1.52 and 1.61 kg for those fed diets 5 and 1, 4 respectively. However, the sorghum SK-5912 variety combined with different plant sources did not significantly influenced the live weight of broiler chickens at the end of the trial. The plucked weight (1.36 to 1.47 kg) and eviscerated weight (1.19 to 1.26 kg) were not affected by the dietary treatments. The dressing percentage values of 67.77 to 69.45% were obtained in broiler chickens fed diets 4 and 1 respectively. The dressing percentage did not differ significantly across the dietary treatments. The lungs values of 0.46 and 0.63% obtained on diets 2 and 3, the heart values of 0.50 and 0.57 obtained in diets 2, and 3, and the liver values of 1.52 and 1.62% obtained on diets 1 and 3 were not significantly different across the dietary levels treatments.

The values of large intestine weight varied between 0.23% (diet 5) and 0.47% (diet 3) and were similar among the dietary groups. The values of kidney weight varied between 0.24% (diets 3 and 4) and 0.28% (diet 5) and that of abdominal fat varied between 1.44% (diet 5) and 1.87% (diet 1), likewise gizzard values of 2.64% (diet 5) and 3.18% (diet 3). However, all did not differ across the dietary treatments. The caecal weight values of (0.47% diet 2) and 0.58 (diet 3), pancreas weights of 0.23% (diet 2) and 0.31 (diet 5), small intestine weight values of 2.53% (diet 3) and 3.12% (diet 1) and spleen weight values of 0.16% (diet 2) and 0.19% (diet 3) were also not influenced by the dietary means. The values obtained for small intestine length varied between148.75cm for diet2 and 158.82cm for diet 1, and all were not significantly affected by the dietary treatments. Large intestine lengths values varied between 8.52cm on diet 5 and 9.39cm on diet 4, and large intestine weight values ranged from 0.23 to 0.47 on diets 5 and 3 respectively, and are similar.

Table 26: Carcass and visceral organs as (% body weight) of broiler chickens fed graded levels of sorghum SK-5912 with different plant protein sources

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **1** |  | **Diets** |  | **5** | **SEM** |
| **2** | **3** | **4** |
| Live weight (kg) | 1.61 | 1.59 | 1.51 | 1.61 | 1.52 | 0.05 NS |
| Plucked weight (kg) | 1.46 | 1.42 | 1.36 | 1.47 | 1.38 | 0.04 NS |
| Eviscerated weight (kg) | 1.26 | 1.26 | 1.19 | 1.24 | 1.22 | 0.04 NS |
| Carcass weight (kg) | 1.13 | 1.10 | 1.04 | 1.13 | 1.04 | 0.04 NS |
| Dressing percentage | 69.45 | 69.35 | 69.30 | 67.77 | 68.39 | 2.04 NS |
| Lungs weight (%) | 0.53 | 0.46 | 0.63 | 0.54 | 0.62 | 0.07NS |
| Heart weight (%) | 0.52 | 0.50 | 0.57 | 0.53 | 0.56 | 0.04 NS |
| Liver weight (%) | 1.52 | 1.58 | 1.62 | 1.54 | 1.59 | 0.10 NS |
| Kidney weight (%) | 0.25 | 0.26 | 0.24 | 0.24 | 0.28 | 0.04 NS |
| Abdominal fat weight (%) | 1.87 | 1.71 | 1.62 | 1.54 | 1.44 | 0.15 NS |
| Gizzard weight (%) | 3.05 | 3.06 | 3.18 | 2.91 | 2.64 | 0.29 NS |
| Small intestine weight (%) | 3.12 | 2.85 | 2.53 | 3.08 | 2.98 | 0.29 NS |
| Small intestine length (cm) | 158.82 | 148.75 | 158.13 | 156.75 | 156.75 | 4.51 NS |
| Large intestine weight (%) | 0.36 | 0.45 | 0.47 | 0.41 | 0.23 | 0.07NS |
| Large intestine length (cm) | 8.73 | 8.88 | 8.62 | 9.39 | 8.52 | 0.56 NS |
| Caaecal weight (%) | 0.52 | 0.47 | 0.58 | 0.52 | 0.54 | 0.04 NS |
| Caecal length (cm) | 17.13 | 16.38 | 16.88 | 16.50 | 16.75 | 0.60 NS |
| Pancreas weight (%) | 0.28 | 0.23 | 0.27 | 0.27 | 0.31 | 0.04 NS |
| Spleen weight (%) | 0.17 | 0.16 | 0.19 | 0.17 | 0.17 | 0.02 NS |

NS=Not Significant, SEM=Standard Error of Mean.

***4.3.4 Cost benefits analysis of broiler chicken fed graded levels of sorghum SK-5912 with different plant protein sources***

The cost benefit analysis of broiler chickens production fed sorghum SK-5912 variety using different plant protein sources is shown in Table 27. The total feed intake at the starter phase varied between 1.41 and 1.51kg on diets 3 and 1 respectively. All the values observed on the dietary treatments were lower than the value on the control diet. The feed cost (₦/kg) ranged from ₦120.18 on diet 5 to ₦161.23 on diet 1. The total feed cost (₦) ranged from ₦170.66 diet 5 and ₦243.46 on diet 1. The total weight gain (kg) ranged from 0.57kg to 0.69kg on diets 1 and 2 respectively during the starter phase. The value on the control diet and diet 2 (0.69kg) were higher compared to other treatment groups. The feed cost in ₦ per kg gain varied between ₦276.97 to ₦352.84 on diets 2 and 1 respectively and were cheaper on other treatment diets than on the control diet ₦352.84.

At the finisher phase, the total feed intake values varied between 2.59kg to 2.70kg for diets 4 and 2 respectively. The values of feed cost (₦/kg) ranged from ₦100.38 to ₦114.03 on diets 5 and 1. The values were higher on maize based diets than the treatment diets. Similarly, the values of total feed cost varied from ₦263.00 to ₦301.04 on diets 5 and 1 respectively. The total weight gain in kg ranged from 0.70 to 0.88kg on diets 3 and 4 respectively. The value on diet 4 (0.88kg) was higher than all other values among the treatment groups. Feed cost ₦/kg gain values varied between ₦320.22 and ₦425.76 on diets 5 and 3 respectively. Except the values on diet 2 (₦425.76), all other values are lower compared to the value on the control diet (₦381.06).

The overall total feed intake varied between 4.03 and 4.17kg on diets 4 and 2 respectively. The values observed on diets 2 was higher then followed by the control diet (4.15kg). The feed cost in ₦ per kg gain ranged from ₦110.28 to ₦137.63 on diets 5 and 1 respectively. The total feed cost varied between ₦445.53 and ₦529.66 on diets 5 and 1 respectively. Chickens on the control diet had the highest (1.48kg) weight while the least (1.37kg) was in diet 2. The highest value observed for feed cost ₦ per kg weight gain was on diet 1 (₦385.92) and the lowest on diet 4 (₦318.24). The feed cost in ₦ per kg gain of all the treatment groups were lower compared to the value on the control diet and there is a cost saving on all the treatment diets. The percentage cost saving varied between 2.33% on diet 3 and 17.54% on diet 5.

Table 27: Cost benefit of broiler chickens fed graded levels of sorghum SK-5912 variety with different plant protein sources

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Parameters** | **1** | **2** | **3** | **4** | **5** |
| **Starter phase:** |  |  |  |  |  |
| Total feed intake (kg) | 1.51 | 1.47 | 1.41 | 1.44 | 1.42 |
| Feed cost (₦/kg) | 161.23 | 130.01 | 141.70 | 136.16 | 120.18 |
| Total feed cost (₦) | 243.46 | 191.11 | 199.80 | 196.07 | 170.66 |
| Total weight gain (kg) | 0.69 | 0.69 | 0.67 | 0.57 | 0.60 |
| Feed cost ₦/kg gain | 352.84 | 276.97 | 298.21 | 343.98 | 284.43 |
| **Finisher phase:** |  |  |  |  |  |
| Total feed intake (kg) | 2.64 | 2.70 | 2.66 | 2.59 | 2.62 |
| Feed cost (₦/kg) | 114.03 | 104.11 | 112.04 | 108.08 | 100.38 |
| Total feed cost (₦) | 301.04 | 281.10 | 298.03 | 281.79 | 263.00 |
| Total weight gain (kg) | 0.79 | 0.75 | 0.70 | 0.88 | 0.80 |
| Feed cost ₦/kg gain | 381.06 | 374.80 | 425.76 | 320.22 | 328.75 |
| **Overall performance** |  |  |  |  |  |
| Total feed intake (kg) | 4.15 | 4.17 | 4.07 | 4.03 | 4.04 |
| Feed cost (₦/kg) | 137.63 | 117.06 | 126.87 | 122.48 | 110.28 |
| Total feed cost (₦) | 571.16 | 488.14 | 516.36 | 493.59 | 445.53 |
| Total weight gain (kg) | 1.48 | 1.44 | 1.37 | 1.45 | 1.40 |
| Feed cost ₦/kg gain | 385.92 | 338.99 | 376.91 | 340.41 | 318.24 |
| Cost saving (₦) | 0.00 | 46.93 | 9.01 | 45.51 | 67.68 |
| % cost saving | 0.00 | 12.16 | 2.33 | 11.79 | 17.54 |
| Ranking cost ₦/kg gain | Diet 5> | Diet 2> | Diet 4> | Diet 3> | - |

**4.4 Experiment 3: Performance, Carcass Characteristics, Blood Composition and Cost Benefit Analysis of Broiler chickens fed Sorghum SK-5912 Variety as Replacement for white sorghum**

**4.4.1. *Productive performance of broiler chickens fed graded levels sorghum SK-5912 variety***

The productive performance of broiler chickens fed sorghum SK-5912 variety as a replacement for white sorghum are presented in Table 28. The initial weight of the broiler chicks varied between 92.83 to 96.43g on diets 5 and 4 respectively, while their body weight at 4 weeks were between 917.95 and 1022.29g on diets 5 and 1 respectively, values obtained were not statistically different. Final weight ranged from 1780.40 to 1912.70g on diets 5 and 2 respectively. The total body weight gain across the treatment groups were also similar and varied from 1687.70g to 1817.90g on broiler chickens fed diets 5 and 2 respectively.

***4.4.1.1. Starter phase (1-4 weeks of Age)***

The daily feed intake at the starter phase varied from 52.47 to 53.22g in broiler birds fed diets 1 and 4 respectively. Although, values obtained did not differ significant among the treatment groups. The daily weight gain values varied between 26.48 to 30.04g on birds fed diets 5 and 2 respectively and the values obtained were statistically similar. The feed conversion ratio varied from 1.75 to 1.99 on diets 2 and 5 respectively and was significantly (P<0.05) affected by levels of replacement of sorghum SK-5912 variety for white sorghum. The mortality values ranged from 0.00 to 2.00 birds on diets 3 and 2, 5 respectively.

***4.4.1.2. Finisher phase (5- 8 weeks)***

At the finisher phase the daily feed intake ranged from 105.96 to 109.53g for birds fed on diets 4 and 5 respectively and there was no significant difference among the treatment groups. The daily weight gain varied from 41.91 to 44.29g for birds on diets 5 and 1 respectively. All the daily weight gain values obtained in broiler birds fed the dietary treatment did not differ significantly at the finisher phase. The feed conversion ratio ranged between 2.45 and 2.63 for birds on diets 1, 4 and 3 respectively. The feed conversion ratios observed on all the dietary levels of sorghum SK-5912 replacing white sorghum were similar. The mortality rate of the chicks during the finisher phase ranged from 1.00 to 2.00 for birds on diets 2, 4, 5 and those on 1, 3 respectively.

***4.4.1.3. Overall phase (1-8 weeks)***

The overall performance showed daily feed intake ranged from 82.89 to 84.66g for broiler chickens fed on diets 4 and 5 respectively. The result showed that there was no significant difference. The daily weight gain varied from 35.16 to 37.87g for birds on diets 5 and 2 respectively. The values observed on broiler chickens fed the dietary treatment did not differ significantly at the overall phase. The feed conversion ratio ranged between 2.22 and 2.42 for birds on diets 1 and 5 respectively and values observed on all the dietary levels of sorghum SK-5912 replacing white sorghum were statistically similar. The mortality rate of the chicks during the overall phase ranged from 2.00 to 3.00 for birds on diets 3, 4 and those on 1, 2 and 5 respectively.

Table 28: Performance of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum

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| --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |  |
|  |  |  |  |  |
| **Parameters** | **1** | **2** | **3** | **4** | **5** | **SEM** |
| **Productive performance** |  |  |  |  |  |  |
| Initial weight (g) | 93.22 | 94.76 | 94.82 | 96.43 | 92.83 | 1.87NS |
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| Body weight at 4 wks (g) | 1022.29 | 1010.85 | 992.28 | 993.43 | 917.95 | 16.31NS |
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| Final weight (g) | 1902.10 | 1912.70 | 1880.70 | 1865.30 | 1780.40 | 23.36 NS |
| Total weight gain (g) | 1808.90 | 1817.90 | 1785.90 | 1768.90 | 1687.70 | 22.96 NS |
| **Starter phase (1-4 wks)** |  |  |  |  |  |  |
| Daily feed intake (g) | 52.47 | 52.62 | 52.69 | 53.22 | 52.69 | 0.99 NS |
| Daily weight gain (g) | 29.19 | 30.04 | 28.70 | 28.32 | 26.48 | 0.86 NS |
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|  |  |  |  |  |  |  |
| Feed Conversion Ratio | 1.80ab | 1.75a | 1.84ab | 1.88ab | 1.99b | 0.14 \* |
| Mortality (Number) | 2 | 1 | 2 | 1 | 1 | - |
| **Finisher phase (5-8wks)** |  |  |  |  |  |  |
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| Daily feed intake (g) | 107.84 | 108.72 | 109.44 | 105.96 | 109.53 | 1.34NS |
| Daily weight gain (g) | 44.29 | 44.06 | 43.83 | 43.49 | 41.91 | 1.72NS |
| Feed conversion ratio | 2.45 | 2.47 | 2.51 | 2.45 | 2.63 | 0.09NS |
| Mortality (Number) | 2 | 1 | 2 | 1 | 1 | - |
| **Overall Phase(1-8 wks)** |  |  |  |  |  |  |
| Daily feed intake (g) | 83.61 | 84.18 | 84.61 | 82.89 | 84.66 | 1.08NS |
| Daily weight gain (g) | 37.69 | 37.87 | 37.21 | 36.85 | 35.16 | 1.20NS |
| Feed conversion ratio | 2.22 | 2.23 | 2.28 | 2.25 | 2.42 | 0.06NS |
| Mortality (Number) | 3 | 3 | 2 | 2 | 3 | - |
|  |  |  |  |  |  |  |
| abc Means bearing different superscripts within the same row differ \* = (P< 0.05), NS= Not significant; SEM= Standard error of means | | | | | | | |

* + 1. ***Blood Parameters***

The results of the haematological and serum biochemistry indices are presented in Tables 30 and 31 respectively. The haematological values observed include packed cell volume which ranges between 27.58% to 30.93% on diets 2 and1 respectively, white blood cells 25.93 to 27.64×103/µL for diets 5 and 3, red blood cells 2.02 to 2.30× 106/ µL for diets 2 and 1, haemoglobin 8.00 to 10.16g/dl on diets 5 and 1 respectively, and mean corpuscular volume (MCV) values ranged between 136.30 to 138.68fl for diets 4 and 3, mean corpuscular haemoglobin (MCH) were between 41.83 to 44.13pg for diets 3 and 5, mean corpuscular haemoglobin concentration ( MCHC) values ranged between 24.75 to 36.08g/dl on diets 1 and 3, and platelet 12.00 to 24.75×103/µL on diets 2 and 1 respectively. All of these were not significantly influenced across the dietary levels of sorghum SK-5912 variety replacing white sorghum.

The results of the serum biochemical indices observed showed that total protein values ranged between 44.50 to 60.25 g/l on diets 5 and 4 respectively, where albumin ranged between 18.50 to 20.00 g/l on diets 5 and 3, and globulin 26.00 to 40.75 g/l for diets 5 and 4. Also values obtained for creatinine were between 4.73 and 7.60 µmol/L on diets 3 and 5, while total cholesterol values were between 3.68 and 5.85mmol/L on diets 5 (100% sorghum SK-5912) and 2 (75% white sorghum) and there was a high significant (P<0.01) among the treatment groups. High Density Lipoprotein did not differ across the treatment means, values obtained ranged between 2.80 and 3.05 mmol/L, for diet 3 and diet 5 respectively. However, Low Density Lipoprotein differ significantly (P<0.05) across the treatment means, values obtained are between 1.55 for diet 4 (75% sorghum SK-5912) and 2.30 mmol/L for diet 5 (100% sorghum SK-5912). Glucose did not differ across the treatment groups, values obtained are between 12.85 to 13.85g on diets 2 and 4 respectively. Similarly, values observed for aspartate aminotransferase (AST) ranged from 338.25 to 371.00IU/L for diets 2 and 4 respectively, and serum alanine aminotransferase (ALT) ranged between 18.50 and 28.75IU/L on diet 1 and 5 respectively and were similar.

Table 29: Haematological values of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** |  |  | **Diets** |  |  |  |
| **1** | **2** | **3** | **4** | **5** | **SEM** |
| PCV (%) | 30.93 | 27.58 | 29.10 | 29.05 | 28.80 | 01.62 NS |
| RBC (×106/µL) | 2.30 | 2.02 | 2.11 | 2.14 | 2.10 | 0.14 NS |
| Hb (g/dl) | 10.16 | 8.60 | 9.38 | 9.28 | 8.00 | 0.73 NS |
| MCV (fl) | 136.40 | 136.93 | 138.68 | 136.30 | 137.53 | 2.55 NS |
| MCH (pg) | 42.58 | 42.73 | 41.83 | 43.50 | 44.13 | 1.70 NS |
| MCHC (g/dl) | 24.75 | 26.60 | 36.08 | 32.00 | 31.93 | 4.49 NS |
| WBC (×103/µL) | 27.27 | 26.19 | 27.64 | 27.18 | 25.93 | 4.49 NS |
| PLT (×103/µL) | 24.75 | 12.00 | 20.75 | 18.25 | 14.75 | 6.05 NS |

NS= Not significant, SEM= Standard error of mean, PCV= Packed Cell Volume, RBC= Red Blood Cell, WBC= White Blood Cell, Hb= Haemoglobin Concentration, MCV= mean corpuscular volume, MCH= mean corpuscular haemoglobin, MCHC= mean corpuscular haemoglobin concentration, PLT= Platelet.

Table 30: Serum biochemical values of broiler chickens fed graded levels of sorghumSK- 5912 as replacement for white sorghum

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** |  |  | **Diets** |  |  |  |
| **1** | **2** | **3** | **4** | **5** | **SEM** |
| Total Protein (g/L) | 58.25 | 53.25 | 59.00 | 60.25 | 44.50 | 5.59 NS |
| Albumin (g/L) | 19.00 | 19.75 | 20.00 | 19.50 | 18.50 | 1.36 NS |
| Globulin (g/L) | 39.25 | 33.50 | 39.00 | 40.75 | 26.00 | 5.53 NS |
| Creatinine (µmol/L) | 7.05 | 5.83 | 4.73 | 7.43 | 7.60 | 1.13 NS |
| Cholesterol (mmol/L) | 5.85a | 3.68c | 3.98ab | 4.78ab | 5.53b | 0.84 \*\* |
| HDL (mmol/L) | 3.03 | 2.83 | 2.80 | 3.03 | 3.05 | 0.30 NS |
| LDL (mmol/L) | 2.18a | 1.63ab | 1.78ab | 1.55b | 2.30a | 0.52 \* |
| Glucose (g) | 13.73 | 12.85 | 13.35 | 13.85 | 12.88 | 0.85 NS |
| AST (IU/L) | 358.00 | 338.25 | 359.75 | 371.00 | 344.00 | 47.56 NS |
| ALT (IU/L) | 18.50 | 26.50 | 20.75 | 24.50 | 28.75 | 8.72 NS |
|  |  |  |  |  |  |  |
| abc Means bearing different superscripts within the same row differ \*\*= (P< 0.01), \* = (P< 0.05), NS= Not significant; SEM= Standard error of means, AST= Aspartate Amino Transferase, ALT= Alanine Amino Transferase | | | | | | | |

***4.4.2 Carcass yield and visceral organs characteristics of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum***

The carcass characteristics of broiler chickens fed dietary levels of sorghum SK-5912 as replacement for white sorghum is presented in Table 29. The live weight of broiler birds slaughtered varied between 1.89 and 2.12kg for those fed diets 5 and 1 respectively. The dietary levels of sorghum SK-5912 have not affected the live weight of the broiler chickens. Similarly, plucked weight, eviscerated weight, carcass and the dressing percentage were not significantly influenced by the dietary treatments. The dressing percentage values of 67.04 and 70.44 were obtained in broiler chickens fed diets 2(25% sorghum SK-5912) and diets 5 (100% sorghum SK-5912) respectively. Results of internal organ characteristics expressed as percentage of live weight were also not influenced by the dietary levels of sorghum SK-5912. The lungs values ranged from 0.41 to 0.56% obtained in diets 2 and 1, the heart values ranged from 0.27 to 0.30% obtained in diets 1, and 2 and 4, and the liver values are between 1.23 and 1.46% obtained in diets 5 and 1 were all not significantly different across the dietary levels of sorghum SK-5912. The highest gizzard value of 1.46% was observed in broiler birds fed diets 1 and 4 and did not differ significantly from the lower values of 1.42%, 1.32% and 1.30% for those fed diets 3, 5 and 2 respectively.

The values of kidney weight varied between 0.03% (diet 5) and 0.04% (diets 1, 2, 3 and 4) and that of abdominal fat varied between 1.47% on diet 5(100% sorghum SK-5912) and 0.99% on diet 2 (25% sorghum SK-5912). However, all did not differ across the dietary treatment. The caecal weight values of 0.44% diet 2 and 0.52 for diets 1 and 3, and caecal length ranged from 16.81cm and 18.56cm on diets 5 and 1 respectively are similar. Likewise, the pancreas weights of 0.12% (diet 1) and 0.19 (diet 4), small intestine weight values of 2.69% (diet 4) and 3.20% (diet 5) and spleen weight values of 0.05% (diet 2) and 0.08% (diet 1) were also not influenced by the dietary levels of sorghum SK-5912 variety. The values obtained for small intestine length varied between154.13 cm for diet4 and 174.38 cm for diets 4 and 1 respectively. Large intestine lengths values varied between 7.88 cm on diet 4 and 10.13 cm on diet 5, and large intestine weight values varied from 0.09 and 0.13 for diets 1, 3 and 4 for diet 5 respectively, and all were not significantly influenced by the dietary levels of sorghum SK-5912.

Table 31: Carcass and visceral organs characteristics of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |  |
| **Parameters** | **1** | **2** | **3** | **4** | **5** | **SEM** |
| Live weight (kg) | 2.12 | 2.02 | 2.04 | 1.96 | 1.89 | 0.09NS |
| Plucked weight (kg) | 1.84 | 1.79 | 1.78 | 1.74 | 1.66 | 0.08NS |
| Eviscerated weight (kg) | 1.61 | 1.53 | 1.50 | 1.48 | 1.45 | 0.08NS |
| Carcass weight (kg) | 1.48 | 1.39 | 1.38 | 1.34 | 1.33 | 0.07NS |
| Dressing Percentage | 69.50 | 67.04 | 67.38 | 68.24 | 70.44 | 1.89NS |
| Lungs weight (%) | 0.56 | 0.41 | 0.46 | 0.54 | 0.45 | 0.04NS |
| Heart weight (%) | 0.27 | 0.27 | 0.29 | 0.30 | 0.29 | 0.02NS |
| Liver weight (%) | 1.46 | 1.30 | 1.27 | 1.32 | 1.23 | 0.08NS |
| Kidney weight (%) | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.01NS |
| Abd.fat weight (%) | 1.31 | 0.99 | 1.19 | 1.23 | 1.47 | 0.13NS |
| Gizzard weight (%) | 1.46 | 1.30 | 1.42 | 1.46 | 1.32 | 0.09NS |
| Caecal weight (%) | 0.52 | 0.44 | 0.52 | 0.50 | 0.50 | 0.06NS |
| Caecal length (cm) | 17.63 | 18.56 | 18.25 | 16.88 | 16.81 | 1.01NS |
| Pancreas weight (%) | 0.12 | 0.14 | 0.16 | 0.19 | 0.16 | 0.03NS |
| Small intestine wt (%) | 2.75 | 2.81 | 2.77 | 2.69 | 3.20 | 0.18NS |
| Small intestine (cm) | 174.38 | 168.88 | 168.00 | 154.13 | 162.13 | 6.38NS |
| Large intestine wt (%) | 0.09 | 0.10 | 0.09 | 0.09 | 0.13 | 0.02NS |
| Large intestine (cm) | 8.69 | 8.71 | 8.25 | 7.88 | 10.13 | 0.81NS |
| Spleen weight (%) | 0.08 | 0.05 | 0.06 | 0.06 | 0.06 | 0.01NS |
| NS= Not significant; SEM= Standard error of means | | | | | | | |

* + 1. ***Cost benefits analysis of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum***

The economic analysis of broiler production using sorghum SK-5912 variety as replacement for white sorghum is presented in Table 32. The total feed intake at starter phase varied between 1.47 and 1.49kg on diets 4, 5 and diet 2 respectively. All the values observed on the dietary treatments were lower than the value on the control diet except diet 2. The feed cost (₦/kg) ranged from ₦149.89 on diet 5 to ₦172.74 on diet 1(control). The values decreased with increasing levels of sorghum SK-5912. The total feed cost (₦) ranged from ₦220.34 diet 5 and ₦255.66 on diet 1. The total weight gain (kg) ranged from 0.74kg to 0.84kg on diets 5 and 2 respectively. The value on the control diet (0.82kg) is only lower compared to diet 2 (0.84kg). The feed cost in ₦ per kg gain varied between ₦268.71 to ₦345.49 on diets 5 and 1(control) respectively and were cheaper on other treatment diets than on the control diet.

At the finisher phase, the total feed intake values varied between 2.12kg to 2.19kg for diet 2 and diets 1 and 3 respectively. The values of feed cost (₦/kg) ranged from ₦123.45 to ₦147.74 on diets 5 and 1. The values reduced with increasing level of sorghum SK-5912 variety. The values of total feed cost varied from ₦266.65 to ₦323.55 on diets5 and 1 respectively. The total weight gain in kg ranged from 0.84 to0.89kg on diets 1 and 5 respectively. The value on diet 1 (0.84) was lower than all other values among the treatment groups. Feed cost ₦/kg gain values varied between ₦314.52 and ₦360.65 on diets 5 and 2 respectively. Except the values on diet 2 (₦299.61), all other values are lower compared to the value on the control diet (₦385.18).

The overall total feed intake varied between 3.98 and 4.14kg on diets 4 and 3 respectively. The values observed on diets 3 was higher then followed by diet 5. The feed cost in ₦ per kg feed ranged from ₦136.67 to ₦159.92 on diets 5 and 1 respectively and decreased with increasing levels of sorghum SK-5912 variety. Similarly, total feed cost decreases with increasing levels of sorghum SK-5912 inclusion in the diets, and values obtained varied between ₦554.88 and ₦641.28.The total weight gain ranged from 1.69kg to 1.82kg on diets 2 and 1 (control). The highest value observed for feed cost ₦ per kg weight gain was on control diet (₦354.30) and the lowest on diet 5 (₦328.33). The feed cost in ₦ per kg gain of all the treatment groups were lower compared to the value on the control diet and there is a cost saving on all the treatment diets. The percentage cost saving varied between 1.88% on diet 2 and 7.33% on diet 5 (100% sorghum SK-5912).

Table 32:Cost benefit analysis of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum

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| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Parameters** | **1** | **2** | **3** | **4** | **5** |
| **Starter phase:** |  |  |  |  |  |
| Total feed intake (kg) | 1.48 | 1.49 | 1.48 | 1.47 | 1.47 |
| Feed cost (₦/kg) | 172.74 | 168.99 | 163.24 | 157.18 | 149.89 |
| Total feed cost (₦) | 255.66 | 251.80 | 241.60 | 231.05 | 220.34 |
| Total weight gain (kg) | 0.74 | 0.79 | 0.80 | 0.84 | 0.82 |
| Feed cost ₦/kg gain | 345.49 | 318.73 | 302.00 | 275.06 | 268.71 |
| **Finisher phase:** |  |  |  |  |  |
| Total feed intake (kg) | 2.19 | 2.12 | 2.19 | 2.17 | 2.16 |
| Feed cost (₦/kg) | 147.74 | 144.23 | 142.36 | 142.80 | 123.45 |
| Total feed cost (₦) | 323.55 | 305.77 | 311.77 | 309.88 | 266.65 |
| Total weight gain (kg) | 0.84 | 0.87 | 0.88 | 0.88 | 0.89 |
| Feed cost ₦/kg gain | 385.18 | 351.46 | 354.28 | 352.14 | 299.61 |
| **Overall performance** |  |  |  |  |  |
| Total feed intake (kg) | 4.01 | 4.04 | 4.14 | 3.98 | 4.06 |
| Feed cost (₦/kg) | 159.92 | 156.61 | 152.30 | 149.99 | 136.67 |
| Total feed cost (₦) | 641.28 | 632.70 | 630.52 | 596.96 | 554.88 |
| Total weight gain (kg) | 1.81 | 1.82 | 1.79 | 1.77 | 1.69 |
| Feed cost ₦/kg gain | 354.30 | 347.64 | 352.25 | 337.27 | 328.33 |
| Cost saving (₦) | 0.00 | 6.66 | 2.05 | 17.03 | 25.97 |
| % cost savings | 0.00 | 1.88 | 0.58 | 4,81 | 7.33 |
| Rankings cost ₦/kg gain | Diet 5> | Diet 4> | Diet 2> | Diet 3> | - |

**4.5. Experiment 4: Performance, Blood Composition Carcass Characteristics, and Cost Benefit Analysis of Broiler Chickens fed Sorghum SK-5912 Variety as Replacement for Pearl millet**

**4.5.1. *Performance of broiler chickens fed graded levels sorghum SK-5912 as replacement for Pearl millet***

The productive performances of broiler chickens fed sorghum SK-5912 variety as replacement for pearl millet is presented in Table 33. The initial weight of the broiler chicks varied between 80.04 to 88.37g on diets 5 and 1 respectively. Body weight at 4 weeks ranged from 952.08 to 992.41g on diets 2 and 1 respectively. Final weight values obtained were between 1903.30 to 1949.30g on diets 4 and 1 respectively. The total body weight gain varied from 1815.30 to 1860.80g on broiler chickens fed diets 4 and 1 respectively. Values recorded were similar.

***4.5.1.1. Starter phase (1-4 weeks of Age)***

The daily feed intake at the starter phase varied from 56.63 to 57.82g in broiler birds fed diets 2 and 3 respectively. However, values obtained did not differ significant among the treatment means. The daily weight gain values varied between 30.99 to 32.42g in broiler chickens fed diets 2 and 3 respectively. Although, the values obtained were statistically similar. The feed conversion ratio varied between 1.79 to 1.83 on diets 1,3 and diets 2, 4 respectively. The mortality values ranges between 1 bird for diets 3 and 5, and 2 each from diets 1, 2 and 4.

***4.5.1.2. Finisher phase (5- 8 weeks)***

The daily feed intake ranged from 123.30 to 127.37g for broiler chickens fed on diets 3 and 4 respectively. This result showed non-significant difference among the treatment groups at the finisher phase. The daily weight gain varied from 43.78 to 45.57g for birds on diets 3 and 1 respectively. All the daily weight gain values obtained in broiler birds fed the dietary treatment did not differ significantly at the finisher phase. The feed conversion ratio ranged from 2.76 to 2.90 for birds fed diets 5 and 3 respectively. The feed conversion ratios observed on all the dietary levels of sorghum SK-5912 as replacement for pearl millet were similar. The mortality rate of the chicks during the finisher phase ranged from 1.00 to 2.00 for birds on diets 1, 4 and those on diets 2, 3, 5 respectively.

***4.5.1.3. Overall phase (1-8 weeks)***

The overall daily feed intake ranged from 85.88 to 87.79g for broiler chickens fed on diets 3 and 4 respectively. The result showed that there was no significant difference at the overall phase. The daily weight gain varied from 37.05 to 37.98g for birds on diets 4 and 1 respectively. All the daily weight gain values obtained in broiler birds fed the dietary treatment are similar at the overall phase. The feed conversion ratio ranged between 2.30 and 2.37 for birds on diets 3, 5 and diet 4 respectively. The feed conversion ratios observed on all the dietary levels of sorghum SK-5912 showed non-significant difference. The mortality rate of the birds during the overall phase ranged between 3.00 and 4.00 for birds on diets 1, 3, 4, 5 and those on diet 2 respectively. There was no evidence of any disease regarding the death of the birds.

Table 33: Performance of broiler chickens fed graded levels sorghum SK-5912 as replacement for Pearl millet

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| --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |  |
| **Parameters** | **1** | **2** | **3** | **4** | **5** | **SEM** |
| **Production performance** |  |  |  |  |  |  |
| Initial weight (g) | 88.37 | 84.38 | 81.08 | 88.02 | 80.04 | 4.32 NS |
| Body weight at 4 wks (g) | 992.41 | 952.08 | 988.89 | 978.47 | 962.51 | 12.83 NS |
| Final weight (g) | 1949.30 | 1906.20 | 1908.30 | 1903.30 | 1915.10 | 41.67NS |
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| Total weight gain (g) | 1860.80 | 1821.80 | 1827.20 | 1815.30 | 1836.30 | 38.77NS |
| **Starter phase (1-4 wks)** |  |  |  |  |  |  |
| Daily weight gain (g) | 57.80 | 56.63 | 57.82 | 58.11 | 57.06 | 0.71NS |
| Daily weight gain (g) | 32.29 | 30.99 | 32.42 | 31.80 | 31.52 | 0.74 NS |
| Feed Conversion Ratio | 1.79 | 1.83 | 1.79 | 1.83 | 1.81 | 0.04 NS |
| Mortality (Number) | 2 | 2 | 1 | 2 | 1 | - |
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| **Finisher phase (5-8 wks)** |  |  |  |  |  |  |
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| Daily feed intake (g) | 126.76 | 125.96 | 123.30 | 127.37 | 124.79 | 1.28NS |
|  |  |  |  |  |  |  |
| Daily weight gain (g) | 45.57 | 45.44 | 43.78 | 44.04 | 45.36 | 1.96NS |
| Feed conversion ratio | 2.80 | 2.79 | 2.83 | 2.90 | 2.76 | 0.11NS |
| Mortality (Number) | 1 | 2 | 2 | 1 | 2 | - |
| **Overall Phase (1-8 wks)** |  |  |  |  |  |  |
| Daily feed intake (g) | 87.35 | 86.34 | 85.88 | 87.79 | 86.09 | 0.83NS |
| Daily weight gain (g) | 37.98 | 37.18 | 37.29 | 37.05 | 37.45 | 0.79NS |
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| Feed conversion ratio  Mortality (Number) | 2.31 | 2.32 | 2.30 | 2.37 | 2.30 | 0.05NS |
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NS= Not significant, SEM= Standard Error of the Mean

***4.5.3. Blood Parameters***

The results of the haematological and serum biochemistry are presented in Tables 35 and 36. The haematological values observed include packed cell volume which ranges between 29.35 to 34.85% on diets 3 and 2 respectively, white blood cells 25.33 to 27.86×103/µL for diets 3 and 2, red blood cells 2.05 to 2.55× 106/ µL for diets 2 and 3, haemoglobin 9.30 to 10.88g/dl on diets 4 and 2 respectively, and mean corpuscular volume (MCV) values ranged between 136.68 to 147.10fl for diets 2 and 4, mean corpuscular haemoglobin (MCH) was significantly (P<0.01), values obtained were between 42.65 to 45.58pg for diets 2 and 3, mean corpuscular haemoglobin concentration ( MCHC) values ranged between 30.68 to 31.58g/dl on diets 5 and 3, and platelet 17.75 to 71.75×103/µL on diets 4 and 1 respectively. All of these were not significantly affected by the dietary levels of sorghum SK-5912 variety replacing pearl millet.

The results of the serum biochemical indices observed showed that total protein values ranged between 30.50 to 35.50 g/l on diets 1 and 3 respectively, where albumin ranged between 12.33 to 13.90 g/l on diets 1 and 5, and globulin 16.85 to 22.35 g/l for diets 5 and 3. Also values obtained for creatinine was between 32.00 and 43.75 µmol/L on diets 4 and 2, while that total cholesterol was between 3.35 and 4.78 mmol/L on diets 1 and 3. High Density Lipoprotein values were 1.55 to 1.90 mmol/L on diets 2 and 1 respectively, and Low Density Lipoprotein values of 0.73 to 1.10 mmol/L for 5 and 4, values observed for triglycerides was between 0.51 to 0.72 mmol/L on diets 2 and 4 respectively. Similarly, values observed for aspartate amino transferase (AST) ranged between 201.75 and 315.75IU/L for diets 2 and 5 respectively, and alkaline amino transferase (ALT) ranged between 20.75 and 32.50IU/L on diet 1 and 5 respectively. All the values were not significantly influenced by dietary levels of sorghum SK-5912 replacing pearl millet.

Table 34: Haematological values of broiler chickens fed graded levels of sorghum SK-5912 as replacement for Pearl millet

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** |  |  | **Diets** |  |  |  |
| **1** | **2** | **3** | **4** | **5** | **SEM** |
| PCV (%) | 32.10 | 34.85 | 29.35 | 31.38 | 33.30 | 1.86 NS |
| RBC (×106/µL) | 2.23 | 2.55 | 2.05 | 2.14 | 2.34 | 0.15 NS |
| Hb (g/dl) | 10.10 | 10.88 | 9.30 | 9.65 | 10.23 | 0.65 NS |
| MCV (fl) | 144.47 | 136.68 | 144.45 | 147.10 | 142.48 | 2.40 NS |
| MCH (pg) | 45.40a | 42.65b | 45.58a | 45.23a | 43.70ab | 2.25 \*\* |
| MCHC (g/dl) | 31.40 | 32.23 | 31.58 | 30.78 | 30.68 | 0.43 NS |
| WBC (×103/µL) | 27.18 | 27.86 | 25.33 | 26.68 | 27.10 | 9.14 NS |
| PLT (×103/µL) | 71.75 | 46.00 | 54.75 | 17.75 | 18.00 | 10.14 NS |

NS= Not significant, SEM= Standard error of mean, PCV= Packed Cell Volume, RBC= Red Blood Cell, WBC= White Blood Cell, Hb= Haemoglobin Concentration, MCV= mean corpuscular volume, MCH= mean corpuscular haemoglobin, MCHC= mean corpuscular haemoglobin concentration, PLT= Platelet.

Table 35: Serum biochemical values of broiler chickens fed graded levels of sorghumSK- 5912 as replacement for Pearl millet

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** |  |  | **Diets** |  |  |  |
| **1** | **2** | **3** | **4** | **5** | **SEM** |
| Total Protein (g/L) | 30.50 | 33.25 | 35.50 | 34.50 | 30.75 | 3.06 NS |
| Albumin (g/L) | 12.33 | 13.43 | 13.15 | 13.65 | 13.90 | 0.99 NS |
| Globulin (g/L) | 18.18 | 19.83 | 22.35 | 20.85 | 16.85 | 2.59 NS |
| Creatinine (µmol/L) | 35.75 | 43.75 | 36.00 | 32.00 | 40.75 | 3.18 NS |
| Cholesterol (mmol/L) | 3.35 | 3.83 | 4.78 | 4.20 | 4.03 | 0.23 NS |
| HDL (mmol/L) | 1.90 | 1.55 | 1.73 | 1.75 | 1.88 | 0.14 NS |
| LDL (mmol/L) | 1.00 | 1.00 | 0.95 | 1.10 | 0.73 | 0.16 NS |
| Glucose (g) | 9.00 | 11.38 | 9.98 | 11.68 | 9.88 | 0.91 NS |
| AST (IU/L) | 233.75 | 201.75 | 294.25 | 222.75 | 315.75 | 29.67 NS |
| ALT (IU/L) | 20.75 | 24.75 | 22.25 | 25.00 | 32.50 | 3.43 NS |
| NS= Not significant; SEM= Standard error of means, AST= Aspartate Amino Transferase, ALT= Alanine Amino Transferase | | | | | | | |

***4.5.2 Carcass yield and visceral organs characteristics of broiler chickens fed graded levels of sorghum SK-5912 as replacement for pearl millet***

The carcass characteristics of broiler chickens fed dietary levels of sorghum SK-5912 as replacement for pearl millet are presented in Table 34. The live weight of birds slaughtered varied between 2.03 and 2.43 kg for those fed diets 4 and 1 respectively. However, the dietary levels of sorghum SK-5912 did not significantly influenced the live weight of broiler chickens at the end of the trial. The plucked weight varied between 1.71 and 2.00kg, and eviscerated weight from 1.42 to 1.71 kg, all were not affected by the dietary treatments. The dressing percentage values of 63.09 to 64.87% were obtained in broiler chickens fed diets 3 and 5 respectively. The dressing percentage did not differ significantly across the dietary treatments. The lungs values of 0.44 and 0.54% obtained in diets 1 and 2, the heart values of 0.31 and 0.36 obtained in diets 4, and 2, the liver values of 1.38 and 1.78% obtained in diets 5 and 1 were not significantly different across the dietary levels of sorghum SK-5912 replacing pearl millet.

The values of kidney weight varied between 0.03% and 0.04% (diet 2) and that of abdominal fat varied between 0.98% (diet 4) and 1.57% (diet 3), likewise gizzard values of 1.56% (diet 1) and 1.92% (diets 4). However, all did not differ across the dietary treatment. The caecal weight differ significantly (P<0.01) and values obtained varied from (0.42%) diet 1 and 0.74% (diet 3), pancreas weights of 0.15% (diets 1, 5) and 0.19 (diets 2, 3), small intestine weight values of 2.49% (diet 1) and 3.36% (diet 4). However, small intestine lengths differ significantly (P<0.01) across the treatment groups, the highest obtained was 194.63cm for diet 3 and lowest (151.88cm) was on diet 4, the values obtained for large intestine weights are between 0.15 and 0.29% for diets 3 and 4 respectively and the large intestine weight values ranged from 11.63 (diet 1) to 14.13cm (diet 5). The spleen weight values of 0.08% (diets 1, 5) and 0.12% (diet 2), all were also not influenced by the dietary levels of sorghum SK-5912 variety replacing pearl millet.

Table 36: Carcass and visceral organs characteristics of broiler chickens fed graded levels of sorghum SK-5912 as replacement for Pearl millet

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |  |
|  |  |  |  |  |  |
| **Parameters** | **1** | **2** | **3** | **4** | **5** | **SEM** |
| Live weight (kg) | 2.43 | 2.27 | 2.26 | 2.03 | 2.23 | 0.10NS |
| Plucked weight (kg) | 2.00 | 1.85 | 1.89 | 1.71 | 1.87 | 0.08NS |
| Eviscerated weight (kg) | 1.71 | 1.58 | 1.56 | 1.42 | 1.55 | 0.07NS |
| Carcass weight (kg) | 1.58 | 1.45 | 1.42 | 1.31 | 1.44 | 0.06NS |
| Dressing Percentage | 64.86 | 64.46 | 63.09 | 64.83 | 64.87 | 1.27NS |
| Lungs weight (%) | 0.44 | 0.54 | 0.48 | 0.48 | 0.45 | 0.03NS |
| Heart weight (%) | 0.32 | 0.36 | 0.35 | 0.31 | 0.32 | 0.02NS |
| Liver weight (%) | 1.45 | 1.78 | 1.71 | 1.70 | 1.38 | 0.27NS |
| Kidney weight (%) | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.006NS |
| Abd.fat weight (%) | 1.41 | 1.34 | 1.57 | 0.98 | 1.44 | 0.22NS |
| Gizzard weight (%) | 1.56 | 1.57 | 1.64 | 1.92 | 1.57 | 0.10NS |
| Caecal weight (%) | 0.42b | 0.67ab | 0.74a | 0.62ab | 0.48b | 0.25\*\* |
| Caecal length (cm) | 18.38 | 20.91 | 19.43 | 20.81 | 19.13 | 1.78NS |
| Pancreas weight (%) | 0.15 | 0.19 | 0.19 | 0.18 | 0.15 | 0.20NS |
| Small intestine wt (%) | 2.49 | 2.68 | 2.86 | 3.36 | 2.69 | 0.22NS |
| S/ intestine length (cm) | 181.25ab | 181.75ab | 194.63a | 151.88b | 159.13b | 32.37\*\* |
| Large intestine wt (%) | 0.23 | 0.22 | 0.15 | 0.29 | 0.25 | 0.04NS |
| L/ intestine length(cm) | 11.63 | 12.35 | 11.89 | 13.13 | 14.13 | 1.62NS |
| Spleen weight (%) | 0.08 | 0.12 | 0.10 | 0.10 | 0.08 | 0.01NS |
| abc Means bearing different superscripts within the same row differ \*\* = (P< 0.01), NS= Not significant; SEM= Standard error of means | | | | | | | |

* + 1. ***Cost benefits analysis of broiler chickens fed graded levels of sorghum SK-5912 as replacement for pearl millet***

The cost effectiveness of broiler chickens fed sorghum SK-5912 variety as replacement for pearl millet based diets is shown in Table 37. The total feed intake at the starter phase varied between 1.59 and 1.63kg on diets 2 and 4 respectively. All the values observed on the dietary treatments were equal or lower than the value on the control diet except diet 4. The feed cost (₦/kg) ranged from ₦155.99 on diet 5 to ₦172.16 on diet 1. The values decreased with increasing levels of sorghum SK-5912 replacing pearl millet. The total feed cost (₦) ranged from ₦249.58 on diet 5 and ₦378.90 on diet 1. The total weight gain (kg) ranged from 0.87kg to 0.91kg on diets 2 and 3 respectively during the starter phase. The value on the control diet (0.90kg) is only lower compared to diet 3 (0.91kg). The feed cost in ₦ per kg gain varied between ₦283.61 to ₦309.89 on diets 5 and 1 respectively and were cheaper on other treatment diets than on the control diet ₦309.89.

At the finisher phase, the total feed intake values varied between 2.59kg to 2.67kg for diets 3 and 4 respectively. The values of feed cost (₦/kg) ranged from ₦141.73 to ₦152.78 on diets 5 and 1. The values reduced with increasing level of sorghum SK-5912 variety. Similarly, the values of total feed cost decreased with increasing level of sorghum SK-5912 variety and varied from ₦371.33 to ₦406.39 on diets5 and 1 respectively. The total weight gain in kg ranged from 0.92 to 0.96kg on diets 3, 4 and diet 1 respectively. The value on control diet (0.96kg) was higher than all other values among the treatment groups. Feed cost ₦/kg gain values varied between ₦390.87 and ₦423.32 on diets 5 and 1 respectively. All other values are lower compared to the value on the control diet (₦423.32).

The overall total feed intake varied between 4.21 and 4.30kg on diets 3 and 4 respectively. The values observed on diets 4 was higher then followed by the control diet (4.28kg). The feed cost in ₦ per kg gain ranged from ₦148.86 to ₦162.47 on diets 5 and 1 respectively and decreased with increasing levels of sorghum SK-5912 variety replacing pearl millet in diet. Similarly, the values of total feed cost decreased with increasing level of sorghum SK-5912 variety and varied from ₦628.19 to ₦695.37 on diets 5 and 1 respectively. The highest value for total weight gain was observed value on the control diet (1.86kg) and the lowest was diet 4 (1.81kg). The highest value observed for feed cost ₦ per kg weight gain was on diet 1 (₦373.85) and the lowest on diet 5 (₦343.27). The feed cost in ₦ per kg gain of all the treatment groups were lower compared to the value on the control diet and there is a cost saving on all the treatment diets. The percentage cost saving varied between 0.18% on diet 2 and 8.18% on diet 5.

Table 37: Cost benefit of broiler chicken fed graded levels of sorghum SK-5912 as replacement for pearl millet

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Diets** |  |  |
| **Parameters** | **1** | **2** | **3** | **4** | **5** |
| **Starter phase:** |  |  |  |  |  |
| Total feed intake (kg) | 1.62 | 1.59 | 1.62 | 1.63 | 1.60 |
| Feed cost (₦/kg) | 172.16 | 168.02 | 161.81 | 158.67 | 155.99 |
| Total feed cost (₦) | 278.90 | 267.15 | 262.13 | 258.63 | 249.58 |
| Total weight gain (kg) | 0.90 | 0.87 | 0.91 | 0.89 | 0.88 |
| Feed cost ₦/kg gain | 309.89 | 307.07 | 288.05 | 290.60 | 283.61 |
| **Finisher phase:** |  |  |  |  |  |
| Total feed intake (kg) | 2.66 | 2.65 | 2.59 | 2.67 | 2.62 |
| Feed cost (₦/kg) | 152.78 | 149.12 | 147.53 | 142.87 | 141.73 |
| Total feed cost (₦) | 406.39 | 395.17 | 382.10 | 381.46 | 371.33 |
| Total weight gain (kg) | 0.96 | 0.95 | 0.92 | 0.92 | 0.95 |
| Feed cost ₦/kg gain | 423.32 | 415.97 | 415.33 | 414.63 | 390.87 |
| **Overall performance** |  |  |  |  |  |
| Total feed intake (kg) | 4.28 | 4.24 | 4.21 | 4.30 | 4.22 |
| Feed cost (₦/kg) | 162.47 | 158.57 | 154.67 | 150.77 | 148.86 |
| Total feed cost (₦) | 695.37 | 672.34 | 651.16 | 648.31 | 628.19 |
| Total weight gain (kg) | 1.86 | 1.82 | 1.83 | 1.81 | 1.83 |
| Feed cost ₦/kg gain | 373.85 | 369.42 | 355.83 | 358.18 | 343.19 |
| Cost saving (₦) | 0.00 | 4.43 | 18.02 | 15.67 | 30.58 |
| % cost saving | 0.00 | 1.18 | 4.82 | 4.19 | 8.18 |
| Rankings cost ₦/kg gain | Diet 5> | Diet 3> | Diet 4> | Diet 2 | - |

# CHAPTER FIVE

## 5.0 DISCUSSION

## 5.1 Chemical Composition of Sorghum SK-5912

The proximate composition of feedstuffs provides information on the constituents that make up the material and is an indication of the quantity of nutrients from which inference may be drawn as to its usefulness or otherwise (Esonu *et al*., 2006). The proximate analysis of sorghum SK-5912 variety was thus performed to find out the quantity of its composition. The proximate composition showed that the sorghum SK-5912 had a crude protein content of 10.96 %, crude fibre content of 2.71%, ether extract content of 3.12% and NFE content of 77.58%. The values obtained were slightly higher than the values reported for sorghum by Olomu (2011), who observed that sorghum had a crude protein of 9.50%, crude fibre content of 2.70%, ether extract content of 2.50% and NFE content of 76.60%, and comparable to values reported by Tamburawa *et al.* (2012) for Nigerian local sorghum. The variation in the nutrients content may be attributed to differences in variety, area of production, edaphic factors and/or agronomic practices. The value obtained for tannin in sorghum SK-5912 is (4.42mg/kg) slightly higher than 2.32% reported by Pour-Reza and Edrissa (1997) for low tannin sorghum.

## 5.2 Experiment 1: Performance, Blood, Carcass characteristics and cost benefit of Broiler chickens fed sorghum SK-5912 as replacement for maize

### *5.2.1 Performance of Broiler chickens fed sorghum SK-5912 based diets*

The productive performance of broiler chickens fed sorghum SK-5912 based diets at both starter and finisher phases as well as the overall performance was not significantly influenced by the dietary treatments. These observations were in conformity with report of Olomu (2011), who reported that low tannin yellow sorghum can replace maize without any adverse effect on performance. The result is also in agreement with the findings of Pour-Reza and Edrissa (1997) who stated that all dietary maize can be replaced with low tannin sorghum without any adverse effect on live weight, feed intake and feed conversion ratio. More so, the result is in agreement with the findings of Adamu (2005) who reported a significant difference in the daily feed intake and daily weight gain when he replaced yellow sorghum for maize. This finding therefore revealed that sorghum SK-5912 hitherto was regarded to have poor taste when prepared as *tuwo* (traditional stiff porridge), unacceptable black colour and poor overnight keeping quality can be effectively used for broiler production with economic benefits.

### *5.2.3 Haematology and serum biochemical indices of boiler chickens fed graded levels of sorghum SK-5912 as replacement for maize*

The blood constituents are the biochemical medium of transportation in all animals and thus their profile shows the health status of the birds. The haematological and serum biochemical indices showed non-significant effect among the treatment groups in all the parameters measured. Kwari *et al.* (2014) obtained similar results for PCV, RBC counts, WBC counts and Hb concentration with broiler chickens fed maize, sorghum and millet and their combinations. This observation showed that sorghum SK-5912 exerted no detrimental effect on broiler chickens. The haematological values obtained were within the normal ranges of 25.00-45.00% PCV, 7.00-13.00g/dl Hb concentration for chickens reported by Opoola *et al.* (2013) indicating that the birds were adequately nourished and thus not anaemic or showing any sign of disease infection or parasite infestation.

The serum biochemical indices also showed no significant differences among the treatment groups. Although, the total serum protein values were higher than the range of 16.00-34.00g/dl reported by Kwari *et al.* (2011) for broiler chickens, and since total protein is usually a reflection of the protein quality of feed (Eggum, 1970) cited by Kwari *et al.* (2014) and thus higher values obtained indicated that the protein levels were sufficient to sustain the normal physiological process of the birds. This observation indicates that sorghum SK-5912 did not have any adverse effect on blood parameters measured in this study.

### *5.2.2 Carcass and visceral organs characteristics of broiler chickens graded levels of fed sorghum SK-5912 as replacement for maize*

The live, plucked, eviscerated and carcass weights showed non-significant difference among the treatment groups. The dressing percentages ranged from 70.20 to 73.49 and did not differ among the treatments. All the values obtained on visceral organs were also similar except in the large intestine that there was a highly significant (P<0.001) difference across the treatment means, and values obtained ranged from 0.16 to 0.33%. The results however, agreed with carcass yield of 68.18 – 78.69% reported by Bello *et al.* (2011) for broiler chickens, and Salami *et al.* (2004) reported similar values for well finished broiler chickens. This observation is also in conformity with the findings of Adamu *et al.* (2012) who reported that replacing maize with yellow sorghum resulted in increased dressing percentage probably due to higher protein content of sorghum and better feed utilization. Although, the result is in contrast with that of Yunusa *et al.* (2014) who reported that the relative weight of intestine were not significantly affected by variation in dietary energy sources.

### *5.2.4 Cost benefits of broiler chickens fed graded levels of sorghum SK- 5912 as replacement for maize*

The feed cost in ₦ per kg which ranged from ₦111.64-₦144.85 decreased with increase in the inclusion level of sorghum SK-5912 in the diets. The feed cost per kg body weight gain also decreased with increasing level of sorghum SK-5912 at both starter and finisher phases. The feed cost in naira per kilogram body weight was least in diet 3 (50% sorghum SK-5912) at the starter phase, while diet 4 (75% sorghum SK-5912) was the cheapest at the finisher and overall performance. This result agreed with the findings of Medugu *et al.* (2010), who reported that replacement of maize by sorghum in broiler diets reduced feed cost.

## 5.3 Experiment 2: Performance, Carcass characteristics, Blood and cost benefits of broiler chickens fed sorghum SK-5912 variety with different plant protein sources

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### *5.3.1 Performance of broiler chickens fed sorghum SK-5912 variety with different plant protein sources*

The daily feed intake of broiler chickens fed sorghum SK-5912 with different plant protein sources in Table 17, showed a highly significant (P<0.01) difference among the treatment means during the starter and overall phases. The values obtained ranged from 43.49g to 51.17g on diet 5 and control diet for the starter and 78.95g to 83.30g on the diets 5 and 2 at the overall phase respectively. This result is in contrast with the findings of Medugu *et al.* (2010) and Pour-Reza and Edriss (1997) who stated that all the dietary maize portion of broiler diets can be replaced with low-tannin sorghum without adverse effects on the live weight gain, feed intake and feed conversion ratio. Since birds have been known to eat in order to satisfy energy requirement (NRC, 1994), this differences could be attributed to the effect of different plant protein sources used in this study.

The treatment means differ significantly in terms of daily weight gain with diets 1 and 2 being significantly higher (P<0.001) than diet 4 at the starter phase. The highest value was observed on the control (24.78g) while diet 4 was the least (20.48g). Feed conversion ratio which is a direct indication of how best the feed given to birds was turned to meat also showed a significant (P<0.05) difference among the treatment groups, with diet 4 (sorghum + industrial groundnuts cake) having the best FCR and the worst was the control diet. This observation do not agree with the report of Ibitoye *et al.* (2012) who observed that replacing maize with sorghum or millet had no adverse effect on feed intake, weight gain and feed conversion ratio. This difference could also be attributed to effect of each different plant protein included in the diets, since it also has influence on performance. This observation is in agreement with the findings of Aguihe *et al.* (2013) who reported that at higher level of inclusion of local groundnuts cake, performance was impaired with less nutrient digestibility, and in contrast with the findings of Mysaa *et al.* (2016) who observed that feeding peanut meal at a high level (100% peanut meal as a protein source) in the birds rations improved final body weight and feed intake, but did not adversely affect feed conversion ratio and average daily gain.

### *5.3.3 Haematology and serum biochemical indices of broiler chickens fed sorghum SK- 5912 with different plant protein sources*

All the haematological parameters showed non-significant difference among the treatment means. The PCV values ranged from 33.80 to 38.40% and the Hb concentration ranged from10.18 to 11.94g/dl which were similar to the values obtained on the control. The serum biochemical indices were also similar except the high density lipoprotein there was a significant (P<0.05) influenced among the treatment groups. The different protein sources therefore, did not affect the haematological and corpuscular indices, the values obtained are within the normal range reported by Swenson (1977) and Anon (1980) cited by Kwari *et al.* (2014) indicating that the birds were nourished and the diets were ideal and adequate for broiler chickens. Mean total serum protein values ranged from 40.50 to 52.75g/l, these values were also similar to values reported by Kwari *et al.* (2014) for birds fed maize, sorghum and millet, and their combinations. Albumin and globulin values were 12.25-19.50g/l and 24.25-40.50g/l respectively. AST and ALT enzymes values were also similar across the dietary treatments and were not beyond the threshold may be an indication of a better quality protein (Babatunde *et al*., 1987; Oluwole-Bonjo *et al*., 2001), beyond threshold, the liver damage and bone marrow demineralization might be implicated (Ekpenyong and Biobaku, 1986) cited by Etuk *et al.* (2015).

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### *5.3.2 Carcass visceral organs characteristics of broiler chickens fed sorghum SK-5912 with different plant protein sources*

The live, plucked, eviscerated and carcass weights were all similar among the dietary treatments. The dressing percentage varied from 67.77 to 69.45 in the birds fed diets 4 (sorghum SK-5912 + Industrial GNC) and control respectively. The results obtained for dressing percentage in this study were similar, although control diet was better. These results are in agreement with that of Torres *et al.* (2013) who reported that there was no significant difference among the treatments in whole carcass or carcass part weights of broiler chickens fed on sorghum based diets at 42 days of age. All the visceral organs measured showed no significant treatment effect among the groups. This finding was similar to the observations of Sanaa *et al.* (2016) who reported that groundnuts cake had no negative effect on carcass characteristics of broiler chickens, and did not agree with the findings of Yunusa *et al.* (2014) who reported variation in carcass characteristics of broiler chickens fed different energy sources.

### *5.3.4 Cost benefit of broiler chickens fed sorghum SK-5912 with different plant protein sources*

The feed cost in ₦ per kg in both starter and finisher phases was higher in the control diet than other dietary treatments. Similarly, the feed cost per kilogram gain was lower on the sorghum SK-5912 based diets (i.e. diets 2, 3, 4 and 5) compared to diet 1 (control) in both the starter and finisher phases. This indicates that sorghum SK-5912 with low price due to low human demand if combined with any plant protein source available in this case boiled soya bean, soya bean meal or groundnuts cake in broiler diets is capable of bringing down the cost of production. This observation was similar to that of Medugu *et al.* (2010) who reported that the highest cost per kg feed was in maize based diet compared to millet, low-tannin sorghum and high-tannin sorghum based diets. The lowest feed cost per kg gain was on diet 5 (sorghum SK-5912 + LGNC).

## 5.4 Experiment 3: Performance, Blood, Carcass characteristics, and Cost benefits of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum

### *5.4.1 Performance of broiler chickens fed graded levels of sorghum SK-5912 as a replacement for white sorghum*

The performance of broiler chickens fed sorghum SK-5912 as replacement for white sorghum is presented in Table 28. The daily feed intake and daily weight gain were not affected by the treatments during both the starter phase and finisher phase, but feed conversion ratio was significantly (P<0.05) affected by the treatments during the starter phase with best FCR value on diet 2 which did not differ from the values obtained on the diets 1 (control), 3 and 4. This result is in conformity with the findings of Medugu *et al.* (2010) who reported no significant difference on final weight, overall weight gain, daily feed intake, daily weight gain and feed conversion ratio, and the findings of Pour-Reza and Edriss (1997) who stated that all the dietary maize portion of broiler diets can be replaced with low-tannin sorghum without adverse effects on live weight, feed intake and feed conversion ratio. Ibitoye *et al.* (2012) also found no significant difference among the treatments for body weight gain when diets containing different energy sources were used in broiler feeding. This result is not in agreement with the findings of Yunusa *et al.* (2015) who reported a poor weight gain in white sorghum based diet.

The daily feed intake, daily weight gain and feed conversion ratio were also not significantly influenced by the dietary treatments at the overall performance of the birds. The improvements in growth performance was similar to that of other workers (Ibitoye *et al*., 2012; Medugu *et al*., 2010; Pour-Reza and Edriss., 1997), who observed that low-tannin sorghum can be used in poultry diet without adverse effects on performance.

### *5.4.3 Haematological and serum biochemical of broiler chickens fed sorghum SK-5912 as replacement for white sorghum*

The packed cell volume, white blood cells counts, haemoglobin and all the corpuscular parameters measured were all similar among the treatment groups and the values obtained are all within the normal range as reported by Kwari *et al.* (2014) when maize, sorghum and millet, and their combinations was fed to broilers and when SAMSORG 17 (sorghum SK-5912) was fed to turkey poults there was no adverse effect on their blood parameters Etuk *et al.* (2015). This observation also showed that sorghum SK-5912 was not toxic or detrimental to broiler chickens.

### *5.4.2 Carcass and visceral organs characteristics of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum*

The dressing percentage (67.04-70.44%), liver, lungs, heart, kidney, abdominal fats, intestine and caecal weights and lengths were not affected by the dietary treatments. This non-significant difference in the carcass yield of the birds was also reported by Kwari *et al.* (2014) who use many varieties of sorghum and obtained a similar result of dressing percentage (68.77%). It means that the diets were converted in the same way to produce carcasses yield. Although, the carcass yields are slightly below those reported by Issa *et al.* (2007) with about 75.76%, but values obtained are within the normal range.

### *5.4.4 Cost benefits of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum*

The feed cost decreased with increase in level of sorghum SK-5912 in the diets at the starter and finisher phases as well as the overall performance. The cost per kg gain also decreased with increase in the level of sorghum SK-5912 inclusion. The overall performance indicated that the cheapest feed cost in naira per kilogram gain was diet 5 (100% sorghum SK-5912), and all the treatment diets had lower feed cost per kg gain than the control (100% white sorghum). This result is in agreement with Medugu *et al.* (2010), but in contrast with findings of Yunusa *et al*. (2015) who reported a lowest feed cost ₦ per kg gain in white sorghum when different energy sources where fed broiler chickens. This result obtained could be attributed to the better gain and fairly good feed utilization by sorghum SK-5912 based diets and the lower cost of sorghum SK-5912 compared to white sorghum.

## 5.5 Experiment 4: Performance, Blood, Carcass characteristics, and Cost effectiveness of broiler chickens fed graded levels of SK-5912 as replacement for pearl millet

### *5.5.1 Performance of broiler chickens fed graded levels of sorghum SK-5912 as replacement for pearl millet*

The performance of broiler chickens fed graded levels of sorghum SK-5912 as replacement for pearl millet is presented in Table 33. The daily feed intake showed non-significant difference among the treatment means during the starter and finisher phases as well as the overall performance. The feed intake ranged from 56.63-58.11g for the starter and 43.78-45.57g for the finisher phase. The daily weight gain also showed no significant difference between treatment groups at all the starter and finisher phases as well as the overall performance. The values obtained in this study are comparable with reports of Kwari *et al.* (2014) who observed this performance when they fed broiler chickens maize, sorghum and millet, and their combinations. However, slightly below values reported by Medugu *et al.* (2010). Feed conversion ratio results also showed non-significant difference at both starter and finisher phases as well as the overall performance. This result is in conformity with the findings of Medugu *et al.* (2010) who also stated that considering the weight gain of the birds, millet and sorghum can completely replace maize in broiler chicken diets without adverse effects on performance. Bulus *et al.* (2014) also, observed and concluded that, complete replacement of maize with pearl millet, finger millets or with yellow guinea corn in broilers diet did not impair feed intake, body weight, feed conversion and nutrient retention.

### *5.5.3 Haematological and serum biochemical indices of broiler chickens fed sorghum SK-5912 as replacement for pearl millet*

The haematological parameters of birds fed graded levels of sorghum SK-5912 as replacement for pearl millet is shown in Tables 35 and 36. All the parameters measured were not significantly affected by the dietary treatments. The packed cell volume ranged from 29.35 to 34.85%, the haemoglobin concentration counts ranged from 9.30 to 10.88g/dl and these slightly lower than the values reported by Kwari *et al.* (2014). The authors reported PCV of 26.67-31.60 and Haemoglobin concentration counts of 9.13-10.07g/dl for broiler chickens fed maize, sorghum and millet, and their combinations.

The total serum protein values ranged from 30.50 to 35.50, total cholesterol values ranged from 3.35 to 4.78mmol/l. All the parameters measured did not show significant difference among the treatment groups. The observation was similar to values reported by Kwari *et al.* (2014) of 43.00-51.50g/dl total protein and 2.95-3.70mmol/l for total cholesterol. This result is in contrast with the findings of Rama Rao *et al.* (2003) who reported that concentration of total cholesterol and LDL cholesterol in blood serum of broilers were found to decrease significantly as the level of pearl millet was higher compared to maize fed group. The values obtained for enzymes AST of 201.75-315.75IU/L and ALT 20.75-32.50IU/L were slightly above values reported by Kwari *et al.* (2014) of 108.00-123.00IU/L for ALT and 105.00-143.50IU/L for AST. The values obtained in this study however fall within normal range. This result showed that sorghum SK-5912 can be used as energy source in broiler chickens diets without adverse effects on the health of the birds.

### *5.5.2 Carcass and visceral organs characteristics of broiler chickens fed graded levels of sorghum SK-5912 as replacement for pearl millet*

The carcass and visceral organs characteristics of broiler chickens fed graded levels of sorghum SK-5912 as replacement for pearl millet is shown in Table 34. All the parameters studied showed non-significant difference among the dietary treatments. Dressing percentage values ranged from 63.09 to 64.87% on diets 3 (50% sorghum SK-5912) and 5 (100% sorghum SK-5912) respectively. Although, similar values obtained were slightly above the values (58.24-63.85%) obtained and reported by Yunusa *et al.* (2014), and below values (67.187-81.247%) reported by Kwari *et al.* (2014), and comparable to that of Salami *et al.* (2004) who reported 65-70% as the ideal dressing percentage for well finished broiler chickens. The result is being supported by Raju *et al.* (2003) in an isocaloric and isonitrogenous diet containing pearl millet found and reported that these parameters were statistically comparable to maize fed group. Likewise, Rama Rao *et al.* (2003) in their experiment in broiler fed with pearl millet at graded levels replacing maize did not find any statistically difference on the parameters measured.

### *5.5.4 Cost benefits of broiler chickens fed graded levels of sorghum SK-5912 as replacement for pearl millet*

The cost benefit analysis of broiler chickens fed graded levels of sorghum SK-5912 as replacement for pearl millet is presented in Table27. The feed cost per kg reduced with increase in level of sorghum SK-5912 inclusion at the starter, finisher and overall phases. Similarly, the feed cost per kilogram gain was lower on other treatment diets compared to the control (100% pearl millet). This result is in agreement with the findings of Yunusa *et al.* (2015) who reported lower feed cost in naira per kg gain on pearl millet when they fed broilers with different energy sources. This observation could be due to the prevailing market price of sorghum SK-5912 at the time of the study that was relatively cheaper compared to that of pearl millet due to competition for human demands. This is in support of the reports of Kekeocha (1984) and Esonu *et al.* (2003) who stated that a strong economic benefit exists by feeding alternative low cost feed materials to poultry, such feeds reduce cost of feed and maximize the returns from poultry farming.

# CHAPTER SIX

## 6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

## 6.1 Summary

A laboratory investigation and four (4) experiments were conducted to evaluate the proximate composition of sorghum SK-5912 variety, effect of replacement of maize with sorghum SK-5912, its utilization with different plant protein sources, its replacement value for white sorghum and its replacement value for pearl millet as dietary energy sources in formulated diets. While the first experiment was conducted to determine the performance of broiler chickens fed sorghum SK-5912 based diets, the second experiment was conducted to determine the birds performance using sorghum SK-5912 with different plant protein sources, and the third and fourth were to determine the performance of broiler chickens fed graded levels of sorghum SK-5912 as replacement for white sorghum and pearl millet respectively. In experiment 1, sorghum SK-5912 variety replaced maize at 0, 25, 50, 75 and 100% levels in the diets of broiler chickens.

The entire growth performance which include feed consumption, body weight changes and feed utilization at both the starter and finisher phases as well as pooled performance were not significantly influenced by the dietary levels of sorghum SK-5912 variety. The blood parameters measured were not affected. Most of the carcass characteristics measured were also not affected by the dietary treatments except the weight of large intestine that was significantly (P<0.001) affected. Cost benefit analysis showed that, feed costs per kilogram body weight gain were better on the sorghum SK-5912 based diets than the control diet. In experiment 2, sorghum SK-5912 was used with different plant protein sources i.e. boiled soya bean, soya bean meal, industrial ground nuts cake and local ground nuts cake, and with maize plus boiled soya bean as the control diet. In the performance parameters measured daily feed intake was significantly (P<0.01) affected, daily weight gain was also affected (P<0.001) and feed conversion ratio was influenced (P<0.05) at the starter phase. At the finisher phase performance parameter measured were similar. While the pooled performance showed non-significant difference for most of the parameters except daily feed intake that was significantly (P<0.05) influenced across the dietary treatments. Almost all the blood parameters were not influenced except the high density lipoprotein that was significantly (P<0.05) influenced by the dietary treatments, and feed cost per kilogram body weight. All the carcass and visceral organs characteristics were not affected.

In experiment 3, sorghum SK-5912 replaced white sorghum in the diets of broiler chickens at 0, 25, 50, 75 and 100% levels. Only feed utilization was affected at P<0.05 during the finisher phase, all other performance parameters were not affected at the starter and finisher phases as well as the overall performance. Almost all of the blood parameters measured were not influenced by the dietary treatments except total cholesterol that was significantly (P<0.01) affected, and low density lipoproteins that significantly (P<0.05) differ among the treatment groups. All of the carcass and visceral organs characteristics were similar. Feed cost per kilogram body weight gain was better on the treatment diets than the control diet. In experiment 4, graded levels of sorghum SK-5912 replaced pearl millet at 0, 25, 50, 75 and 100% in the diets of broiler chickens. All of the growth performances were not affected during the starter and finisher phases as well as the overall performance. Almost all of the blood parameters studied, were not affected except in mean corpuscular haemoglobin which there was a significant (P<0.01) difference among the treatment groups. Similarly, most of the parameters measured for carcass and visceral organs characteristics were also not affected except small intestine length that was influenced (P<0.01) across the treatment groups. The feed cost per kg body weight gain was lower on the treatment diets compared to the control diet.

## 6.2 Conclusion

In conclusion,

Sorghum SK-5912 variety can replace maize, white sorghum and pearl millet in the diets of broiler chickens without adverse effect on the performance, blood parameters and carcass yield. Sorghum SK-5912 can be combined with different plant protein sources in broiler production without depression in the performance, blood components and carcass yield. The use of sorghum SK-5912 in broiler diets resulted in reduction in feed cost (₦/kg) and feed cost in naira per kilogram body weight gain, thereby improving the profit margin of the poultry farmer. The use of sorghum SK-5912 variety can lead to the reduction in overdependence on conventional feedstuffs such as maize, white sorghum and pearl millet, and hence contributes to animal production at minimal cost, ultimately improving the animal protein intake of the citizens. Since, sorghum SK-5912 variety has been shown to be an acceptable alternative to other grains, intensive efforts to increase production and initiate marketing are justified.

## 6.3 Recommendations

Based on the results obtained, the following recommendations are made:

1. Sorghum SK-5912 can favourably replace maize, white sorghum and pearl millet in broiler production with concomitant reduction in feed cost.
2. Sorghum SK-5912 can be mixed with different plant protein sources provided they are well processed without negative effect on the performance of the birds.
3. Sorghum SK-5912 production should be encouraged, thus its utilization in poultry diets will improve the feed supply system at affordable cost.
4. Further studies should be conducted in other animal species like layers, cockerels, quails, turkeys and guinea fowls to ascertain its suitability as energy source.

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# APPENDICES

**APPENDIX I: ANALYSIS OF VARIANCE FOR FEED INTAKE EXPERIMENT 1**

a. Analysis of variance for daily feed intake (1 – 4 weeks)

Source DF SS MS F P

DIETS 4 37.992 9.498 1.29 0.319 NS

Error 15 110.448 7.363

Total 19 148.440

b. Analysis of variance for daily feed intake (5 – 8 weeks)

Source DF SS MS F P

DIETS 4 60.60 15.15 0.79 0.549 NS

Error 15 287.17 19.14

Total 19 347.77

c. Analysis of variance for daily feed intake (1–8weeks)

Source DF SS MS F P

DIETS 4 29.461 7.365 0.90 0.487 NS

Error 15 122.453 8.164

Total 19 151.915

d. Analysis of variance for total feed intake

Source DF SS MS F P

DIETS 4 73759 18440 0.90 0.487 NS

Error 15 306430 20429

Total 19 380189

**APPENDIX II: ANALYSIS OF VARIANCE FOR WEIGHT GAIN EXPERIMENT 1**

a. Analysis of variance for daily weight gain (1-4 weeks)

Source DF SS MS F P

DIETS 4 40.111 10.028 1.88 0.166 NS

Error 15 79.839 5.323

Total 19 119.950

b. Analysis of variance for daily weight gain (5-8 weeks)

Source DF SS MS F P

DIETS 4 209.83 52.46 0.98 0.448 NS

Error 15 804.15 53.61

Total 19 1013.98

c. Analysis of variance for daily weight gain (1-8 weeks)

Source DF SS MS F P

DIETS 4 67.021 16.755 1.93 0.158 NS

Error 15 130.474 8.698

Total 19 197.495

d. Analysis of variance for total weight gain

Source DF SS MS F P

DIETS 4 181488 45372 2.13 0.128 NS

Error 15 320065 21338

Total 19 501553

e. Analysis of Variance for Ave. initial weight

Source DF SS MS F P

DIETS 4 8.964 2.241 0.77 0.561 NS

Error 15 43.640 2.909

Total 19 52.604

**APPENDIX III: ANALYSIS VARAIANCE FEED CONVERSION RATIO**

a. Analysis of Variance for feed conversion ratio (1-4 weeks)

Source DF SS MS F P

DIETS 4 0.26963 0.06741 2.67 0.073 NS

Error 15 0.37863 0.02524

Total 19 0.64825

b. Analysis of variance for feed conversion ratio (5-8 weeks)

Source DF SS MS F P

DIETS 4 0.8587 0.2147 1.09 0.397 NS

Error 15 2.9541 0.1969

Total 19 3.8128

c. Analysis of variance for feed conversion ratio (1-8 weeks)

Source DF SS MS F P

DIETS 4 0.32715 0.08179 1.69 0.204 NS

Error 15 0.72582 0.04839

Total 19 1.05297

**APPENDIX IV: ANALYSIS OF VARIANCE FOR HAEMATOLOGICAL PARAMETERS EXPERIMENT 1**

a. Analysis of variance for PCV

Source DF SS MS F P

DIETS 4 72.281 18.070 4.30 0.071 NS

Error 5 20.992 4.199

Total 9 93.274

b. Analysis of variance for WBC

Source DF SS MS F P

DIETS 4 141.02 35.26 1.11 0.443 NS

Error 5 158.45 31.69

Total 9 299.48

c. Analysis of variance for RBC

Source DF SS MS F P

DIETS 4 0.02520 0.00630 0.33 0.847 NS

Error 5 0.09545 0.01909

Total 9 0.12065

d. Analysis of variance for MCV

Source DF SS MS F P

DIETS 4 17823.7 4455.9 110.62 0.000 \*\*\*

Error 5 201.4 40.3

Total 9 18025.1

e. Analysis of variance for MCH

Source DF SS MS F P

DIETS 4 4.3150 1.0798 1.30 0.383 NS

Error 5 4.1513 0.8303

Total 9 8.4703

f. Analysis of variance for MCHC

Source DF SS MS F P

DIETS 4 5.386 1.346 0.67 0.642 NS

Error 5 10.106 2.021

Total 9 15.492

h. Analysis of variance for PLT

Source DF SS MS F P

DIETS 4 21095 5274 0.93 0.515 NS

Error 5 28362 5672

Total 9 49457

**APPENDIX V: ANALYSIS OF VARIANCE FOR SERUM BIOCHEMICAL INDICES EXPERIMENT 1**

a. Analysis of variance for T. Protein

Source DF SS MS F P

DIETS 4 170.00 43.75 1.11 0.44 NS

Error 5 197.00 39.40

Total 9 372.00

b. Analysis of variance for Albumin

Source DF SS MS F P

DIETS 4 15.00 3.75 0.14 0.962 NS

Error 5 137.00 27.40

Total 9 152.00

c. Analysis of variance for Globulin

Source DF SS MS F P

DIETS 4 127.00 31.75 0.87 0.542 NS

Error 5 183.00 36.60

Total 9 310.00

d. Analysis of variance for Creatinine

Source DF SS MS F P

DIETS 4 35.34 8.83 0.66 0.648 NS

Error 5 67.42 13.48

Total 9 102.75

e. Analysis of variance for T. cholesterol

Source DF SS MS F P

DIETS 4 19.616 4.904 1.04 0.463 NS

Error 5 23.477 4.696

Total 9 43.094

f. Analysis of variance for HDL

Source DF SS MS F P

DIETS 4 3.4610 0.8653 3.43 0.104 NS

Error 5 1.2612 0.2522

Total 9 4.7222

g. Analysis of ariance for LDL

Source DF SS MS F P

DIETS 4 0.9235 0.2309 0.90 0.527 NS

Error 5 1.2525 0.2565

Total 9 2.2060

h. Analysis of variance for AST

Source DF SS MS F P

DIETS 4 22827 5707 4.73 0.05 NS

Error 5 6033 1207

Total 9 28860

i. Analysis of variance for ALT

Source DF SS MS F P

DIETS 4 4394.6 1098.7 2.26 0.197 NS

Error 5 2427.0 485.4

Total 9 6821.6

**APPENDIX VI: CARCASS AND VISCERAL ORGANS CHARACTERISTICS EXPERIMENT 1**

a. Analysis of variance for live weight

Source DF SS MS F P

DIETS 4 0.05087 0.01272 0.69 0.602 NS

Error 35 0.64312 0.01837

Total 39 0.69400

b. Analysis of variance for plucked weight

Source DF SS MS F P

DIETS 4 0.06867 0.01717 0.81 0.526 NS

Error 35 74011 0.02115

Total 39 0.80878

c. Analysis of variance for eviscerated weight

Source DF SS MS F P

DIETS 4 0.13663 0.03416 1.12 0.363 NS

Error 35 1.06813 0.03052

Total 39 1.20475

d. Analysis of variance for carcass weight

Source DF SS MS F P

DIETS 4 0.02587 0.00647 0.34 0.852 NS

Error 35 0.67406 0.01926

Total 39 0.6994

e. Analysis of variance for Head

Source DF SS MS F P

DIETS 4 0.2006 0.0501 0.33 0.853 NS

Error 35 5.2601 0.1503

Total 39 5.4607

f. Analysis of variance for Legs

Source DF SS MS F P

DIETS 4 3.7940 0.9485 1.30 0.288 NS

Error 35 25.4662 0.7276

Total 39 29.2602

g. Analysis of variance for Gizzard

Source DF SS MS F P

DIETS 4 0.4455 0.1114 0.68 0.609 NS

Error 35 5.7119 0.1632

Total 39 6.1574

h. Analysis of variance for Heart

Source DF SS MS F P

DIETS 4 0.026865 0.006716 1.04 0.399 NS

Error 35 0.225175 0.006434

Total 39 0.252040

i. Analysis of variance for Liver

Source DF SS MS F P

DIETS 4 0.7004 0.1751 1.04 0.394 NS

Error 35 5.8235 0.1664

Total 39 6.5239

j. Analysis of variance for Pancreas

Source DF SS MS F P

DIETS 4 0.028725 0.007181 1.36 0.269 NS

Error 35 0.185425 0.005298

Total 39 0.214150

k. Analysis of variance for Lungs

Source DF SS MS F P

DIETS 4 0.02876 0.00719 0.46 0.767 NS

Error 35 0.55167 0.01576

Total 39 0.58044

l. Analysis of variance for Abdominal fat

Source DF SS MS F P

DIETS 4 0.5236 0.1309 1.17 0.342 NS

Error 35 3.9219 0.1121

Total 39 4.4454

m. Analysis of variance for Spleen

Source DF SS MS F P

DIETS 4 0.020015 0.005004 1.59 0.200 NS

Error 35 0.0110363 0.003153

Total 39 0.130378

n. Analysis of variance for Small intestine

Source DF SS MS F P

DIETS 4 3.0833 0.7708 2.31 0.077 NS

Error 35 11.6726 0.3335

Total 39 14.7559

o. Analysis of variance for Large intestine

Source DF SS MS F P

DIETS 4 0.155385 0.038846 6.98 0.000 \*\*\*

Error 35 0.194725 0.005564

Total 39 1.350110

p. Analysis of variance for Caeca

Source DF SS MS F P

DIETS 4 0.018085 0.004521 0.95 0.445 NS

Error 35 0.165912 0.004740

Total 39 0.183997

q. Analysis of variance for dressed percentage

Source DF SS MS F P

DIETS 4 52.55 13.14 0.92 0.462 NS

Error 35 498.84 14.25

Total 39 551.39

r. Analysis of variance for Small intestine length

Source DF SS MS F P

DIETS 4 2774.1 693.3 2.21 0.088 NS

Error 35 10997.3 314.2

Total 39 13770.4

s. Analysis of variance for Large intestine length

Source DF SS MS F P

DIETS 4 29.703 7.426 1.01 0.414 NS

Error 35 356.577 7.331

Total 39 286.280

t. Analysis of variance for caeca length

Source DF SS MS F P

DIETS 4 8.087 2.022 0.99 0.425 NS

Error 35 71.313 2.038

Total 39 79.400

**APPENDIX VII: ANALYSIS OF VARIANCE FOR FEED INTAKE EXPERIMENT 2**

a. Analysis of variance for daily feed intake (1-4 weeks)

Source DF SS MS F P

DIETS 4 154.819 38.705 7.36 0.002 \*\*

Error 15 78.873 5.258

Total 19 233.693

b. Analysis of variance for daily feed intake (5-8 weeks)

Source DF SS MS F P

DIETS 4 15.26 3.81 0.27 0.894 NS

Error 15 213.88 14.26

Total 19 229.14

c. Analysis of variance for daily feed intake (1-8 weeks)

Source DF SS MS F P

DIETS 4 56.288 14.072 4.97 0.009 NS

Error 15 42.483 2.832

Total 19 98.771

d. Analysis of variance for total feed intake

Source DF SS MS F P

DIETS 4 132036 33009 4.39 0.015 NS

Error 15 112782 7519

Total 19 244818

**APPENDIX VIII: ANALYSIS OF VARIANCE FOR WEIGHT GAIN EXPERIMENT 2**

Analysis of variance for daily weight gain (1-4 weeks)

Source DF SS MS F P

DIETS 4 64.940 16.235 13.800.000 \*\*\*

Error 15 17.647 1.176

Total 19 82.588

b. Analysis of variance for daily weight gain (5-8 weeks)

Source DF SS MS F P

DIETS 4 137.92 34.48 0.77 0.561 NS

Error 15 671.97 44.80

Total 19 809.89

c. Analysis of variance for daily weight gain (1-8 weeks)

Source DF SS MS F P

DIETS 4 11.495 2.874 0.43 0.784 NS

Error 15 100.032 6.669

Total 19 111.526

d. Analysis of variance for total weight gain

Source DF SS MS F P

DIETS 4 28729 7182 0.43 0.784 NS

Error 15 25221 16681

Total 19 278950

e. Analysis of variance for Ave. Initial weight

Source DF SS MS F P

DIETS 4 17.69 4.42 0.23 0.918 NS

Error 15 290.66 19.36

Total 19 308.35

f. Analysis of Variance for Ave. Final weight

Source DF SS MS F P

DIETS 4 29194 7299 0.45 0.770 NS

Error 15 242866 16191

Total 19 272060

**APPENDIX IX: ANALYSIS OF VARIANCE FOR FCR EXPERIMENT 2**

Analysis of variance for feed conversion ratio (1-4 weeks)

Source DF SS MS F P

DIETS 4 0.221970 0.055493 5.60 0.006 NS

Error 15 0.148725 0.009915

Total 19 0.3706915

b. Analysis of variance for feed conversion ratio (5-8 weeks)

Source DF SS MS F P

DIETS 4 2.4493 0.6123 1.01 0.435 NS

Error 15 9.1250 0.6083

Total 19 11.5743

c. Analysis of variance for feed conversion ratio (1-8 weeks)

Source DF SS MS F P

DIETS 4 0.28973 0.07243 0.91 0.483 NS

Error 15 1.19465 0.07964

Total 19 1.48438

**APPENDIX X: ANALYSIS OF VARIANCE FOR HAEMATOLOGICAL PARAMETERS EXPERIMENT 2**

a. Analysis of variance for PCV

Source DF SS MS F P

DIETS 4 34.12 8.33 0.56 0.702 NS

Error 5 75.90 15.18

Total 9 110.01

b. Analysis of variance for WBC

Source DF SS MS F P

DIETS 4 412.4 103.1 0.88 0.535 NS

Error 5 584.2 116.8

Total 9 996.6

c. Analysis of variance for RBC

Source DF SS MS F P

DIETS 4 0.14216 0.03554 0.59 0.688 NS

Error 5 0.30320 0.0664

Total 9 0.44536

d. Analysis of variance for Hb

Source DF SS MS F P

DIETS 4 3.9159 0.9790 1.62 0.303 NS

Error 5 3.0287 0.6057

Total 9 6.9446

e. Analysis of variance for MCV

Source DF SS MS F P

DIETS 4 1301.0 325.2 1.04 0.472 NS

Error 5 1570.3 314.1

Total 9 2871.3

f. Analysis of variance for MCH

Source DF SS MS F P

DIETS 4 2.331 0.583 0.18 0.942 NS

Error 5 16.618 3.324

Total 9 18.949

g. Analysis of variance for MCHC

Source DF SS MS F P

DIETS 4 4.221. 1.055 0.34 0.843 NS

Error 5 15.678 3.136

Total 9 19.899

h. Analysis of variance for PLT

Source DF SS MS F P

DIETS 4 22587 5647 1.90 0.248 NS

Error 5 14825 2965

Total 9 37411

**APPENDIX XI: ANALYSIS OF VARIANCE FOR SERUM BIOCHEMICAL INDICES EXPERIMENT 2**

a. Analysis of variance for T. Protein

Source DF SS MS F P

DIETS 4 155.35 38.84 1.60 0.306 NS

Error 5 121.25 24.25

Total 9 276.60

b. Analysis of variance for Albumin

Source DF SS MS F P

DIETS 4 71.75 17.94 1.48 0.335 NS

Error 5 60.75 12.15

Total 9 132.50

c. Analysis of variance for Globulin

Source DF SS MS F P

DIETS 4 294.35 73.59 3.60 0.096 NS

Error 5 102.25 20.45

Total 9 396.60

d. Analysis of variance for Creatinine

Source DF SS MS F P

DIETS 4 283.53 70.88 0.88 0.538 NS

Error 5 404.74 80.95

Total 9 688.27

e. Analysis of variance for T. Cholesterol

Source DF SS MS F P

DIETS 4 6.4985 1.6246 1.83 0.261 NS

Error 5 4.4375 0.8875

Total 9 10.9360

f. Analysis of variance for HDL

Source DF SS MS F P

DIETS 4 3.49500 0.87375 12.310.008 NS

Error 5 0.35500 0.07100

Total 9 3.85000

g. Analysis of variance for LDC

Source DF SS MS F P

DIETS 4 0.5415 0.1354 0.39 0.812 NS

Error 5 1.7575 0.3515

Total 9 2.2990

h. Analysis of variance for TG

Source DF SS MS F P

DIETS 4 0.6840 0.1710 0.39 0.811 NS

Error 5 2.2163 0.4433

Total 9 2.9003

i. Analysis of variance for AST

Source DF SS MS F P

DIETS 4 22840 5710 3.29 0.112 NS

Error 5 8665 1733

Total 9 31505

j. Analysis of variance for ALT

Source DF SS MS F P

DIETS 4 4213.4 1053.3 4.44 0.067 NS

Error 5 1185.3 237.1

Total 9 5398.6

k. Analysis of variance for MCV

Source DF SS MS F P

DIETS 4 1301.0 325.2 1.04 0.472 NS

Error 5 1570.3 314.1

Total 9 2871.3

**APPENDIX XII: CARCASS AND VISCERAL ORGANS CHARACTERISTICS EXPERIMENT 2**

a. Analysis of variance for Live weight

Source DF SS MS F P

DIETS 4 0.07600 0.01900 1.53 0.215 NS

Error 35 0.43500 0.01243

Total 39 0.51100

b. Analysis of variance for plucked weight

Source DF SS MS F P

DIETS 4 0.077750 0.019437 1.97 0.120 NS

Error 35 0.345000 0.009857

Total 39 0.422750

c. Analysis of variance for eviscerated weight

Source DF SS MS F P

DIETS 4 0.029625 0.007406 0.90 0.475 NS

Error 35 0.288125 0.008232

Total 39 0.317750

d. Analysis of variance for carcass weight

Source DF SS MS F P

DIETS 4 0.063125 0.015781 2.16 0.094 NS

Error 35 0.255625 0.007304

Total 39 0.318750

e. Analysis of variance for Head

Source DF SS MS F P

DIETS 4 0.5104 0.1276 0.76 0.558 NS

Error 35 5.8778 0.1679

Total 39 6.3882

f. Analysis of variance for Legs

Source DF SS MS F P

DIETS 4 2.3340 0.5835 1.10 0.372 NS

Error 35 18.5746 0.5307

Total 39 20.9086

g. Analysis of Variance for Gizzard

Source DF SS MS F P

DIETS 4 1.3351 0.3338 0.79 0.537 NS

Error 35 14.7093 0.4203

Total 39 16.0443

h. Analysis of variance for Heart

Source DF SS MS F P

DIETS 4 0.02733 0.00683 0.68 0.609 NS

Error 35 0.35043 0.01001

Total 39 0.37775

i. Analysis of variance for Liver

Source DF SS MS F P

DIETS 4 0.04911 0.01228 0.23 0.920 NS

Error 35 1.86988 0.05343

Total 39 1.91899

j. Analysis of variance for Pancreas

Source DF SS MS F P

DIETS 4 0.021475 0.005369 0.71 0.591 NS

Error 35 0.265125 0.007575

Total 39 0.286600

k. Analysis of variance for Lungs

Source DF SS MS F P

DIETS 4 0.14616 0.03654 1.58 0.200 NS

Error 35 0.80743 0.02307

Total 39 0.95359

l. Analysis of variance for Abdominal fats

Source DF SS MS F P

DIETS 4 0.8663 0.2166 0.70 0.597 NS

Error 35 10.8300 0.3094

Total 39 11.6963

m. Analysis of variance for Spleen

Source DF SS MS F P

DIETS 4 0.004315 0.001079 0.47 0.756 NS

Error 35 0.079962 0.002285

Total 39 0.084277

n. Analysis of variance for Small intestine

Source DF SS MS F P

DIETS 4 17312 4328 1.02 0.409 NS

Error 35 148122 4232

Total 39 165434

o. Analysis of variance for Large intestine

Source DF SS MS F P

DIETS 4 0.30828 0.07707 3.20 0.024 NS

Error 35 0.84212 0.02406

Total 39 1.15040

p. Analysis of variance for Caeca

Source DF SS MS F P

DIETS 4 0.047063 0.011766 1.29 0.293 NS

Error 35 0.319375 0.009125

Total 39 0.366440

q. Analysis of variance for dressed percentage

Source DF SS MS F P

DIETS 4 17.55 4.39 0.43 0.786 NS

Error 35 356.93 10.20

Total 39 374.48

r. Analysis of variance for Small intestine length

Source DF SS MS F P

DIETS 4 528.4 132.1 1.30 0.290 NS

Error 35 3563.1 101.9

Total 39 4091.5

s. Analysis of variance for Large intestine length

Source DF SS MS F P

DIETS 4 3.708 0.927 0.60 0.667 NS

Error 35 54.329 1.552

Total 39 58.037

t. Analysis of Variance for Caeca length

Source DF SS MS F P

DIETS 4 2.850 0.713 0.40 0.811 NS

Error 35 63.125 1.804

Total 39 65.975

**APPENDIX XIII: ANALYSIS OF VARIANCE FOR FEED INTAKE EXPERIMENT 3**

a. Analysis of variance for daily feed intake (1-4 weeks)

Source DF SS MS F P

DIETS 4 1.284 0.321 0.08 0.987 NS

Error 15 59.329 3.955

Total 19 60.614

b. Analysis of variance for daily feed intake (5-8 weeks)

Source DF SS MS F P

DIETS 4 34.626 8.657 1.21 0.347 NS

Error 15 107.176 7.145

Total 19 141.803

c. Analysis of variance for daily feed intake (1-8 weeks)

Source DF SS MS F P

DIETS 4 8.925 2.231 0.48 0.753 NS

Error 15 70.243 4.683

Total 19 79.169

d. Analysis of variance for total feed intake

Source DF SS MS F P

DIETS 4 56337 14084 0.75 0.571 NS

Error 15 280008 18667

Total 19 336345

**APPENDIX XIV: ANALYSIS OF VARIANCE FOR WEIGHT GAIN EXPERIMNET 3**

a. Analysis of variance for daily weight gain (1-4 weeks)

Source DF SS MS F P

DIETS 4 27.986 6.996 2.37 0.099 NS

Error 15 44.206 2.947

Total 19 72.191

b. Analysis of variance for daily weight gain (5-8 weeks)

Source DF SS MS F P

DIETS 4 14.31 3.58 0.30 0.872 NS

Error 15 177.99 11.87

Total 19 192.30

c. Analysis of variance for daily weight gain (1-8 weeks)

Source DF SS MS F P

DIETS 4 18.684 4.671 0.82 0.534 NS

Error 15 85.791 5.719

Total 19 104.475

d. Analysis of variance for Initial weight

Source DF SS MS F P

DIETS 4 33.26 8.32 0.59 0.673 NS

Error 15 210.05 14.00

Total 19 243.31

e. Analysis of variance for Final weight

Source DF SS MS F P

DIETS 4 44028 11007 0.81 0.540 NS

Error 15 204608 13641

Total 19 248636

**APPENDIX XV: ANALYSIS OF VARIANCE FOR FCR EXPERIMENT 3**

a. Analysis of variance for feed conversion ratio (1-4 weeks)

Source DF SS MS F P

DIETS 4 0.133220 0.033305 4.13 0.019 NS

Error 15 0.121000 0.008067

Total 19 0.254220

b. Analysis of variance for feed conversion ratio (5-8 weeks)

Source DF SS MS F P

DIETS 4 0.08917 0.02229 0.73 0.586 NS

Error 15 0.45913 0.03061

Total 19 0.54830

c. Analysis of variance for feed conversion ratio (1-8 weeks)

Source DF SS MS F P

DIETS 4 0.10123 0.02531 1.98 0.149 NS

Error 15 0.19135 0.01276

Total 19 0.29258

**APPENDIX XVI: ANALYSIS OF VARIANCE FOR HAEMATOLOGICAL PARAMETERS EXPERIMENT 3**

Analysis of variance for WBC

Source DF SS MS F P

DIETS 4 870.0 217.5 0.43 0.782 NS

Error 15 7505.5 500.4

Total 19 8375.5

Analysis of variance for RBC

Source DF SS MS F P

DIETS 4 0.17267 0.04317 0.58 0.679 NS

Error 15 1.10985 0.07399

Total 19 1.28252

Analysis of variance for Hb

Source DF SS MS F P

DIETS 4 10.710 2.677 1.25 0.331 NS

Error 15 32.059 2.137

Total 19 42.769

Analysis of variance for HCT

Source DF SS MS F P

DIETS 4 22.99 5.75 0.55 0.705 NS

Error 15 158.13 10.54

Total 19 181.12

Analysis of variance for MCV

Source DF SS MS F P

DIETS 4 15.20 3.80 0.15 0.962 NS

Error 15 390.16 26.01

Total 19 405.37

Analysis of variance for MCH

Source DF SS MS F P

DIETS 4 12.56 3.14 0.27 0.893 NS

Error 15 174.29 11.62

Total 19 186.85

Analysis of variance for MCHC

Source DF SS MS F P

DIETS 4 333.48 83.37 1.03 0.422 NS

Error 15 1209.33 80.62

Total 19 1542.80

Analysis of variance for PLT

Source DF SS MS F P

DIETS 4 398.8 99.7 0.68 0.615 NS

Error 15 2193.0 146.2

Total 19 2591.8

**APPENDIX XVII: ANALYSIS OF VARIANCE FOR SERUM BIOCHEMISTRY INDICES EXPERIMENT 3**

a. Analysis of variance for T. Protein

Source DF SS MS F P

DIETS 4 669.7 167.4 1.34 0.300 NS

Error 15 1871.3 124.8

Total 19 2540.9

b. Analysis of variance for Albumin

Source DF SS MS F P

DIETS 4 5.800 1.450 0.20 0.936 NS

Error 15 110.750 7.383

Total 19 116.550

c. Analysis of variance for Globulin

Source DF SS MS F P

DIETS 4 591.7 147.9 1.21 0.347 NS

Error 15 1832.5 122.2

Total 19 2424.2

d. Analysis of variance for Glucose

Source DF SS MS F P

DIETS 4 3.457 0.864 0.30 0.874 NS

Error 15 43.245 2.883

Total 19 46.702

e. Analysis of variance for Creatinine

Source DF SS MS F P

DIETS 4 23.885 5.971 1.17 0.365 NS

Error 15 76.853 5.124

Total 19 100.738

f. Analysis of variance for T. Cholesterol

Source DF SS MS F P

DIETS 4 21.0580 5.2645 6.69 0.003 \*

Error 15 11.8100 0.7873

Total 19 32.8680

g. Analysis of variance for HDL

Source DF SS MS F P

DIETS 4 0.2370 0.0593 0.17 0.950 NS

Error 15 5.2325 0.3488

Total 19 5.4695

h. Analysis of variance for LDL

Source DF SS MS F P

DIETS 4 1.7930 0.4482 3.75 0.026 NS

Error 15 1.7925 0.1195

Total 19 3.5855

i. Analysis of variance for AST

Source DF SS MS F P

DIETS 4 2744 686 0.08 0.989 NS

Error 15 135725 9048

Total 19 138469

j. Analysis of variance for ALT

Source DF SS MS F P

DIETS 4 278.7 69.7 0.23 0.918 NS

Error 15 4566.5 304.4

Total 19 4845.2

**APPENDIX XVIII: ANALYSIS VARIANCE FOR CARCASS AND VISCERAL ORGANS CHARACTERISTICS EXPERIMENT 3**

a. Analysis of variance for Live weight

Source DF SS MS F P

DIETS 4 0.26412 0.06603 1.01 0.417 NS

Error 35 2.29281 0.06551

Total 39 2.55694

b. Analysis of variance for Plucked weight

Source DF SS MS F P

DIETS 4 0.14866 0.03717 0.67 0.615 NS

Error 35 1.93265 0.05522

Total 39 2.08131

c. Analysis of variance for Eviscerated weight

Source DF SS MS F P

DIETS 4 0.11189 0.02797 0.58 0.679 NS

Error 35 1.68669 0.04819

Total 39 1.79858

d. Analysis of variance for Carcass weight

Source DF SS MS F P

DIETS 4 0.11499 0.02875 0.70 0.600 NS

Error 35 1.44672 0.04133

Total 39 1.56171

e. Analysis of variance for Head

Source DF SS MS F P

DIETS 4 0.07481 0.01870 0.36 0.837 NS

Error 35 1.82746 0.05221

Total 39 1.90228

f. Analysis of variance for Legs

Source DF SS MS F P

DIETS 4 0.2874 0.0718 0.30 0.878 NS

Error 35 8.4767 0.2422

Total 39 8.7641

g. Analysis of variance for Gizzard

Source DF SS MS F P

DIETS 4 0.16056 0.04014 0.63 0.646 NS

Error 35 2.23944 0.06398

Total 39 2.40000

h. Analysis of variance for Liver

Source DF SS MS F P

DIETS 4 0.25764 0.06441 1.38 0.261 NS

Error 35 1.63576 0.04674

Total 39 1.89340

i. Analysis of variance for Heart

Source DF SS MS F P

DIETS 4 0.006100 0.001525 0.49 0.747 NS

Error 35 0.110038 0.003144

Total 39 0.116138

j. Analysis of variance for Lungs

Source DF SS MS F P

DIETS 4 0.13226 0.03307 2.38 0.070 NS

Error 35 0.48565 0.01388

Total 39 0.61791

k. Analysis of variance for Abdominal fats

Source DF SS MS F P

DIETS 4 0.9793 0.2448 1.73 0.166 NS

Error 35 4.9604 0.1417

Total 39 5.9397

l. Analysis of variance for Kidney

Source DF SS MS F P

DIETS 4 0.000515 0.000129 0.12 0.976 NS

Error 35 0.038725 0.001106

Total 39 0.039240

m. Analysis of variance for Pancreas

Source DF SS MS F P

DIETS 4 0.018740 0.004685 0.94 0.454 NS

Error 35 0.175050 0.005001

Total 39 0.193790

n. Analysis of variance for Spleen

Source DF SS MS F P

DIETS 4 0.0030750 0.0007688 0.85 0.502 NS

Error 35 0.0315625 0.0009018

Total 39 0.0346375

o. Analysis of variance for Small Intestine weight

Source DF SS MS F P

DIETS 4 1.3200 0.3300 1.24 0.310 NS

Error 35 9.2803 0.2652

Total 39 10.6003

p. Analysis of variance for Small Intestine Length

Source DF SS MS F P

DIETS 4 1897.5 474.4 1.46 0.236 NS

Error 35 11390.5 325.4

Total 39 13288.0

q. Analysis of variance for Large Intestine

Source DF SS MS F P

DIETS 4 0.008985 0.002246 0.85 0.505 NS

Error 35 0.092775 0.002651

Total 39 0.101760

r. Analysis of variance for Large Intestine weight

Source DF SS MS F P

DIETS 4 23.276 5.819 1.10 0.373 NS

Error 35 185.547 5.301

Total 39 208.824

s. Analysis of variance for Caeca

Source DF SS MS F P

DIETS 4 0.02984 0.00746 0.28 0.886 NS

Error 35 0.91960 0.02627

Total 39 0.94944

t. Analysis of variance for Caeca length

Source DF SS MS F P

DIETS 4 19.938 4.984 0.61 0.655 NS

Error 35 283.938 8.113

Total 39 303.875

u. Analysis of variance for dressed percentage

Source DF SS MS F P

DIETS 4 67.23 16.81 0.59 0.672 NS

Error 35 995.89 28.45

Total 39 1063.11

**APPENDIX XIX: ANALYSIS OF VARIANCE FOR FEED INTAKE EXPERIMENT 4**

a. Analysis of variance for daily feed intake (1-4 weeks)

Source DF SS MS F P

DIETS 4 6.045 1.511 0.75 0.576 NS

Error 15 30.413 2.028

Total 19 36.45

b. Analysis of variance for daily feed intake (5-8 weeks)

Source DF SS MS F P

DIETS 4 42.236 10.559 1.61 0.222 NS

Error 15 98.084 6.539

Total 19 140.320

c. Analysis of variance for daily feed intake (1-8 weeks)

Source DF SS MS F P

DIETS 4 11.160 2.790 1.02 0.429 NS

Error 15 41.037 2.736

Total 19 52.197

d. Analysis of variance for total feed intake

Source DF SS MS F P

DIETS 4 26841 6710 1.02 0.428 NS

Error 15 98670 6578

Total 19 125510

**APPENDIX XX: ANALYSIS OF VARIANCE FOR WEIGHT GAIN EXPERIMENT 4**

a. Analysis of variance for daily weight gain (1-4 weeks)

Source DF SS MS F P

DIETS 4 5.444 1.361 0.61 0.659 NS

Error 15 33.277 2.218

Total 19 38.721

b. Analysis of variance for daily weight gain (5-8 weeks)

Source DF SS MS F P

DIETS 4 11.68 2.92 0.19 0.940 NS

Error 15 230.88 15.39

Total 19 242.56

c. Analysis of variance for daily weight gain (1-8 weeks)

Source DF SS MS F P

DIETS 4 2.089 0.522 0.21 0.930 NS

Error 15 37.596 2.506

Total 19 39.685

d. Analysis of variance for Initial weight

Source DF SS MS F P

DIETS 4 235.81 58.95 0.79 0.550 NS

Error 15 1119.98 74.67

Total 19 1355.78

e. Analysis of Variance for Final weight

Source DF SS MS F P

DIETS 4 5707 1427 0.21 0.931 NS

Error 15 104202 6947

Total 19 109909

f. Analysis of variance for total weight gain

Source DF SS MS F P

DIETS 4 5017 1254 0.21 0.930 NS

Error 15 90184 6012

Total 19 95202

**APPENDIX XXI: ANALYSIS OF VARIANCE FOR FCR EXPERIMENT 4**

a. Analysis of variance for feed conversion ratio (1-4 weeks)

Source DF SS MS F P

DIETS 4 0.006080 0.001520 0.23 0.916 NS

Error 15 0.098300 0.006553

Total 19 0.104380

b. Analysis of variance for feed conversion ratio (5-8 weeks)

Source DF SS MS F P

DIETS 4 0.04732 0.01183 0.23 0.915 NS

Error 15 0.76130 0.05075

Total 19 0.80862

c. Analysis of variance for feed conversion ratio (1-8 weeks)

Source DF SS MS F P

DIETS 4 0.014770 0.003693 0.45 0.771 NS

Error 15 0.123125 0.008208

Total 19 0.137895

**APPENDIX XXII: ANALYSIS OF VARIANCE FOR HAEMATOLOGICAL PARAMETERS EXPERIMENT 4**

a. Analysis of variance for WBC

Source DF SS MS F P

DIETS 4 1414.0 353.5 1.06 0.411 NS

Error 15 5008.7 333.9

Total 19 6422.7

b. Analysis of variance for RBC

Source DF SS MS F P

DIETS 4 0.61428 0.15357 1.80 0.182 NS

Error 15 1.28310 0.08554

Total 19 1.89738

c. Analysis of variance for Hb

Source DF SS MS F P

DIETS 4 5.737 1.434 0.85 0.513 NS

Error 15 25.185 1.679

Total 19 30.922

d. Analysis of variance for HCT

Source DF SS MS F P

DIETS 4 68.18 17.05 1.23 0.340 NS

Error 15 207.87 13.86

Total 19 276.05

e. Analysis of variance for MCV

Source DF SS MS F P

DIETS 4 245.45 61.36 2.66 0.074 NS

Error 15 346.09 23.07

Total 19 591.55

f. Analysis of variance for MCH

Source DF SS MS F P

DIETS 4 26.213 6.555 5.62 0.006 NS

Error 15 17.505 1.167

Total 19 43.718

g. Analysis of variance for MCHC

Source DF SS MS F P

DIETS 4 2.4520 0.6130 0.85 0.517 NS

Error 15 10.8500 0.7233

Total 19 13.3020

h. Analysis of variance for PLT

Source DF SS MS F P

DIETS 4 8908 2227 0.87 0.507 NS

Error 15 38570 2571

Total 19 47479

**APPENDIX XXIII: ANALYSIS OF VARIANCE FOR SERUM BIOCHEMICAL INDICES EXPERIMENT 4**

a. Analysis of variance for Protein

Source DF SS MS F P

DIETS 4 79.30 19.82 0.53 0.717 NS

Error 15 562.50 37.50

Total 19 641.80

b. Analysis of variance for Albumen

Source DF SS MS F P

DIETS 4 5.883 1.471 0.37 0.825 NS

Error 15 59.315 3.954

Total 19 65.198

c. Analysis of variance for Globulin

Source DF SS MS F P

DIETS 4 75.07 18.77 0.70 0.605 NS

Error 15 403.36 26.89

Total 19 478.44

d. Analysis of variance for LDL

Source DF SS MS F P

DIETS 4 0.31200 0.07800 0.79 0.548 NS

Error 15 1.47750 0.09850

Total 19 1.78950

e. Analysis of variance for TGS

Source DF SS MS F P

DIETS 4 0.15913 0.03978 1.83 0.175 NS

Error 15 0.32593 0.02173

Total 19 0.48506

f. Analysis of variance for Glocuse

Source DF SS MS F P

DIETS 4 19.962 4.990 1.50 0.251 NS

Error 15 49.810 3.321

Total 19 69.772

h. Analysis of variance for Creatinine

Source DF SS MS F P

DIETS 4 340.30 85.08 2.10 0.132 NS

Error 15 608.25 40.55

Total 19 948.55

j. Analysis of variance for AST

Source DF SS MS F P

DIETS 4 38197 9549 2.71 0.070 NS

Error 15 52832 3522

Total 19 91029

k. Analysis of variance for ALT

Source DF SS MS F P

DIETS 4 327.70 81.92 1.74 0.194 NS

Error 15 707.25 47.15

Total 19 1034.95

**APPENDIX XXIV: ANALYSIS OF VARIANCE FOR CARCASS AND VISCERAL ORGANS CHARACTERISTICS EXPERIMENT 4**

a. Analysis of variance for Live weight

Source DF SS MS F P

DIETS 4 0.67038 0.16759 2.14 0.097 NS

Error 35 2.74563 0.07845

Total 39 3.41600

b. Analysis of variance for Plucked weight

Source DF SS MS F P

DIETS 4 0.35248 0.08812 1.77 0.157 NS

Error 35 1.74311 0.04980

Total 39 2.09560

c. Analysis of variance for Eviscerated weight

Source DF SS MS F P

DIETS 4 0.33678 0.08420 2.22 0.087 NS

Error 35 1.32733 0.03792

Total 39 1.66411

d. Analysis of variance for Carcass weight

Source DF SS MS F P

DIETS 4 0.29524 0.07381 2.26 0.082 NS

Error 35 1.14066 0.03259

Total 39 1.43590

e. Analysis of variance for Heart weight

Source DF SS MS F P

DIETS 4 0.016135 0.004034 1.50 0.222 NS

Error 35 0.093863 0.002682

Total 39 0.109998

f. Analysis of variance for Liver weight

Source DF SS MS F P

DIETS 4 1.01282 0.25320 3.58 0.015 NS

Error 35 2.47436 0.07070

Total 39 3.48718

g. Analysis of variance for Gizzard weight

Source DF SS MS F P

DIETS 4 0.77186 0.19296 2.47 0.062 NS

Error 35 2.72884 0.07797

Total 39 3.50070

h. Analysis of Variance for Lungs weight

Source DF SS MS F P

DIETS 4 0.043865 0.010966 1.13 0.359 NS

Error 35 0.339975 0.009714

Total 39 0.383840

i. Analysis of variance for Pancreas weight

Source DF SS MS F P

DIETS 4 0.016035 0.004009 2.10 0.101 NS

Error 35 0.066662 0.001905

Total 39 0.082697

j. Analysis of variance for Abdominal fats

Source DF SS MS F P

DIETS 4 1.5981 0.3995 1.91 0.131 NS

Error 35 7.3337 0.2095

Total 39 8.9318

k. Analysis of variance for Kidney

Source DF SS MS F P

DIETS 4 0.0019150 0.0004788 1.59 0.198 NS

Error 35 0.0105250 0.0003007

Total 39 0.0124400

l. Analysis of variance for Spleen

Source DF SS MS F P

DIETS 4 0.010385 0.002596 2.24 0.085 NS

Error 35 0.040613 0.001160

Total 39 0.050998

m. Analysis of variance for Small int.

Source DF SS MS F P

DIETS 4 3.4801 0.8700 2.26 0.083 NS

Error 35 13.4908 0.3855

Total 39 16.9710

n. Analysis of variance for Small int. lenght

Source DF SS MS F P

DIETS 4 9987.3 2496.8 4.42 0.005\*

Error 35 19768.6 564.8

Total 39 29756.0

o. Analysis of variance for Large int. weight

Source DF SS MS F P

DIETS 4 0.07863 0.01966 1.75 0.160 NS

Error 35 0.39232 0.01121

Total 39 0.47095

p. Analysis of variance for Large Int. lenght

Source DF SS MS F P

DIETS 4 33.01 8.25 0.39 0.811 NS

Error 35 732.68 20.93

Total 39 765.69

q. Analysis of variance for Caeca weight

Source DF SS MS F P

DIETS 4 0.56537 0.14134 4.31 0.006 NS

Error 35 1.14823 0.03281

Total 39 1.71360

r. Analysis of variance for Caeca length

Source DF SS MS F P

DIETS 4 38.92 9.73 0.38 0.818 NS

Error 35 885.40 25.30

Total 39 924.32

s. Analysis of variance for Head

Source DF SS MS F P

DIETS 4 0.12108 0.03027 0.42 0.794 NS

Error 35 2.53061 0.07230

Total 39 2.65170

t. Analysis of variance for Legs

Source DF SS MS F P

DIETS 4 3.3125 0.8281 3.22 0.024 NS

Error 35 9.0092 0.2574

Total 39 12.3218

u. Analysis of Variance for dressing percentage

Source DF SS MS F P

DIETS 4 18.80 4.70 0.37 0.831 NS

Error 35 448.69 12.82

Total 39 467.49